

**Global Initiative for
Chronic Obstructive
Lung Disease**

**2025
REPORT**



**Global Strategy for the Diagnosis, Management, and
Prevention of Chronic Obstructive Pulmonary Disease**

GLOBAL INITIATIVE FOR CHRONIC OBSTRUCTIVE LUNG DISEASE

GLOBAL STRATEGY FOR THE DIAGNOSIS, MANAGEMENT, AND PREVENTION OF CHRONIC OBSTRUCTIVE PULMONARY DISEASE (2025 REPORT)



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GLOBAL STRATEGY FOR THE DIAGNOSIS, MANAGEMENT, AND PREVENTION OF COPD (2025)

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GOLD 2025 REPORT HIGHLIGHTS

The GOLD report is revised annually and has been used worldwide by healthcare professionals as a tool to implement effective management programs based on local healthcare systems.

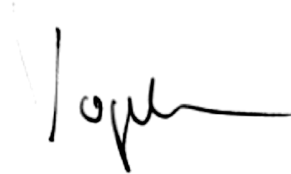
In the 2025 revision of the GOLD report several important changes have been made as follows:

- i. **Chapter 6** on the topic of **COVID-19 and COPD** has now been removed from the GOLD report.
- ii. Three new figures have been introduced for 2025:
 - New **Figure 2.6** 'Pre- and Post- Bronchodilator Spirometry'
 - New **Figure 3.22** 'Management of Patients Currently on LABA+ICS'
 - New **Figure 5.1** 'Treatable Traits in Pulmonary Hypertension-COPD (PH-COPD) & Suggested Management'
- iii. The following figures have been edited or updated:
 - Figure 3.6** 'Vaccination for Stable COPD' has been updated with the latest vaccination recommendations
 - Figure 3.9** 'Follow-up Pharmacological Treatment' has been updated to add information about new treatments ensifentrine and dupilumab
 - Figure 3.18** 'Maintenance Medications in COPD' has been updated and ensifentrine and dupilumab have been included
 - Figure 3.19** 'Bronchodilators in Stable COPD' has been updated to include ensifentrine
 - Figure 3.20** 'Anti-Inflammatory Therapy in Stable COPD' has been updated to include ensifentrine and dupilumab
 - Figure 4.11** 'Interventions that Reduce the Frequency of COPD Exacerbations' has had dupilumab added.
- iv. A new paragraph and references have been added to the **Trajectories of Lung Function: Development and Aging** section, including a link to free software on the ERS website for monitoring spirometry over time (Page 11)
- v. A new section on **Dysbiosis** has been included (Page 17)
- vi. The information on **Spirometry** has been updated to include more comprehensive information on LLN values, z-scores and reference values and a new **Figure 2.6 Pre- and Post-Bronchodilator Spirometry** has been added (Page 27)
- vii. **Cardiovascular Risk in COPD** is now covered in a new section (Page 38)
- viii. **Computed Tomography (CT)** has been updated and now includes information on emphysema, lung nodules, airways and COPD related morbidities (Page 42)
- ix. **Climate Change & COPD** is now included (Page 50)
- x. **Vaccination Recommendations** for people with COPD have been updated in line with current guidance from the US Centers for Disease Control (CDC) (Page 52)
- xi. **Follow-up Pharmacological Treatment** and corresponding **Figure 3.9** have been updated to include information about ensifentrine and dupilumab (Page 57)
- xii. Information about the **Delivery of Pulmonary Rehabilitation, Education & Self-management: in-person versus virtual** has been included (Page 67), **Remote Patient Follow-up** has been moved from the COVID-19 chapter to this part of the document and the **COPD Follow-up Checklist** has been moved to the Appendix (Page 135)
- xiii. The section on withdrawal of ICS has been revised and a new **Figure 3.22** about the **Management of Patients Currently on LABA+ICS** has been included (Page 88)
- xiv. The sections on **Phosphodiesterase 3 and 4 (PDE3 & PDE4) Inhibitors** and **Other Drugs with the Potential to Reduce Exacerbations** have been revised to reflect the latest evidence for ensifentrine and dupilumab (Page 91)
- xv. **Pulmonary Hypertension** is now covered, and **Figure 5.1** has been added (Page 126)

GOLD has been fortunate to have a network of international distinguished health professionals from multiple disciplines. Many of these experts have initiated investigations into the causes and prevalence of COPD in their countries and have developed innovative approaches for the dissemination and implementation of the GOLD management strategy. The GOLD initiative will continue to work with National Leaders and other interested healthcare professionals to bring COPD to the attention of governments, public health officials, healthcare workers, and the general public, to raise awareness of the burden of COPD and to develop programs for early detection, prevention and approaches to management.



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GLOBAL STRATEGY FOR THE DIAGNOSIS, MANAGEMENT AND PREVENTION OF COPD 2025 UPDATE¹

METHODOLOGY

When the Global Initiative for Chronic Obstructive Lung Disease (GOLD) program was initiated in 1998, a goal was to produce recommendations for management of COPD based on the best scientific information available. The first report, *Global Strategy for the Diagnosis, Management and Prevention of COPD* was issued in 2001. In 2006 and again in 2011 a complete revision was prepared based on published research. These reports, and their companion documents, have been widely distributed and translated into many languages and can be found on the GOLD website (www.goldcopd.org).

The GOLD Science Committee² was established in 2002 to review published research on COPD management and prevention, to evaluate the impact of this research on recommendations in the GOLD documents related to management and prevention, and to post yearly updates on the GOLD website. Its members are recognized leaders in COPD research and clinical practice with the scientific credentials to contribute to the task of the Committee and are invited to serve in a voluntary capacity.

This 2025 GOLD Report is the second update of the 2023-revised report. The 2023 GOLD Report was the 5th major revision of GOLD, and incorporated a reassessment and revision of recommendations for the diagnosis, assessment and treatment of COPD. Updates of the 2017-revised report were made in 2018, 2019, 2020, 2021 and 2022. Updates of the 2011-revised report were released in January 2013, 2014, 2015, and 2016.

Process: To produce the GOLD report, a PubMed search (National Center for Biotechnology Information, U.S. National Library of Medicine, Bethesda MD, USA) was completed using search fields established by the Committee: 1) *COPD or Chronic Obstructive Pulmonary Disease (All Fields) AND 2) Clinical Trials or Meta-analysis (All Fields) OR 3) articles in the top 20 medical or respiratory journals (available on request) or The Cochrane Database of Systematic Reviews.*

Publications in peer reviewed journals not captured by the PubMed searches may be submitted to the Chair, GOLD Science Committee, providing the full paper, including abstract, is submitted in (or translated into) English.

Members of the Committee receive a summary of citations and all abstracts. Each abstract is assigned to two unbiased Committee members, although all members are offered the opportunity to provide input on any abstract. Members evaluate the abstract or, subject to her/his judgment, the full publication, by answering four specific written questions from a short questionnaire, to indicate if the scientific data presented impacts on recommendations in the GOLD report. If so, the member is asked to specifically identify modifications that should be made.

The GOLD Science Committee meets twice yearly to discuss each publication that was considered by at least one member of the Committee to potentially have an impact on the management of COPD. The full Committee then reaches a consensus on whether to include it in the report, either as a reference supporting current recommendations, or to change the report. In the absence of consensus, disagreements are decided by an open vote of the full Committee. Only high-quality systematic reviews and meta-analyses that provide strong evidence for changing clinical

¹ The Global Strategy for Diagnosis, Management and Prevention of COPD (updated 2025), the Pocket Guide (updated 2025) and the complete list of references examined by the Committee is available on the GOLD website: www.goldcopd.org.

² GOLD Science Committee Members (2024-2025): C. Vogelmeier, Chair, A. Agusti, A. Anzueto, J. Bourbeau, G. Criner, D. Halpin, M. Han, F. Martinez, M. Montes de Oca, O. Ozoh, A. Papi, I. Pavord, N. Roche, D. Sin, D. Singh, R. Stockley, T. Troosters, J. Wedzicha, J. Zheng.

practice are cited in the GOLD report with preference given to citing the original randomized controlled trial(s).

Recommendations by the GOLD Committee for use of any medication are based on the best evidence available from the published literature and not on labeling directives from government regulators. The Committee does not make recommendations for therapies that have not been approved by at least one major regulatory agency.

NEW REFERENCES

The GOLD 2025 report is a further update of the GOLD 2023 report, which was a major revision. Following systematic literature searches and double-blind review by the GOLD Science Committee, the GOLD report has been updated to include key peer-reviewed research publications from January 2023 to July 2024. In total, 164 new references have been added to the GOLD 2025 report.

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GLOBAL STRATEGY FOR THE DIAGNOSIS, MANAGEMENT, AND PREVENTION OF COPD

INTRODUCTION

The aim of the GOLD Report is to provide a non-biased review of the current evidence for the assessment, diagnosis and treatment of people with COPD. One of the strengths of GOLD reports is the treatment objectives. Treatment objectives are organized into two groups: objectives that are directed towards relieving and reducing the impact of symptoms, and objectives that reduce the risk of adverse health events that may affect the patient at some point in the future (exacerbations are an example of such events). This emphasizes the need for clinicians to focus on both the short-term and long-term impact of COPD on their patients.

A second strength of the original strategy was the simple, intuitive system for classifying COPD severity. This was based on FEV1 and was called a staging system because it was believed, at the time, that the majority of patients followed a path of disease progression in which the severity of COPD tracked the severity of airflow obstruction. Much is now known about the characteristics of patients in the different GOLD stages – for example, their risk of exacerbations, hospitalization, and death. However, at an individual patient level, FEV1 alone is an unreliable marker of the severity of breathlessness, exercise limitation, health status impairment, and risk of exacerbation.

At the time of the original report, improvement in both symptoms and health status was a GOLD treatment objective, but symptoms assessment did not have a direct relation to the choice of management, and health status measurement was a complex process largely confined to clinical studies. Now, there are simple and reliable questionnaires designed for use in routine daily clinical practice. These are available in many languages. These developments have enabled an assessment system to be developed that draws together a measure of the impact of the patient's symptoms and an assessment of the patient's risk of having a serious adverse health event. This management approach can be used in any clinical setting anywhere in the world and moves COPD treatment towards individualized medicine – matching the patient's therapy more closely to his or her needs.

BACKGROUND

Chronic Obstructive Pulmonary Disease (COPD) is now one of the top three causes of death worldwide and 90% of these deaths occur in low- and middle-income countries (LMICs).^(1,2) More than 3 million people died of COPD in 2012 accounting for 6% of all deaths globally. COPD represents an important public health challenge that is both preventable and treatable. COPD is a major cause of chronic morbidity and mortality throughout the world; many people suffer from this disease for years and die prematurely from it or its complications. Globally, the COPD burden is projected to increase in coming decades because of continued exposure to COPD risk factors and aging of the population.⁽³⁾

In 1998, with the cooperation of the National Heart, Lung, and Blood Institute, National Institutes of Health and the World Health Organization the Global Initiative for Chronic Obstructive Lung Disease (GOLD) was implemented. Its goals were to increase awareness of the burden of COPD and to improve prevention and management of COPD through a concerted worldwide effort of people involved in all facets of healthcare and healthcare policy. An important and related goal was to encourage greater research interest in this highly prevalent disease.

In 2001, GOLD released its first report, *Global Strategy for the Diagnosis, Management, and Prevention of COPD*. This report was not intended to be a comprehensive textbook on COPD, but rather to summarize the current state of the

field. It was developed by individuals with expertise in COPD research and patient care and was based on the best-validated concepts of COPD pathogenesis at that time, along with available evidence on the most appropriate management and prevention strategies. It provided state-of-the-art information about COPD for pulmonary specialists and other interested physicians and served as a source document for the production of various communications for other audiences, including an Executive Summary, a Pocket Guide for Healthcare Professionals, and a Patient Guide.

Immediately following the release of the first GOLD report in 2001, the GOLD Board of Directors appointed a Science Committee, charged with keeping the GOLD documents up to date by reviewing published research, evaluating the impact of this research on the management recommendations in the GOLD documents, and posting yearly updates of these documents on the GOLD website.

In 2018 GOLD held a one-day summit to consider information about the epidemiology, clinical features, approaches to prevention and control, and the availability of resources for COPD in LMICs.⁽¹⁾ Major conclusions of the summit included that: there are limited data about the epidemiological and clinical features of COPD in LMICs but the data available indicate there are important differences in these features around the world; there is widespread availability of affordable tobacco products as well as other exposures (e.g., household air pollution) thought to increase the risk of developing COPD; diagnostic spirometry services are not widely available and there are major problems with access to affordable quality-assured pharmacological and non-pharmacological therapies. GOLD is therefore concerned that COPD is not being taken seriously enough at any level, from individuals and communities, to national governments and international agencies.⁽⁴⁾ It is time for this to change and the GOLD Board of Directors challenge all relevant stakeholders to work together in coalition with GOLD to address the avoidable burden of COPD worldwide. GOLD is committed to improving the health of people at risk of and with COPD, wherever they happen to have been born, and wishes to do its bit to help achieve the *United Nations Sustainable Development Goal 3.4* to reduce premature mortality from non-communicable diseases - including COPD - by one third by 2030.⁽⁵⁾

LEVELS OF EVIDENCE

Levels of evidence have been assigned to evidence-based recommendations where appropriate (**Table A**). Evidence levels are indicated in boldface type enclosed in parentheses after the relevant statement e.g., (**Evidence A**). The methodological issues concerning the use of evidence from meta-analyses were carefully considered when i) treatment effect (or effect size) was consistent from one study to the next, and we needed to identify the common effect; ii) the effect varied from one study to the next, and there was a need to identify the reason for the variation.

Description of Levels of Evidence

Table A

Evidence Category	Sources of Evidence	Definition
A	Randomized controlled trials (RCTs)	Evidence is from endpoints of well-designed RCTs that provide consistent findings in the population for which the recommendation is made without any important limitations.
	Rich body of high quality evidence without any significant limitation or bias	Requires high quality evidence from ≥ 2 clinical trials involving a substantial number of subjects, or a single high quality RCT involving substantial numbers of patient without any bias.
B	Randomized controlled trials (RCTs) with important limitations	Evidence is from RCTs that include only a limited number of patients, <i>post hoc</i> or subgroup analyses of RCTs or meta-analyses of RCTs.
	Limited body of evidence	Also pertains when few RCTs exist, or important limitations are evident (methodological flaws, small numbers, short duration, undertaken in a population that differs from the target population of the recommendation, or the results are somewhat inconsistent).
C	Non-randomized trials Observational studies	Evidence is from outcomes of uncontrolled or non-randomized trials or from observational studies.
D	Panel consensus judgment	Provision of guidance is deemed valuable but clinical literature addressing the subject is insufficient. Panel consensus is based on clinical experience or knowledge that does not meet the above stated criteria.

CHAPTER 1: DEFINITION AND OVERVIEW

KEY POINTS:

Definition

- Chronic Obstructive Pulmonary Disease (COPD) is a heterogeneous lung condition characterized by chronic respiratory symptoms (dyspnea, cough, sputum production and/or exacerbations) due to abnormalities of the airways (bronchitis, bronchiolitis) and/or alveoli (emphysema) that cause persistent, often progressive, airflow obstruction.

Causes and Risk Factors

- COPD results from gene(G)-environment(E) interactions occurring over the lifetime(T) of the individual (GETomics) that can damage the lungs and/or alter their normal development/aging processes.
- The main environmental exposures leading to COPD are tobacco smoking and the inhalation of toxic particles and gases from household and outdoor air pollution, but other environmental and host factors (including abnormal lung development and accelerated lung aging) can also contribute.
- The most relevant (albeit rare) genetic risk factor for COPD identified to date are mutations in the SERPINA1 gene that lead to α -1 antitrypsin deficiency. A number of other genetic variants have also been associated with reduced lung function and risk of COPD, but their individual effect size is small.

Diagnostic Criteria

- In the appropriate clinical context (see 'Definition' & 'Causes and Risk Factors' above), the presence of non-fully reversible airflow obstruction (i.e., $FEV_1/FVC < 0.7$ post-bronchodilation) measured by spirometry confirms the diagnosis of COPD.
- Some individuals can have respiratory symptoms and/or structural lung lesions (e.g., emphysema) and/or physiological abnormalities (including low FEV_1 , gas trapping, hyperinflation, reduced lung diffusing capacity and/or rapid FEV_1 decline) without airflow obstruction ($FEV_1/FVC \geq 0.7$ post-bronchodilation). These subjects are labeled 'Pre-COPD'. The term 'PRISm' (Preserved Ratio Impaired Spirometry) has been proposed to identify those with normal ratio but abnormal spirometry. Subjects with Pre-COPD or PRISm are at risk of developing airflow obstruction over time, but not all of them do.

Clinical Presentation

- Patients with COPD typically complain of dyspnea, activity limitation and/or cough with or without sputum production and may experience acute respiratory events characterized by increased respiratory symptoms called exacerbations that require specific preventive and therapeutic measures.
- Patients with COPD frequently harbor other comorbid diseases that influence their clinical condition and prognosis and require specific treatment as well. These comorbid conditions can mimic and/or aggravate an acute exacerbation.

New Opportunities

- COPD is a common, preventable, and treatable disease, but extensive under-diagnosis and misdiagnosis leads to patients receiving no treatment or incorrect treatment. Appropriate and earlier diagnosis of COPD can have a very significant public-health impact.
- The realization that environmental factors other than tobacco smoking can contribute to COPD, that it can start early in life and affect young individuals, and that there are precursor conditions (Pre-COPD, PRISm), opens new windows of opportunity for its prevention, early diagnosis, and prompt and appropriate therapeutic intervention.

WHAT IS COPD?

Definition

Chronic Obstructive Pulmonary Disease (COPD) is a heterogeneous lung condition characterized by chronic respiratory symptoms (dyspnea, cough, sputum production and/or exacerbations) due to abnormalities of the airways (bronchitis, bronchiolitis) and/or alveoli (emphysema) that cause persistent, often progressive, airflow obstruction.⁽⁶⁾

Causes and risk factors

COPD results from gene(G)-environment(E) interactions occurring over the lifetime(T) of the individual (GETomics) that can damage the lungs and/or alter their normal development/aging processes.⁽⁷⁾

The main environmental exposures leading to COPD are tobacco smoking and the inhalation of toxic particles and gases from household and outdoor air pollution, but other environmental^(8,9) and host factors (including abnormal lung development and accelerated lung aging) can also contribute.⁽⁷⁾

The most relevant (albeit epidemiologically rare) genetic risk factor for COPD identified to date are mutations in the SERPINA1 gene, leading to α 1-antitrypsin deficiency, but other genetic variants, with a low individual effect size, are associated with reduced lung function and risk of COPD too.⁽¹⁰⁾

Diagnostic criteria

In the appropriate clinical context (See 'Definition' and 'Causes and Risk Factors' above), the presence of non-fully reversible airflow obstruction ($FEV_1/FVC < 0.7$ post-bronchodilation) measured by spirometry confirms the diagnosis of COPD.

Yet, some individuals may present with structural lung lesions (e.g., emphysema) and/or physiological abnormalities (including low FEV₁, gas trapping, hyperinflation, reduced lung diffusing capacity and/or rapid FEV₁ decline) without airflow obstruction ($FEV_1/FVC \geq 0.7$ post-bronchodilation). These subjects are labeled 'Pre-COPD'. The term 'PRISm' (Preserved Ratio Impaired Spirometry) has been proposed to identify those with normal ratio but abnormal spirometry. Subjects with Pre-COPD or PRISm are at risk of developing airflow obstruction over time, but not all of them do.^(11,12) Research is needed to determine what is the best treatment for these individuals (beyond smoking cessation).

Clinical presentation

Patients with COPD typically complain of dyspnea, wheezing, chest tightness, fatigue, activity limitation, and/or cough with or without sputum production, and may experience acute events characterized by increased respiratory symptoms called exacerbations that influence their health status and prognosis, and require specific preventive and therapeutic measures.

Patients with COPD frequently harbor other comorbid diseases that also influence their clinical condition and prognosis and require specific treatment as well. These comorbid conditions can mimic and/or aggravate an acute exacerbation.

New opportunities

COPD is a common, preventable, and treatable disease, but extensive under and misdiagnosis leads to patients receiving no treatment or incorrect treatment. The realization that environmental factors other than tobacco smoking

can contribute to COPD, that it can start early in life and affect young individuals, and that there are precursor conditions (Pre-COPD, PRISm), opens new windows of opportunity for its prevention, early diagnosis, and prompt and appropriate therapeutic intervention.⁽¹³⁾

BURDEN OF COPD

COPD is a leading cause of morbidity and mortality worldwide with an economic and social burden that is both substantial and increasing.^(14,15) COPD prevalence, morbidity and mortality vary across countries.^(16,17) The prevalence of COPD is often directly related to the prevalence of tobacco smoking, but in many countries outdoor, occupational and household air pollution (resulting from the burning of wood and other biomass fuels) are important COPD risk factors.^(18,19)

The prevalence and burden of COPD are projected to increase over the coming decades due to a combination of continued exposure to COPD risk factors and aging of the world's population.⁽³⁾ Information on the burden of COPD can be found on international websites, such as the World Health Organization (WHO)⁽²⁰⁾ and the World Bank/WHO Global Burden of Disease (GBD) Study.^(21,22)

Prevalence

Existing COPD prevalence data vary widely due to differences in survey methods, diagnostic criteria, and analytical approaches.⁽³⁾ Of note, all of these epidemiologic studies defined COPD by spirometry alone. The lowest estimates of prevalence are those based on self-reporting of a doctor's diagnosis of COPD, or equivalent condition. For example, most national data show that < 6% of the adult population have been told that they have COPD.⁽²³⁾ This is likely to be a reflection of the widespread under-recognition and under-diagnosis of COPD.⁽²⁴⁾

Data are emerging that enable more accurate estimates of COPD prevalence. A number of systematic reviews and meta-analyses provide evidence that the prevalence of COPD is appreciably higher in smokers and ex-smokers compared to non-smokers, in those ≥ 40 years of age compared to those < 40, and in men compared to women.⁽²⁵⁻²⁷⁾ The Latin American Project for the Investigation of Obstructive Lung Disease (PLATINO)⁽²⁸⁾ examined the prevalence of post-bronchodilator airflow obstruction among persons ≥ 40 years in one major city from each of five Latin American countries – Brazil, Chile, Mexico, Uruguay, and Venezuela. The prevalence of COPD increased steeply with age, with the highest prevalence among those > 60 years. Prevalence in the total population ranged from 7.8% in Mexico City to 19.7% in Montevideo, Uruguay. The prevalence was appreciably higher in men than in women,⁽²⁸⁾ which contrasts with findings from European cities such as Salzburg, Austria.⁽²⁹⁾ Analyses of the GBD database suggests an overall increase in COPD prevalence in females while it has decreased in males and in some countries in the European Union between 2001 and 2019.⁽³⁰⁾ The Burden of Obstructive Lung Diseases (BOLD) program used standardized methodology comprising questionnaires and pre- and post-bronchodilator spirometry to assess prevalence and risks for COPD globally in people aged ≥ 40 years.^(29,31,32) BOLD reported an overall prevalence of COPD of 11.8% (standard error (SE) 7.9) for men and 8.5% (SE 5.8) for women⁽³³⁾ and a substantial prevalence of COPD of 3%-11% among never-smokers.⁽³³⁾ BOLD examined the prevalence of COPD in north and sub-Saharan Africa and Saudi Arabia and found similar results.⁽³⁴⁻³⁷⁾ Based on BOLD and other large scale epidemiological studies, it is estimated that **the global prevalence of COPD is 10.3%** (95% confidence interval (CI) 8.2%,12.8%).^(25,38) With the increasing prevalence of smoking in LMICs, and aging populations in high-income countries, the prevalence of COPD is expected to rise.⁽³⁹⁾ Modeling risk factor data from the Global Burden of Disease database it has been estimated that the number of COPD cases globally among those aged ≥ 25 years will increase by 23% from 2020 to 2050, approaching 600 million patients with COPD by 2050.⁽⁴⁰⁾ The increase is projected to be greater among women and in LMICs.⁽⁴⁰⁾

Morbidity

Morbidity measures traditionally include physician visits, emergency department visits, and hospitalizations. To date studies indicate that morbidity due to COPD increases with age,^(23,24,28) and in patients with COPD the development of comorbidities is seen at an earlier age.^(41,42) Morbidity in COPD may also be influenced by concomitant chronic conditions (e.g., cardiovascular disease, musculoskeletal impairment, diabetes mellitus)⁽⁴³⁾ that are related to smoking, aging and/or COPD.⁽⁴⁴⁾

Mortality

The World Health Organization (WHO) publishes mortality statistics for selected causes of death annually for all WHO regions.⁽⁴⁵⁾ However, data must be interpreted with caution because of the inconsistent use of COPD terminology. In the 10th revision of the International Statistical Classification of Diseases and Related Health Problems (ICD-10), deaths from COPD or chronic airways obstruction are included in the broad category of “COPD and allied conditions” (ICD-10 codes J42-46).

Under-recognition and under-diagnosis of COPD reduces the accuracy of mortality data.^(46,47) Furthermore, the accuracy of COPD diagnosis codes recorded in administrative health databases is also uncertain.^(48,49) In some jurisdictions, reliance on administrative health data, particularly those that only record hospitalizations, may underestimate the burden of COPD.⁽⁵⁰⁾ The reliability of recording of COPD-related deaths in mortality data is also problematic. Although COPD is often a primary cause of death, it is more likely to be listed as a contributory cause of death or omitted from the death certificate entirely.⁽⁵¹⁾ However, it is clear that COPD is one of the most important causes of death in most countries. For instance, in 2011, COPD was the third leading cause of death in the United States.⁽⁵²⁾ This increase in COPD-related mortality has mainly been driven by the expanding epidemic of smoking; reduced mortality from other common causes of death (e.g., ischemic heart disease, infectious diseases); the aging of the world’s population, particularly in high-income countries; and scarcity of effective disease modifying therapies. Data from the GBD Study 2017 estimated a COPD-attributable death rate was 42/100,000 (4.72% of all-cause deaths)^(3,53)

With these caveats in mind, it can be estimated that **globally there are around three million deaths annually due to COPD.**⁽⁵⁴⁾ It is estimated that the increased prevalence of smoking in LMICs coupled with aging populations in high-income countries will result in over 5.4 million annual deaths from COPD and related conditions by 2060.^(55,56)

Economic burden

COPD is associated with significant economic burden. In the European Union, the total direct costs of respiratory disease are estimated to be about 6% of the total annual healthcare budget, with COPD accounting for 56% (38.6 billion Euros) of the cost of respiratory disease.⁽⁵⁷⁾ In the United States the costs attributable to COPD are expected to increase over the next 20 years, with projected costs of \$800.90 billion or \$40 billion per year.^(58,59) Dynamic modeling also predicts that women are expected to incur higher direct costs than men and lose more quality-adjusted life years.⁽⁵⁹⁾ COPD exacerbations account for the greatest proportion of the total COPD burden on the healthcare system.⁽⁶⁰⁾ Not surprisingly, there is a striking direct relationship between the severity of COPD and the cost of care, and the cost distribution changes as the disease progresses. For example, hospitalization and ambulatory oxygen costs soar as COPD severity increases. Any estimate of direct medical expenditure for home-based care under-represents the true cost of home-based care to society because it ignores the economic value of the care provided by family members to people with COPD.

In LMICs both direct and indirect medical costs may be substantial. Recent work from the WHO and other organizations suggest that inhaled medicines for COPD are poorly available and largely unaffordable in LMICs.⁽⁶¹⁾ Most inhaled medications are still branded and there are few options currently available for generic inhalers. The situation is similar

for access to diagnostic spirometry. Because the healthcare sector might not provide long-term supportive care services for severely disabled individuals, COPD may force at least two individuals to leave the workplace – the affected individual and a family member who must now stay home to care for their disabled relative.⁽⁶²⁾ Since human capital is often the most important national asset for LMICs, the indirect costs of COPD may represent a serious threat to their economy.

Social burden

Since mortality offers only a limited perspective on the human burden of a disease, it is desirable to find other measures of disease burden that are consistent and measurable within and between nations. The GBD study designed a method to estimate the fraction of mortality and disability attributable to major diseases and injuries using a composite measure of the burden of each health problem: the Disability-Adjusted Life Years (DALY).⁽⁶³⁾ The DALY for a specific condition is the sum of years lost because of premature mortality and years of life lived with disability, adjusted for the severity of disability. The GBD Study found that from 1990 to 2019, COPD was the primary driver of increased DALY worldwide, especially in LMICs.^(21,64) The global health burden caused by COPD increasing by 25.7% from 59.2 million DALY in 1990 to 74.4 DALY in 2019 with largest increases in South East Asia, India, Sub-Saharan Africa and South America.⁽⁶⁵⁾ In 2005 COPD was the eighth leading cause of DALY lost across the world but by 2013 COPD was ranked as the fifth leading cause of DALY lost.^(53,66) In the United States, COPD is the second leading cause of reduced DALY, trailing only ischemic heart disease.⁽⁶⁷⁾ Data from GBD 2017 estimated that the DALY rate was 1068.02/100,000 for COPD.⁽⁵³⁾

PATHOGENESIS

COPD is the end-result of complex, cumulative and dynamic gene-environment interactions over the lifetime that can damage the lungs and/or alter their normal developmental or aging processes.⁽⁷⁾ Understanding the relationships and interactions between the genetic (G) background of the host and varied environmental (E) risk factors over the lifetime (T) requires further investigation. The term GETomics has been recently proposed to illustrate the complex and dynamic series of interactions between Genetics and Environment over Time.⁽⁷⁾ According to this GETomics proposal, the end result of a given GxE interaction depends not only on G and E, but also on T, as determined by both the age of the individual at which that particular interaction occurs (development vs aging) and the previous history of GxE interactions that the individual has encountered earlier in her/his life (biological memory).⁽⁷⁾

Environmental risk factors

Cigarette smoking

Cigarette smoking is a key environmental risk factor for COPD. Cigarette smokers have a higher prevalence of respiratory symptoms and lung function abnormalities, a greater annual rate of decline in FEV1, and a greater COPD mortality rate than non-smokers.⁽⁶⁸⁾ Most COPD studies have included patients with a cigarette exposure of a minimum of 10 pack-years. However, one study has suggested that even at reduced smoking exposure (<10 pack-years) the 5-year risk of developing COPD is increased in middle-aged adults, and these individuals have an increased risk of severe exacerbation and early death.⁽⁶⁹⁾ Yet fewer than 50% of heavy smokers develop COPD⁽⁷⁰⁾ and it is estimated that half of all COPD cases worldwide are due to risk factors other than tobacco so other pathogenic factors beyond smoking need to be considered.⁽⁹⁾

Genetics modify the risk of COPD in smokers, but there may also be other risk factors involved. For example, gender and social pressure may influence whether a person takes up smoking or experiences certain occupational or environmental exposures; socioeconomic status may be linked to birthweight (which may impact lung growth and development, and in turn susceptibility to developing COPD);⁽⁷¹⁾ and longer life expectancy will allow greater lifetime

exposure to risk factors.

Other types of tobacco (e.g., pipe, cigar, water pipe)⁽⁷²⁻⁷⁴⁾ and marijuana⁽⁷⁵⁾ are also risk factors for COPD. Passive exposure to cigarette smoke, also known as environmental tobacco smoke (ETS) and second-hand smoking, may also contribute to respiratory symptoms and COPD,⁽⁷⁶⁾ especially after long-term exposure.⁽⁷⁷⁾ Smoking during pregnancy poses a risk for the fetus, by altering lung growth and development *in utero*, and possibly priming the immune system by inducing specific epigenetic changes.⁽⁷⁸⁾ This is a good example of the GETomics approach discussed above. The fetus exposed to 'passive smoking' is likely to respond differently to a second GxE hit later in life.⁽⁷⁾

Biomass exposure

Tobacco smoking has been recognized as a major risk factor associated with COPD for over five decades, but this was largely because most research was conducted in high income countries. As more studies from LMICs were conducted,⁽¹⁹⁾ it became apparent that non-smoking risk factors were more important in these parts of the world. Whilst tobacco smoking remains the leading risk factor for COPD in high income countries, accounting for over 70% of the cases, in LMICs tobacco smoking contributes to around 30% to 40% of the total burden.⁽⁹⁾ Because the LMICs together contribute to over 85% of the total burden of COPD globally, non-smoking risk factors now contribute to over 50% of the global burden of COPD.⁽⁹⁾

Wood, animal dung, crop residues, and coal, typically burned in open fires or poorly functioning stoves, may lead to very high levels of household air pollution.⁽⁷⁹⁾ Household air pollution exposure is associated with an increased risk of developing COPD in LMICs⁽⁸⁰⁾ although the extent to which household air pollution versus other poverty-related exposures explain the association is unclear.⁽⁸¹⁻⁸⁴⁾ Almost three billion people worldwide use biomass and coal as their main source of energy for cooking, heating, and other household needs, so the population at risk worldwide is very large.^(85,86) There is limited research about household air pollution related COPD or the interventions that could reduce the risk of developing it.⁽⁸⁷⁾ Based on a systematic review, the use of gas for heating and cooking reduced the risk of COPD and other respiratory diseases and may be considered as a transitional fuel option in areas where clean fuel (electricity) is not readily available.⁽⁸⁸⁾

Many of the environmental exposures in LMICs are currently unregulated and, in combination with poverty and poor nutrition, amplify the risk of airway and lung parenchymal damage. Advocacy efforts to minimize exposure to risk factors must continue, based on robust evidence from epidemiological, translational, clinical and implementation research.⁽⁹⁾ There are no randomized controlled trials (RCTs) that have addressed the appropriate pharmacotherapy of non-smoking COPD. There is therefore an urgent need to conduct robust RCTs to better understand the most effective treatment that can be offered to non-smoking COPD. Phenotypic differences between smoking and non-smoking COPD have been reported in only a few studies. In brief, compared to COPD in smokers, non-smoking COPD is more common in females, in younger age groups, exhibits similar (or milder) respiratory symptoms and quality of life, a lesser rate of decline in lung function over time, lower neutrophils and a trend towards higher eosinophil numbers in the airway sputum, similar spirometric indices, greater small airways obstruction (respiratory oscillometry and radiology), less emphysema and a similar defect in macrophage phagocytosis of pathogenic bacteria.⁽⁸⁹⁻⁹¹⁾ Potential molecular mechanisms for non-smoking COPD include inflammation, oxidative stress, airway remodeling and lung aging.⁽⁹⁾ There is evidence from the SPIROMICS cohort study that the association of indoor PM2.5 with annual FEV1 decline differed by smoking status. Among people with, or at risk of, COPD former smokers living in high PM2.5 homes had rates of lung function decline similar to current smokers, whereas in low PM2.5 homes lung function decline was similar to never smokers.⁽⁹²⁾ A small RCT has shown that in-home use of portable particulate air cleaners may help to improve outcomes such as moderate exacerbation risk and breathlessness, with people who spend more time indoors more likely to benefit.⁽⁹³⁾ However, there are still several knowledge gaps that exist. Research is urgently needed to fill these gaps, as COPD related to biomass exposure, tobacco smoking or various other causes (see below) might exhibit different clinical features and trajectories, and benefit from different approaches to both

pharmacological and non-pharmacological treatments.⁽⁹⁾

Occupational exposures

Occupational exposures, including organic and inorganic dusts, chemical agents and fumes, are an under-appreciated environmental risk factor for COPD.^(18,94) Individuals with exposure to inhalation of high doses of pesticides have a higher incidence of respiratory symptoms, airways obstruction and COPD.^(95,96) A study of the population-based UK biobank cohort identified occupations including sculptors, gardeners and warehouse workers that were associated with an increased COPD risk among never-smokers without asthma.⁽⁹⁷⁾ A cross-sectional observational study demonstrated that self-reported exposure to workplace dust and fumes is associated with not only increased airflow obstruction and respiratory symptoms, but also more emphysema and gas trapping, as assessed by computed tomography scan, in both men and women.⁽⁹⁸⁾ An analysis of the large U.S. population-based National Health and Nutrition Examination Survey III survey of almost 10,000 adults aged 30-75 years estimated the fraction of COPD attributable to workplace exposures was 19.2% overall, and 31.1% among never-smokers.⁽⁹⁹⁾ These estimates are consistent with a statement published by the American Thoracic Society that concluded that occupational exposures account for 10-20% of either symptoms or functional impairment consistent with COPD.⁽¹⁰⁰⁾ The risk from occupational exposures in less regulated areas of the world is likely to be much higher than reported in studies from Europe and North America.

Air pollution

Air pollution typically consists of particulate matter (PM), ozone, oxides of nitrogen or sulfur, heavy metals, and other greenhouse gases, is a major worldwide cause of COPD, responsible for approximately 50% of the attributable risk for COPD in low- and middle-income countries (LMICs).⁽¹⁰¹⁾ In never smokers, air pollution is the leading known risk factor for COPD.⁽¹⁰²⁾ The respiratory risk of air pollution to individuals is dose-dependent with no apparent “safe” thresholds. Even in countries with low ambient air pollution levels, chronic exposure to PM_{2.5} and nitrogen dioxides significantly impairs lung growth in children,⁽¹⁰³⁾ accelerates lung function decline in adults and increases the risk for COPD, especially among those with additional risk factors for COPD.⁽¹⁰⁴⁾ Poor air quality from air pollution also increases the risk of COPD exacerbations, hospitalizations and mortality.^(105,106) Thus, reduction in both indoor and outdoor air pollution is a key goal in the prevention and management of COPD.

Genetic factors

A significant familial risk of airflow obstruction has been observed in people who smoke and are siblings of patients with severe COPD,⁽¹⁰⁷⁾ suggesting that genetics (in combination with environmental risk factors) could influence this susceptibility. The best documented genetic risk factor for COPD are mutations in the SERPINA1 gene that leads to the hereditary deficiency of α -1 antitrypsin (AATD),⁽¹⁰⁸⁾ a major circulating inhibitor of serine proteases. Although AATD deficiency is relevant to only a small part of the world’s population, it illustrates the interaction between genes and environmental exposures that predispose an individual to COPD. A systematic review of 20 studies in European populations found AATD PIZZ genotypes in 0.12% of COPD patients (range 0.08-0.24%), and a prevalence ranging from 1 in 408 in Northern Europe to 1 in 1,274 in Eastern Europe.⁽¹⁰⁹⁾

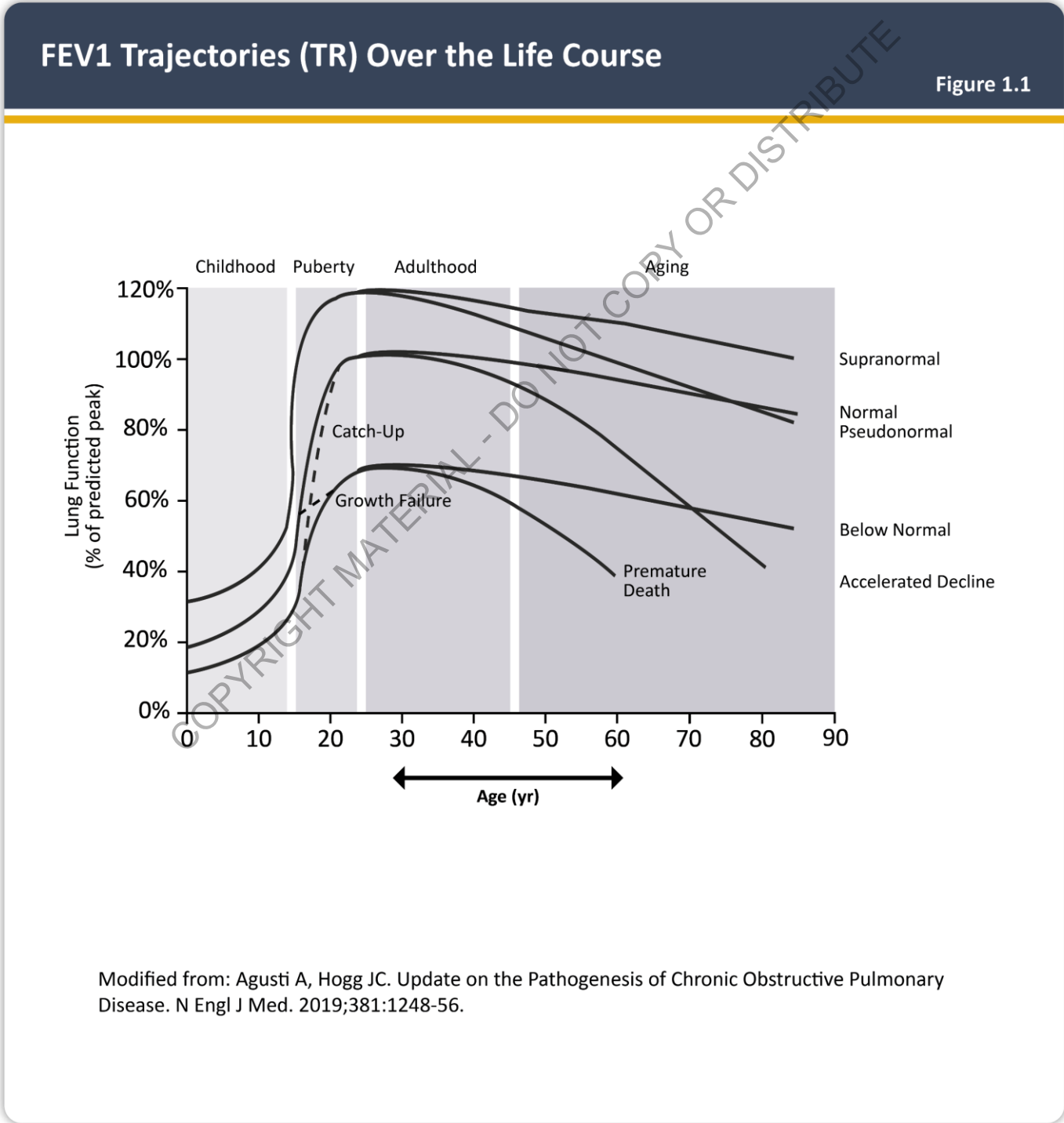
There has been a long-standing controversy concerning the risk of heterozygotes (MZ and SZ) for the development of COPD. This has largely reflected acquisition bias but is of critical importance due to the large numbers of such individuals worldwide⁽¹¹⁰⁾ who may potentially benefit from augmentation therapy. Recent careful sibling studies^(111,112) indicated no increased risk in these heterozygotes in the absence of smoking although lung function was reduced in smokers compared to MM siblings. This likely reflects the presence of low concentrations of the Z AAT protein rather than an absolute lack of it⁽¹¹³⁾ and is not an indication for augmentation therapy (discussed in more detail in **Chapter 3**).

To date, hundreds of genetic variants associated with reduced lung function and risk of COPD have been identified,

including genes encoding matrix metalloproteinase 12 (MMP-12), glutathione S-transferase, the alpha-nicotinic acetylcholine receptor, and the hedgehog interacting protein (HHIP).^(114,115) Yet, their individual effect size is small⁽¹⁰⁾ and it remains uncertain whether these genes are directly responsible for COPD or are merely markers of other causal genes.⁽¹¹⁶⁻¹²⁰⁾

Trajectories of lung function: development and aging

At birth, the lungs are not fully developed. They grow and mature until about 20-25 years of age (earlier in females), when lung function reaches its peak (**Figure 1.1**).⁽⁶⁸⁾ This is followed by a short plateau and a final phase of mild lung function decline due to physiological lung aging.⁽⁶⁸⁾ This constitutes the normal lung function trajectory in **Figure 1.1**.⁽¹²¹⁾ This normal lung function trajectory can be altered by processes occurring during gestation, birth, childhood, and adolescence that affect lung growth (hence, peak lung function) and/or processes shortening the plateau phase and/or accelerating the aging phase (hence accelerating the normal rate of lung function decline with age).^(122,123)



As a result, there is a range of potential lung function trajectories a given individual may follow through her/his lifetime, both below and above the normal one (**Figure 1.1**). It is now well established that those above the normal trajectory are associated with healthier aging⁽¹²⁴⁾ whereas those below it have an increased prevalence and incidence of respiratory, cardiovascular and metabolic diseases and premature death.^(42,125) From this perspective, spirometry can be considered a marker of global health. In fact, free downloadable software to monitor spirometry over time can now be accessed from the ERS website (gli-calculator.ersnet.org/lung_tracker/).^(126,127)

Spirometrically measured reduced maximal attained lung function can identify individuals who are at increased risk for the development of COPD.^(16,128) A large study and meta-analysis confirmed a positive association between birthweight and FEV1 in adulthood.⁽¹²⁹⁾ Factors in early life termed “childhood disadvantage factors” are key determinants of lung function in adult life.⁽¹²⁹⁻¹³⁷⁾ One study in three independent longitudinal cohorts (Framingham, Copenhagen and Lovelace) found that approximately 50% of patients developed COPD due to accelerated decline in FEV1 over time (the traditional Fletcher and Peto model),⁽¹³⁸⁾ while the other 50% developed COPD due to abnormal lung growth and development (with normal lung function decline over time; **Figure 1.1**).⁽¹²¹⁾

Age is often listed as a risk factor for COPD because there is a physiologic decline in lung function with age. Yet, it is unclear if healthy aging as such leads to COPD or if age reflects the sum of cumulative exposures throughout life.⁽¹³⁹⁾ However, aging of the airways and parenchyma mimic some of the structural changes associated with COPD⁽¹³⁹⁾ and there is evidence of accelerated aging in patients with COPD.⁽¹³¹⁾ A prospective study showed an association between accelerated telomere shortening (a marker of accelerated aging) and progressive worsening of pulmonary gas exchange, lung hyperinflation and extrapulmonary affection in COPD patients followed over 10 years.⁽¹⁴⁰⁾ Further, persistently shorter telomeres over this observation time increase the risk for all-cause mortality.⁽¹⁴⁰⁾ Age-related epigenetic changes in DNA in immune cells are also associated with increased risk of exacerbations and mortality in COPD patients.^(141,142) In the Tasmanian Longitudinal Health Study, the mixed (low FVC and low FEV1/FVC ratio) and the obstructive-only (low FEV1/FVC ratio) spirometric patterns showed the highest prevalence of COPD at age 53 (37% and 22% respectively).⁽¹³⁵⁾

The term *dysanapsis* refers to an anthropometric mismatch of airway tree calibre relative to lung volume.^(143,144) It was first proposed by Green and colleagues almost fifty years ago from maximal expiratory airflow variation among healthy adults.⁽¹³⁰⁾ There are still major gaps in our understanding of the origins and clinical implications of dysanapsis, but recent research using computed tomography (CT) has shown that: (1) it is common in the general population;^(130,134,145) (2) it is associated with FEV1/FVC from early adulthood;⁽¹⁴⁶⁾ (3) in explanted lungs from adult healthy donors, central airway dysanapsis (detectable by CT) extended to peripheral airways (non-visible on CT);⁽¹⁴⁶⁾ (4) dysanapsis is associated with baseline airflow obstruction and risk of incident COPD independently of age, sex, height and race-ethnicity, but not with lung function decline over time.⁽¹³⁴⁾ This observation is consistent with the trajectory of low peak lung function in early adulthood followed by normal lung function decline that accounts for 50% of COPD in older adults;⁽¹²¹⁾ (5) a computational study of airway tree fluid dynamics and an *in vivo* study of regional lung ventilation suggest that dysanapsis may contribute to obstructive lung disease pathophysiology and deposition of aerosolized drugs;⁽¹⁴⁷⁻¹⁴⁹⁾ and, (6) the mechanisms contributing to the development of dysanapsis are not well understood. It is not clear whether it is due to genetic predisposition, *in utero* exposures to noxious particulates or pathogens, premature birth, low birth weight, neonatal lung injury, repeated respiratory infections in early life or a combination of them, but factors affecting airway tree growth early in life^(130,132,134) and factors affecting airway tree homeostasis later in life have been implicated.^(131,133) Of note, investigating the aetiology of dysanapsis earlier in life will require radiation-free (or lower dose radiation) methods in order to quantify lung structure in children.

The fact that COPD can result from reduced peak lung function in early adulthood and/or accelerated lung function decline later in life^(122,150) opens novel opportunities for prevention, and earlier diagnosis and treatment of the disease⁽¹³⁾ but, at the same time, has generated several nosological terms that require proper definition to avoid confusion and facilitate future research:⁽¹⁵¹⁾

Early COPD

The word “early” means “near the beginning of a process”. Because COPD can start early in life and take a long time to manifest clinically, identifying “early” COPD is difficult. Further, a biological “early” related to the initial mechanisms that eventually lead to COPD should be differentiated from a clinical “early”, which reflects the initial perception of symptoms, functional limitation and/or structural abnormalities noted. Thus, we propose to use the term “early COPD” only to discuss the “biological” first steps of the disease in an experimental setting.

Mild COPD

Some studies have used “mild” airflow obstruction as a surrogate for “early” disease.⁽¹⁵²⁾ This assumption is incorrect because not all patients started their journey from a normal peak lung function in early adulthood, so some of them may never suffer “mild” disease in terms of “severity” of airflow obstruction.⁽¹²²⁾ Further, “mild” disease can occur at any age and may progress or not over time.⁽¹⁵⁰⁾ Accordingly, we propose that “mild” should not be used to identify “early” COPD and used only to describe the severity of airflow obstruction measured spirometrically.

Young COPD

The term “young COPD” is seemingly straightforward because it directly relates to the chronological age of the patient. Given that lung function peaks at around 20-25 years,⁽⁶⁸⁾ we propose to operationally consider “young COPD” in patients aged 20–50 years.⁽¹⁵³⁾ Of note, this can include patients who had never achieved normal peak lung function in early adulthood and/or those with shorter *plateau* and/or early lung function decline.^(154,155) Young COPD may be associated with significant structural and functional lung abnormalities (i.e., young COPD is not necessarily synonymous with “mild” COPD) that can have a substantial impact on health and, importantly, is frequently not diagnosed and thus not treated. A family history of respiratory diseases and/or early-life events (including hospitalizations before the age of 5 years) is reported by a significant proportion of young patients with COPD, further supporting the possibility of early-life origins of COPD.^(151,155)

Pre-COPD

This term has been recently proposed to identify individuals (importantly, of any age) who have respiratory symptoms and/or other detectable structural and/or functional abnormalities, in the absence of airflow obstruction on forced spirometry.⁽¹⁵⁶⁾ These patients may (or not) develop persistent airflow obstruction (i.e., COPD) over time.⁽¹⁵⁷⁾ A recent publication highlights the need for RCTs, both in patients with ‘Pre-COPD’, and in young people with COPD.⁽¹⁵⁸⁾

PRISm

The term PRISm (preserved ratio impaired spirometry) describes individuals with preserved ratio ($FEV1/FVC \geq 0.7$ after bronchodilation) but impaired spirometry ($FEV1 < 80\%$ of reference, after bronchodilation).^(12,159) The prevalence of PRISm in population-based studies ranges from 7.1% to 11%⁽¹⁶⁰⁻¹⁶³⁾ and from 10.4% to 11.3% in a selected population of current and former smokers such as the COPDGene cohort.⁽¹⁶⁴⁾ The prevalence of PRISm is particularly high in current and former smokers, and it is associated with both high and low body mass index (BMI) values, female gender, obesity and multimorbidity.⁽¹⁶⁰⁻¹⁶³⁾ PRISm is associated with increased risk of: respiratory symptoms; cardiopulmonary disease; all-cause and cardiovascular mortality; hospitalization; and an increased risk of developing airways obstruction.^(160,161,163,165-169)

PRISm is not always a stable phenotype and can transition to both normal and obstructed spirometry over time. It has been reported that around 20% to 30% of PRISm subjects transitioned to obstructed spirometry over time and the most important predictors of transition from PRISm spirometry to COPD are lower baseline FEV1%, and FEV1/FVC, higher age, current smoking, female gender, and a longer FET in the second assessment.^(161,163,164) Despite an increasing body of literature on PRISm, significant knowledge gaps remain in relation to its pathogenesis and treatment.

Not all individuals with pre-COPD or PRISm will eventually develop fixed airflow obstruction over time (and hence

COPD) but they should be considered “patients” (because they already suffer symptoms and/or have functional and/or structural abnormalities) and, as such, they deserve care and treatment. The challenge is that there is no evidence on what the best treatment is for these patients yet. ⁽¹⁷⁰⁾

Asthma and airway hyper-reactivity

Asthma may also be a risk factor for the development of chronic airflow obstruction and COPD. In a report from a longitudinal cohort of the Tucson Epidemiological Study of Airway Obstructive Disease, adults diagnosed of asthma were found to have a 12-fold higher risk of acquiring COPD over time compared to those without asthma, after adjusting for smoking. ⁽¹⁷¹⁾ Another longitudinal study of people with asthma found that around 20% developed irreversible airflow obstruction and reduced diffusing lung capacity. ⁽¹⁷²⁾ A third longitudinal study observed that self-reported asthma was associated with excess loss of FEV1 in the general population. ⁽¹⁷³⁾ A study examining the pattern of lung-growth decline in children with asthma found that 11% met lung function impairment consistent with the spirometric classification of COPD in early adulthood. ⁽¹⁷⁴⁾ In the European Community Respiratory Health Survey, airway hyper-responsiveness was second only to cigarette smoking as the leading risk factor for COPD, responsible for 15% of the population attributable risk (smoking had a population attributable risk of 39%). ⁽¹⁷⁵⁾ The pathology of chronic airflow obstruction in asthmatic non-smokers and non-asthmatic smokers is markedly different, suggesting that the two disease entities may remain different even when presenting with similarly reduced lung function. ^(171,176,177) However, separating asthma from COPD in adults may be clinically difficult at times. Further, abnormal lung development in childhood and adolescence can cause asthma-like symptoms. Given that poor lung development is associated with COPD in adulthood (**Figure 1.1**), these infants and adolescents may have been mislabeled as asthma.

On the other hand, airway hyper-responsiveness can exist without a clinical diagnosis of asthma and has been shown to be an independent predictor of COPD and respiratory mortality in population studies ^(178,179) as well as an indicator of risk of excess decline in lung function in patients with mild COPD. ⁽¹⁸⁰⁾

Chronic bronchitis

Chronic bronchitis (CB) is a common, but variable condition in patients with COPD. CB is defined by the presence of cough with expectorated sputum on a regular basis over a defined period. Variability in the prevalence of CB depends upon the definition used which differs in the regularity or duration of CB symptoms. ⁽¹⁸¹⁾ The classic description defines CB as chronic cough and sputum production for at least 3 months per year for two consecutive years, in the absence of other conditions that can explain these symptoms (an important caveat that is often ignored). Using this definition, the prevalence of CB ranges from 27-35% in large observational studies in patients with COPD. ⁽¹⁸²⁻¹⁸⁴⁾ Other factors associated with increased prevalence of CB in COPD includes male sex, younger age, greater pack-years of smoking, more severe airflow obstruction, rural location and increased occupational exposures. ⁽¹⁸¹⁻¹⁸⁷⁾ Although the primary risk for CB is smoking, 4-22% of CB is found in never smokers suggesting other factors are involved. ^(188,189) Inhalational exposures to dusts, biomass fuels, chemical fumes or domestic heating and cooking fuels may be important. ^(186,187,190) Gastroesophageal reflux is also associated with an increased incidence of CB. ^(191,192)

Normal airway mucus is a gel comprised of 97% water and 3% solids (mucins, non-mucin proteins, cellular debris, salts and lipids) that traps inhaled toxins which are subsequently expectorated via the processes of ciliary beating and cough. ⁽¹⁹³⁾ Mucins are large glycoproteins, two of the secreted mucin polymers, MUC5AC and MUC5B, line the human airways. ^(194,195) In healthy normal individuals, MUC5AC is produced by proximal airway surface goblet cells while MUC5B is produced by surface secretory cells found throughout the airways and submucosal glands. ⁽¹⁹⁴⁻¹⁹⁸⁾ In COPD, MUC5B levels markedly increase due to submucosal gland hyperplasia and airway occlusion can occur. ⁽¹⁹⁹⁻²⁰¹⁾ Viruses, acrolein and many cytokines (IL-4, IL-13, IL-17, IL-23 and IL-25) can also increase MUC5AC production. ⁽²⁰²⁻²⁰⁷⁾

Lung health depends upon effective mucus clearance. In disease states, thick and viscid mucus can lead to airway

inflammation and infection. Cough and dyspnea are the principal symptoms of impaired mucus clearance.^(208,209) Cough and sputum production are predominately associated with mucus production in the large airways. However, increased mucus production also occurs in the smaller conducting airways and is associated with luminal occlusion, hallmarked by dyspnea but less cough and sputum production.^(210,211) Radiographic manifestations of mucus plugging may be present and persist in patients with COPD despite a lack of CB symptoms and is associated with greater airflow obstruction, lower oxygen saturation, poorer exercise tolerance, more exacerbations and worsened quality of life⁽²¹²⁻²¹⁴⁾ and all-cause mortality.⁽²¹⁵⁾ A high index of suspicion for mucus hypersecretion should be maintained in all patients with COPD due to the protean clinical problems that accompanies its presence.⁽²¹⁶⁾ How patients who have mucus hypersecretion evident on CT but do not manifest symptoms differ phenotypically and vice versa is not fully understood.

The relationship between chronic mucus production and lung function, exacerbations and mortality has been the subject of multiple investigations. In young adults without a history of asthma and normal lung function, the presence of chronic cough with sputum identified a subgroup at high risk of developing COPD independently of smoking habits.⁽²¹⁷⁾ In adults less than 50 years of age, CB without airflow obstruction represents an early marker for susceptibility to the long-term risk of COPD and all-cause mortality.⁽²¹⁸⁾ In smokers between 36 to 43 years of age with chronic mucus production, there was a significant higher risk of airflow obstruction, however, following smoking cessation, mucus production returned to levels observed amongst never smokers.⁽²¹⁹⁾ Importantly, the longer chronic mucus hypersecretion is present, the greater the concurrent decrease in FEV1. While both MUC5AC and MUC5B have been associated with CB symptoms, among current smokers, it is sputum MUC5AC that has been associated more specifically with increased exacerbation frequency, increased symptoms and greater lung function decline.^(220,221) Large epidemiologic studies have shown after adjustment for height, age and smoking history, men with cough or phlegm and women with cough show accelerated loss of lung function.⁽²²²⁾ Other studies have suggested an association between chronic sputum production and lower lung function, or greater FEV1 decline in patients with COPD.⁽²²²⁻²²⁶⁾

The association of chronic mucus hypersecretion and mortality is unclear. Several studies report no predictive value of mucus production on mortality when controlling for respiratory impairment and smoking;⁽²²⁷⁻²²⁹⁾ other studies state sputum production has an independent role in predicting both overall and COPD-specific mortality.^(185,230-232) In the Copenhagen city heart study, chronic mucus hypersecretion was associated with pulmonary infection that was implicated in 54% of the deaths.⁽²³³⁾ Moreover, chronic mucus hypersecretion was associated with excessive FEV1 decline and increased COPD hospitalizations.⁽²²⁵⁾ In patients with advanced emphysema, chronic bronchitis has been associated with increased hospitalizations and mortality.⁽²³⁴⁾ In patients with non-obstructive chronic bronchitis, increased all-cause and respiratory disease related mortality has been reported.^(235,236)

Infections

A history of severe childhood respiratory infections has been associated with reduced lung function and increased respiratory symptoms in adulthood.⁽¹⁷⁵⁾ The Medical Research Council National Survey of Health and Development documented a synergistic interaction between smoking and infant respiratory infections as well as early life home overcrowding with lung function at age 43.⁽²³⁷⁾ Chronic bronchial infection, particularly with *Pseudomonas aeruginosa*, has been associated with accelerated FEV1 decline.⁽²³⁸⁾ Tuberculosis (TB) is a risk factor for COPD (23 studies; pooled odds ratio 2.59 (95% CI 2.12,3.15); pooled prevalence of COPD in patients with prior pulmonary TB was 21% (95% CI: 16–25%)).^(239,240) Tuberculosis is both a differential diagnosis for COPD and a potential comorbidity.^(241,242) Finally, HIV patients are at increased risk of COPD compared to HIV negative controls (11 studies; pooled odds ratio for 1.14 (95% CI 1.05,1.25))^(243,244) probably due to methylation disruptions in airway epithelium.⁽²⁴⁵⁾ IgG subclass deficiency has also been observed in hospitalized patients with COPD and this was associated with a significantly increased risk of mortality.⁽²⁴⁶⁾

Sex

Sex related differences in immune pathways and pattern of airway damage might be clinically important although more work in this area is needed. In the past, most studies have reported that COPD prevalence and mortality are greater among men than women, but later data from developed countries has shown that the prevalence of COPD is almost equal in males and females, probably reflecting the changing patterns of tobacco smoking.⁽²⁴⁷⁾ Although controversial, some studies have suggested that women may be more susceptible to the harmful effects of smoking than men,^(26,248-250) leading to more severe disease for the equivalent quantity of cigarettes consumed.⁽²⁵¹⁾ This notion has been validated in animal studies and human pathology specimens, which have demonstrated a greater burden of small airway disease in females compared with males with COPD despite a similar history of tobacco smoke exposure.^(252,253) A systematic review and meta-analysis of the global prevalence of COPD reported sex-based prevalence differences across WHO Global Burden of Disease sub-regions. In females the highest prevalence of COPD was observed in North America (8.07% vs 7.30%) and in urban settings (13.03% vs 8.34%). Using the World Bank's income categories prevalence was highest in upper-middle income countries for males (9.00%) and in high-income countries for females. Multiple female reproductive factors including age at menarche, number of children, miscarriage, stillbirth, and age at natural menopause were associated with the risk of COPD in a large cohort study.⁽²⁵⁴⁾

Race and ethnicity

An ATS workshop report⁽²⁵⁵⁾ has recommended replacing race- and ethnicity-specific equations with race-neutral average reference equations in pulmonary function testing. It also emphasized the importance of further research and education into the clinical and epidemiological consequences of these changes.^(106,255)

Socioeconomic status

Poverty is consistently associated with airflow obstruction⁽²⁵⁶⁾ and lower socioeconomic status is associated with an increased risk of developing COPD.^(257,258) It is not clear, however, whether this pattern reflects exposures to household and outdoor air pollutants, crowding, poor nutrition, infections, or other factors related to low socioeconomic status.

PATHOBIOLOGY

In patients with COPD pathological changes can be found in the airways, lung parenchyma, and pulmonary vasculature.⁽²⁵⁹⁾ These include inflammatory and structural changes which increase with the severity of airflow obstruction and can persist on smoking cessation (**Figure 1.1**).

Inflammatory changes

The inflammation observed in the lungs of COPD patients appears to be a modification of the normal inflammatory response to chronic irritants such as cigarette smoke. The mechanisms for this amplified inflammation are not yet fully understood but may, at least in part, be genetically determined.

COPD is characterized by increased numbers of macrophages in peripheral airways, lung parenchyma and pulmonary vessels, together with increased activated neutrophils and increased lymphocytes. These inflammatory cells, together with epithelial cells and other structural cells release multiple inflammatory mediators⁽²⁶⁰⁾ which attract inflammatory cells from the circulation (chemotactic factors), amplify the inflammatory process (via proinflammatory cytokines), and induce structural changes (via growth factors).⁽²⁶¹⁾ Lung inflammation can persist after smoking cessation through as yet unclear mechanisms, although autoantigens and perturbations in the lung microbiome may play a role.^(262,263) Systemic inflammation may also be present and could play a role in the comorbid conditions frequently found in patients with COPD.⁽²⁶⁰⁾ The nature of the inflammatory response in non-smoking related COPD is much less well

characterized.

Although both COPD and asthma are associated with chronic inflammation of the respiratory tract, there are differences in the inflammatory cells and mediators involved in the two diseases.⁽²⁶⁴⁾ albeit some patients with COPD have an inflammatory pattern with increased eosinophils and ILC2 cells, similar to that of asthma.⁽²⁶⁵⁾

Oxidative stress can also contribute to COPD.^(260,266) Biomarkers of oxidative stress (e.g., hydrogen peroxide, 8-isoprostane) are increased in the exhaled breath condensate, sputum, and systemic circulation of COPD patients. Oxidative stress is further increased during exacerbations. Oxidants are both generated by cigarette smoke and other inhaled particulates and released from activated inflammatory cells such as macrophages and neutrophils.^(241,267)

Structural changes

There is compelling evidence for an imbalance in the lungs of COPD patients between proteases derived from inflammatory and epithelial cells that break down connective tissue components and antiproteases that counterbalance this action.⁽²⁶⁸⁾ Protease-mediated destruction of elastin, a major connective tissue component of the lung parenchyma, is an important feature of emphysema but its role may be more difficult to establish in airway changes.⁽²⁶⁹⁾

Peribronchiolar fibrosis and interstitial opacities have been reported in patients with COPD and in asymptomatic smokers.^(262,270-272) An excessive production of growth factors may be found in smokers and patients with COPD.⁽²⁷³⁾ Inflammation may precede the development of fibrosis or repeated injury of the airway wall itself may lead to excessive production of muscle and fibrous tissue.⁽²⁷⁴⁾ This may contribute to the development of small airways obstruction.⁽²⁷⁵⁾

The lung vasculature can also be altered in patients with COPD, even those with mild disease.⁽²⁷⁶⁾

Dysbiosis

Gene sequencing analysis of respiratory samples has been used to describe the lung microbiome. These techniques are markedly more sensitive than traditional cultures used in clinical practice, which detect only live bacteria colonizing the airways or associated with symptoms of infection. Gene sequencing studies provide information about the relative abundance and diversity of microbiota and have shown that the lower respiratory tract is not sterile but permanently contains a diverse array of bacteria.

Dysbiosis refers to disruption of the microbiome and has been observed in several compartments in patients with COPD including the airways. Very diverse risk factors for COPD such as cigarette smoking or prematurity alter mucosal immunity and the gut and airway microbiota, which interact in both directions (the 'gut-lung axis') through immune cross-talk and microbial metabolites and peptides.⁽²⁷⁷⁾ Dysbiosis is cross-sectionally associated with the presence of COPD and different disease characteristics such as frequency of exacerbations,⁽²⁷⁸⁾ likely through the alteration of mucosal defences (vicious circle) and stimulation of lung inflammation by immune responses.^(279,280) The microbiome profile is modified following viral infections and during exacerbations and is differentially altered by antibiotics and oral or inhaled corticosteroids.⁽²⁸¹⁻²⁸³⁾ Overall, these observations suggest a role for dysbiosis in the development and progression of COPD, but the paucity of longitudinal data⁽²⁸⁴⁾ and interventional studies underline the need for further research to ascertain the direction(s) of causality and possible prognostic, diagnostic or therapeutic applications.⁽²⁸³⁾

PATHOPHYSIOLOGY

Airflow obstruction and gas trapping

Airflow obstruction is usually measured by spirometry as this is the most widely available and reproducible test of lung function. In COPD, airflow obstruction is caused by a mixture of small airways disease (which increases airway resistance) and parenchymal destruction (emphysema, that reduces the normal elastic recoil of the lung parenchyma), the relative contributions of which vary from person to person. Further, these changes do not always occur together and may evolve at different rates over time. Chronic inflammation causes structural changes, narrowing of the small airways, luminal exudates in the small airways and destruction of the lung parenchyma that leads to the loss of alveolar attachments to the small airways and decreases lung elastic recoil. In turn, these changes diminish the ability of the airways to remain open during expiration. A loss of small airways may also contribute to airflow obstruction and mucociliary dysfunction.⁽²⁸⁵⁾ The reduced number of small airways identified in patients with COPD⁽²⁸⁵⁾ may be due to an enhanced loss of airways and/or to deficient lung development (see dysanapsis above; **Figure 1.1**).⁽¹⁵⁰⁾ Collectively, all these changes limit emptying of the lungs during forced expiration, decrease FEV1 and the FEV1/FVC ratio, and contribute to gas trapping and lung hyperinflation.⁽²⁸⁶⁾

Hyperinflation

Hyperinflation occurs when gas volume in the lungs is increased compared to normal values at the end of spontaneous expiration.^(287,288) Hyperinflation is clinically relevant in patients with COPD and contributes to dyspnea,⁽²⁸⁹⁻²⁹²⁾ impaired exercise tolerance,⁽²⁹³⁻²⁹⁵⁾ increased number of hospitalizations,⁽²⁹⁶⁾ development of respiratory failure⁽²⁹⁷⁾ and increased mortality.^(294,296,298) In patients with COPD, hyperinflation arises due to loss of elastic recoil and expiratory flow obstruction.⁽²⁹⁹⁾ Expiratory flow obstruction occurs when the expiratory flows generated during spontaneous breathing are the maximal flows that can be generated at that operational lung volume.⁽²⁸⁷⁾ Expiratory flow obstruction is caused by the dual effects of emphysematous parenchymal destruction and airways abnormalities (e.g., mucus obstruction, airway edema, heightened bronchial tone, airway wall remodeling). The lung can be hyperinflated at rest (static hyperinflation due to the loss of elastic lung recoil as a consequence of emphysema) and/or during exercise (dynamic hyperinflation as a consequence of airflow obstruction) when ventilatory demands are increased and expiratory times are reduced.^(287,288)

Hyperinflation is common in patients with COPD and can be found in patients with even mild obstruction at rest and even more so during exercise.^(300,301) In patients with moderate to severe obstruction, the level of dynamic hyperinflation correlates more closely with the impairment in diffusion capacity and severity of small airways obstruction and higher ventilatory response to exercise than FEV1 measurement.^(287,293)

Lung volumes assessed by body plethysmography or gas dilution techniques (helium dilution or nitrogen washout) represent the reference measurements to assess the presence and degree of hyperinflation, however, values may vary due to differences in measuring compressible gas volumes or communicating gas volumes, respectively.^(302,303) Measurement of inspiratory capacity at rest and during exercise is an indirect measurement of increased end-expiratory lung volumes and indicates the presence of static and/or dynamic hyperinflation.⁽³⁰⁴⁾ Hyperinflation can also be detected on chest imaging but standardization is lacking.⁽²⁸⁷⁾

Hyperinflation can be addressed with bronchodilators,^(305,306) supplemental oxygen,^(307,308) heliox,⁽³⁰⁹⁾ pulmonary rehabilitation,⁽³¹⁰⁾ pursed lip breathing,⁽³¹¹⁾ inspiratory muscle training⁽³¹²⁾ or in selected cases of emphysema causing severe hyperinflation, lung reduction surgery⁽³¹³⁾ or bronchoscopic lung reduction techniques.^(314,315)

Pulmonary gas exchange abnormalities

Structural abnormalities in the airways, alveoli and pulmonary circulation in patients with COPD alter the normal ventilation-perfusion (V_A/Q) distributions. This is the main mechanism of abnormal pulmonary gas exchange resulting in different degrees of arterial hypoxemia, without or with hypercapnia.⁽³¹⁶⁾ Rarely, reduced ventilation may also be due to reduced ventilatory drive (e.g., sedatives and hypnotic drugs), causing hypercapnic respiratory failure and acidosis.⁽³¹⁷⁾ Parenchymal destruction due to emphysema also leads to decreased lung diffusing capacity (DLco). In general, pulmonary gas exchange worsens as the disease progresses.

Pulmonary hypertension

In smokers with normal spirometry and in COPD patients with mild airflow obstruction there may be abnormalities in the pulmonary circulation that include intimal hyperplasia and smooth muscle hypertrophy/hyperplasia.⁽³¹⁸⁻³²¹⁾ Moreover, an inflammatory response in vessels, similar to that seen in the airways, can be observed in these individuals along with evidence of endothelial cell dysfunction. Yet, severe pulmonary hypertension in COPD is rare.^(322,323) It may develop late in the course of COPD and it can be due to a combination of loss of pulmonary capillary bed due to emphysema and/or hypoxic vasoconstriction of the small pulmonary arteries. Progressive pulmonary hypertension may lead to right ventricular hypertrophy and eventually to right-sided heart failure ('*cor pulmonale*'). Severe pulmonary hypertension worsens survival.⁽³²⁴⁾ Interestingly, the diameter of pulmonary artery as measured on computed tomography (CT) scans has been shown to relate to the increased risk of suffering exacerbations, independent of previous history of exacerbations.⁽³²⁵⁾

Exacerbations

Exacerbations of respiratory symptoms in patients with COPD can be triggered by a number of different factors (alone or in combination), including respiratory infections with bacteria or viruses (which may coexist), environmental pollutants, or unknown factors. During exacerbations there is evidence of increased airway and systemic inflammation, increased gas trapping and hyperinflation with reduced expiratory flow, thus accounting for increased dyspnea,⁽³²⁶⁾ and worsening of VA/Q abnormalities that can result in arterial hypoxemia with or without hypercapnia.⁽³²⁷⁾ Other conditions, such as pneumonia, pulmonary, and/or heart failure, among others, may mimic or aggravate an exacerbation of COPD, and need to be considered in the clinical management of these episodes.⁽³²⁸⁾ See **Chapter 4** for an extended discussion on exacerbations.

Multimorbidity

Most patients with COPD suffer concomitant chronic comorbid diseases linked to the same risk factors i.e., smoking, aging, and inactivity, which may have a major impact on health status and survival.^(329,330) The term syndemics has been introduced to describe the co-occurrence of COPD with other conditions that have possible shared mechanisms and risk factors.⁽³³¹⁾ Airflow obstruction and particularly hyperinflation affect cardiac function.⁽³²⁶⁾ Inflammatory mediators in the circulation may contribute to skeletal muscle wasting and cachexia, and may initiate or worsen comorbidities such as ischemic heart disease, heart failure, osteoporosis, normocytic anemia, diabetes, and metabolic syndrome (see **Chapter 5**).

TAXONOMY

COPD has been traditionally understood as a single "disease" caused by tobacco smoking.⁽¹³⁸⁾ Accordingly, most efforts have been devoted to the study of the pathogenetic mechanisms of only one major cause of COPD (cigarette smoking), failing to expand the horizon about the heterogeneity of processes that we know can contribute to its final clinical presentation.⁽⁷⁾ It is therefore important to expand the taxonomy (classification) of COPD to include non-smoking

related COPD types, so specific studies can be designed and conducted for these different types of COPD or *etiotypes*.⁽³³²⁾ **Figure 1.2** combines two recent taxonomic proposals developed independently.^(6,333) This proposal has relatively little impact on current clinical practice, other than illuminating this so-far ignored aspect of COPD, but it is of the outmost importance to highlight the need to explore current and future therapies in these other *etiotypes* of COPD.

Proposed Taxonomy (Etiotypes) for COPD

Figure 1.2

Classification	Description
Genetically determined COPD (COPD-G)	Alpha-1 antitrypsin deficiency (AATD) Other genetic variants with smaller effects acting in combination
COPD due to abnormal lung development (COPD-D)	Early life events, including premature birth and low birthweight, among others
Environmental COPD	
Cigarette smoking COPD (COPD-C)	<ul style="list-style-type: none"> • Exposure to tobacco smoke, including <i>in utero</i> or via passive smoking • Vaping or e-cigarette use • Cannabis
Biomass and pollution exposure COPD (COPD-P)	Exposure to household pollution, ambient air pollution, wildfire smoke, occupational hazards
COPD due to infections (COPD-I)	Childhood infections, tuberculosis-associated COPD, HIV-associated COPD
COPD & asthma (COPD-A)	Particularly childhood asthma
COPD of unknown cause (COPD-U)	

*Adapted from Celli et al. (2022) and Stolz et al. (2022)

CHAPTER 2: DIAGNOSIS AND ASSESSMENT

KEY POINTS:

- A diagnosis of COPD should be **considered** in any patient who has dyspnea, chronic cough or sputum production, a history of recurrent lower respiratory tract infections and/or a history of exposure to risk factors for the disease, but **spirometry** showing the presence of a post-bronchodilator $FEV_1/FVC < 0.7$ is **mandatory** to establish the diagnosis of COPD.
- The goals of the initial COPD assessment are to determine the severity of airflow obstruction, the impact of disease on the patient's health status, and the risk of future events (such as exacerbations, hospital admissions, or death), to guide therapy.
- Additional clinical assessment, including the measurement of lung volumes, diffusion capacity, exercise testing and/or lung imaging may be considered in COPD patients with persistent symptoms after initial treatment.
- Concomitant chronic diseases (multimorbidity) occur frequently in COPD patients, including cardiovascular disease, skeletal muscle dysfunction, metabolic syndrome, osteoporosis, depression, anxiety, and lung cancer. These comorbidities should be actively sought, and treated appropriately when present, because they influence health status, hospitalizations and mortality independently of the severity of airflow obstruction due to COPD.

DIAGNOSIS

A diagnosis of COPD should be **considered** in any patient who has dyspnea, chronic cough or sputum production, and/or a history of exposure to risk factors for the disease (**Figure 2.1**) but **forced spirometry** that demonstrates the presence of a post-bronchodilator $FEV_1/FVC < 0.7$ is **mandatory** to establish the diagnosis of COPD.⁽⁴⁶⁾

CLINICAL PRESENTATION

Symptoms

Chronic dyspnea is the most characteristic symptom of COPD. Cough with sputum production is present in up to 30% of patients. These symptoms may vary from day-to-day⁽³³⁴⁾ and may precede the development of airflow obstruction by many years. Individuals, particularly those with COPD risk factors, presenting with these symptoms should be examined to search for the underlying cause(s). Airflow obstruction may also be present without chronic dyspnea and/or cough and sputum production and *vice versa*.⁽³³⁵⁾ Although COPD is defined on the basis of airflow obstruction, in practice the decision to seek medical help is usually determined by the impact of symptoms on a patient's functional status. A person may seek medical attention either because of chronic respiratory symptoms or because of an acute, transient episode of exacerbated respiratory symptoms.

Clinical Indicators for Considering a Diagnosis of COPD

Figure 2.1

Consider the diagnosis of COPD, and perform spirometry, if any of these clinical indicators are present: (these indicators are not diagnostic themselves, but the presence of multiple key indicators increases the probability of the presence of COPD; in any case, spirometry is required to establish a diagnosis of COPD)

Dyspnea that is	Progressive over time Worse with exercise Persistent
Recurrent wheeze	
Chronic cough	May be intermittent and may be non-productive
Recurrent lower respiratory tract infections	
History of risk factors	Tobacco smoke (including popular local preparations) Smoke from home cooking and heating fuels Occupational dusts, vapors, fumes, gases and other chemicals Host factors (e.g., genetic factors, developmental abnormalities, low birthweight, prematurity, childhood respiratory infections etc.)

Dyspnea

Dyspnea is a cardinal symptom of COPD and a major cause of the disability and anxiety associated with the disease.⁽³³⁶⁾ Dyspnea comprises a sensory and an affective component.⁽³³⁷⁾ Typically, COPD patients describe their dyspnea as a sense of increased effort to breathe, chest heaviness, air hunger, or gasping.⁽³³⁸⁾ However, the terms used to describe dyspnea may vary both individually and culturally.⁽³³⁸⁾

Dyspnea is highly prevalent across all stages of airflow obstruction.⁽³³⁹⁾ It occurs particularly during exertion or physical activity. Moderate-to-severe dyspnea has been reported by >40% of patients diagnosed with COPD in primary care.⁽³⁴⁰⁾

Dyspnea is complex and multiple mechanisms can be involved in its pathogenesis, including impaired respiratory mechanics as a consequence of airflow obstruction and lung hyperinflation, gas exchange abnormalities, peripheral muscle dysfunction related to deconditioning (and systemic inflammation in some patients), psychological distress, dysfunctional breathing, cardiovascular or other comorbid diseases.^(341,342)

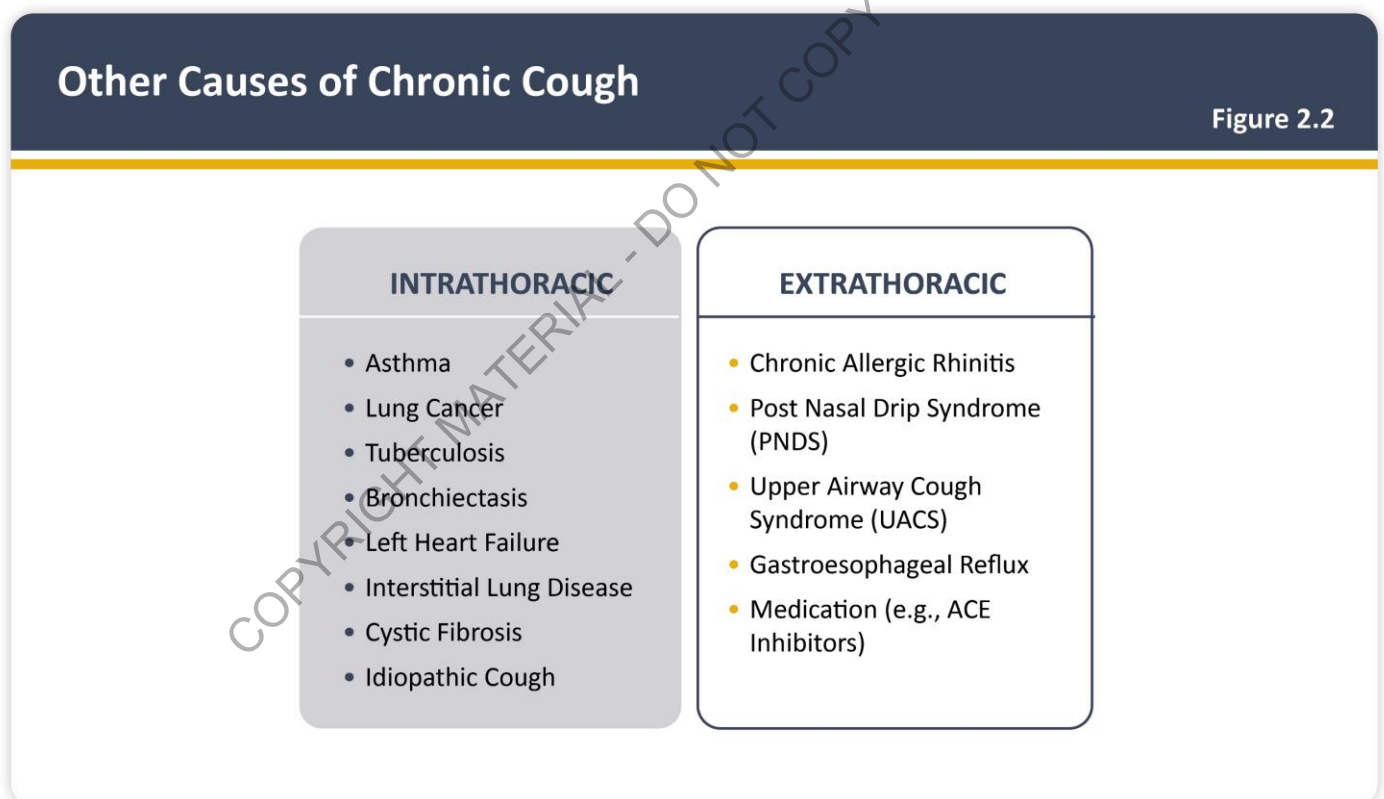
Dyspnea measured by the 5-level modified Medical Research Council scale is integrated in the GOLD clinical classification scheme (see below) because patients with high dyspnea scores incur higher healthcare resource utilization and costs.⁽³⁴³⁾ Dyspnea in daily life can be measured by a number of detailed questionnaires that are more discriminant and sensitive to change.^(344,345)

Chronic cough

Chronic cough is often the first symptom of COPD and is frequently discounted by the patient as an expected consequence of smoking and/or environmental exposures. Initially, the cough may be intermittent, but subsequently it may be present every day, often throughout the day. Chronic cough in COPD may be productive or non-productive.⁽³⁴⁶⁾ In some cases, significant airflow obstruction may develop without the presence of a cough. Other causes of chronic cough are listed in **Figure 2.2**. Syncope during cough in patients with severe COPD can occur due to rapid increases in intrathoracic pressure during prolonged attacks of coughing. Coughing spells may also cause rib fractures, which are sometimes asymptomatic.

Sputum production

COPD patients commonly raise small quantities of tenacious sputum with coughing. Regular production of sputum for three or more months in two consecutive years (in the absence of any other conditions that may explain it) is the classical definition of chronic bronchitis,⁽³⁴⁷⁾ but this is a somewhat arbitrary definition that does not reflect the entire range of sputum production that occurs in COPD (see detailed discussion in **Chapter 1**). Sputum production is often difficult to evaluate because patients may swallow sputum rather than expectorate it, a habit that is subject to significant cultural and sex variation. Furthermore, sputum production can be intermittent with periods of flare-up interspersed with periods of remission.⁽²¹⁹⁾ Patients producing large volumes of sputum may have underlying bronchiectasis.^(348,349) The presence of purulent sputum reflects an increase in inflammatory mediators,^(350,351) and its development may identify the onset of a bacterial exacerbation, though the association is relatively weak.^(351,352)



Wheezing and chest tightness

Inspiratory and/or expiratory wheezes and chest tightness are symptoms that may vary between days, and over the course of a single day. Alternatively, widespread inspiratory or expiratory wheezes can be present on auscultation. Chest tightness often follows exertion, is poorly localized, is muscular in character, and may arise from isometric contraction of the intercostal muscles. An absence of wheezing or chest tightness does not exclude a diagnosis of COPD, nor does the presence of these symptoms confirm a diagnosis of asthma.

Fatigue

Fatigue is the subjective feeling of tiredness or exhaustion and is one of the most common and distressing symptoms experienced by people with COPD.⁽³⁵³⁾ People with COPD describe their fatigue as a feeling of “general tiredness” or as a feeling of being “drained of energy”.^(354,355) Fatigue impacts a patient’s ability to perform activities of daily living and their quality of life.

Additional clinical features in severe disease

Weight loss, muscle mass loss, and anorexia are common problems in patients with severe and very severe COPD.⁽³⁵⁶⁻³⁵⁸⁾ They have prognostic importance^(359,360) and can also be a sign of other diseases, such as tuberculosis or lung cancer, and therefore should always be investigated. Ankle swelling may indicate the presence of *cor pulmonale*. Symptoms of depression and/or anxiety merit specific enquiry when obtaining the medical history because they are common in COPD,⁽³⁶¹⁾ are associated with poorer health status, increased risk of exacerbations, and emergency hospital admission, and are treatable.⁽³⁶²⁾

DIFFERENTIAL DIAGNOSIS OF COPD

In some patients with COPD, a clear distinction from asthma is difficult using current imaging and physiological testing techniques, since the two conditions share common traits and clinical expressions.⁽³⁶³⁾ Most other potential differential diagnoses are easier to distinguish from COPD (**Figure 2.3**).

MEDICAL HISTORY

A detailed medical history of a new patient who is known, or suspected, to have COPD should include:

- ▶ *Patient’s exposure to risk factors*, such as smoking and environmental exposures (household/outdoor).
- ▶ *Past medical history*, including early life events (prematurity, low birthweight, maternal smoking during pregnancy, passive smoking exposure during infancy), asthma, allergy, sinusitis, or nasal polyps; respiratory infections in childhood; HIV; tuberculosis.
- ▶ *Family history of COPD or other chronic respiratory disease*.
- ▶ *Pattern of symptom development*: COPD typically develops in adult life and most patients are conscious of increased breathlessness, more frequent or prolonged “winter colds,” and some social restriction for a number of years before seeking medical help.
- ▶ *History of exacerbations or previous hospitalizations for respiratory disorder*. Patients may be aware of periodic worsening of symptoms even if these episodes have not been identified as exacerbations of COPD.
- ▶ *Presence of comorbidities*, such as heart disease, osteoporosis, musculoskeletal disorders, anxiety and depression, and malignancies that may also contribute to restriction of activity.
- ▶ *Impact of disease on patient’s life*, including limitation of activity, missed work and economic impact, effect on family routines, feelings of depression or anxiety, wellbeing, and sexual activity.
- ▶ *Social and family support available to the patient*.
- ▶ *Possibilities for reducing risk factors, especially smoking cessation*.

Differential Diagnosis of COPD

Figure 2.3

Diagnosis	Suggestive Features
COPD	Symptoms slowly progressive History of tobacco smoking or other risk factors
Asthma	Variable airflow obstruction Symptoms vary widely from day to day Symptoms worse at night/early morning Allergy, rhinitis, and/or eczema also present Often occurs in children Family history of asthma
Congestive heart failure	Chest X-ray shows dilated heart, pulmonary edema Pulmonary function tests indicate volume restriction, not airflow obstruction
Bronchiectasis	Large volumes of purulent sputum Commonly associated with bacterial infection Chest X-ray/HRCT shows bronchial dilation
Tuberculosis	Onset at all ages Chest X-ray shows lung infiltrate Microbiological confirmation High local prevalence of tuberculosis
Obliterative bronchiolitis	Can occur in children Seen after lung or bone marrow transplantation HRCT on expiration shows hypodense areas
Diffuse panbronchiolitis	Predominantly seen in patients of Asian descent Most patients are male and nonsmokers Almost all have chronic sinusitis Chest X-ray & HRCT show diffuse small centrilobular nodular opacities & hyperinflation

These features tend to be characteristic of the respective diseases, but are not mandatory. For example, a person who has never smoked may develop COPD (especially in LMICs where other risk factors may be more important than cigarette smoking).

PHYSICAL EXAMINATION

Although an important part of patient care, a physical examination is rarely (if ever) diagnostic in COPD. Physical signs of airflow obstruction are usually not present until significant impairment of lung function has occurred, [\(364,365\)](#) and detection based on physical examination has relatively low sensitivity and specificity. A number of physical signs (e.g., lung hyperinflation, cyanosis) may be present in COPD, but their absence does not exclude the diagnosis.

SPIROMETRY

Forced spirometry is the most reproducible and objective measurement of airflow obstruction. It is a noninvasive, reproducible, cheap, and readily available test. Good quality spirometric measurement is possible in any healthcare setting and all healthcare workers who care for people with COPD should have access to spirometry. Some of the factors needed to achieve accurate test results are summarized in **Figure 2.4**.^(366,367) Despite its good sensitivity, peak expiratory flow measurement alone cannot be reliably used as the only diagnostic test because of its weak specificity.^(368,369)

Considerations in Performing Spirometry

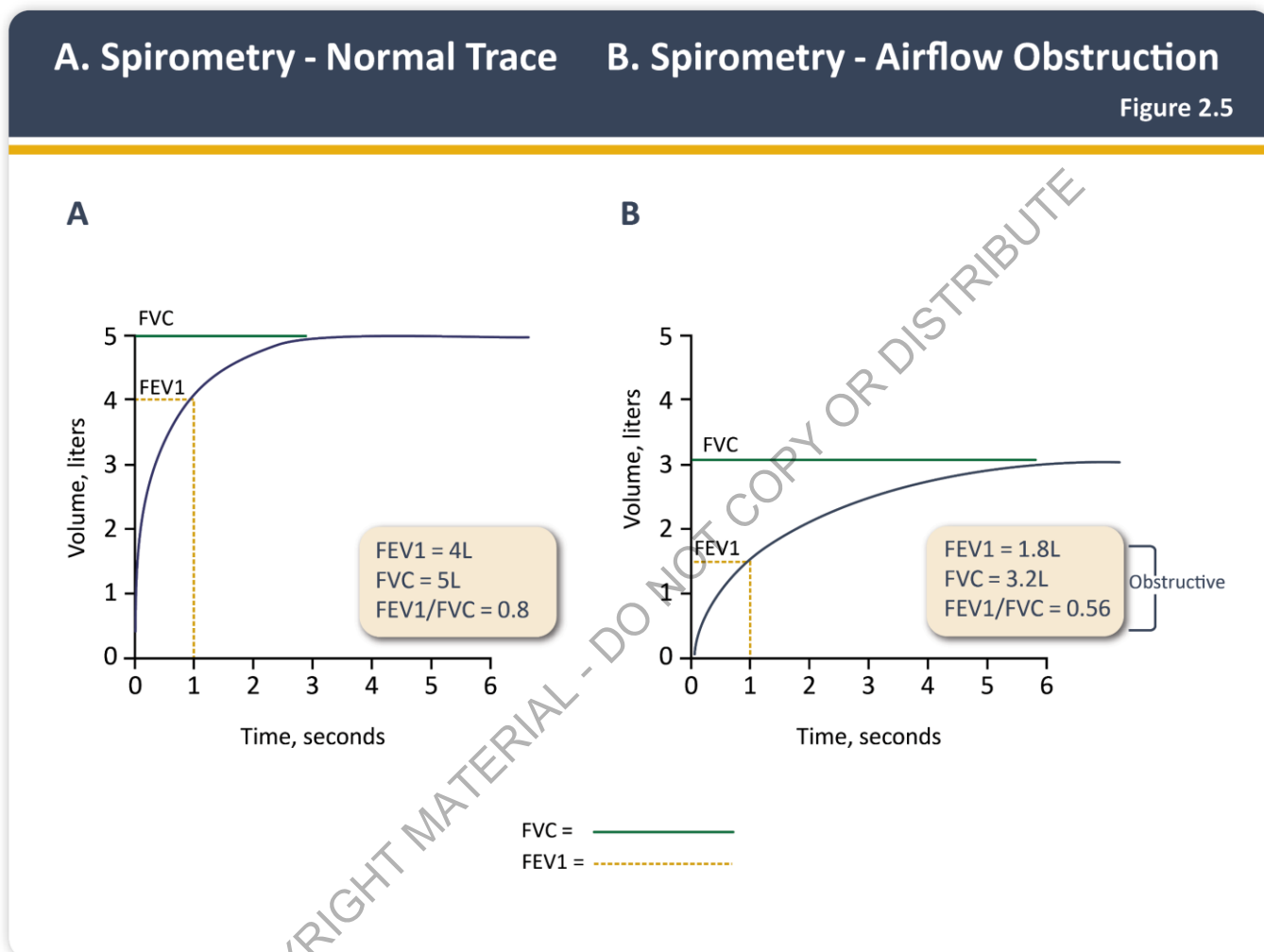
Figure 2.4

PREPARATION	<ul style="list-style-type: none">• Spirometers should produce hard copy or have a digital display of the expiratory curve to permit detection of technical errors or have an automatic prompt to identify an unsatisfactory test and the reason for it• The supervisor of the test needs training in optimal technique and quality performance• Maximal patient effort in performing the test is required to avoid underestimation of values and hence errors in diagnosis and management
PERFORMANCE	<ul style="list-style-type: none">• Spirometry should be performed following national and/or international recommendations^a• The expiratory volume/time traces should be smooth and free from irregularities• The pause between inspiration and expiration should be less than one second• The recording should go on long enough for a volume plateau to be reached, which may take more than 15 seconds in severe disease• Both FVC and FEV1 should be the largest value obtained from any of three technically satisfactory curves and the FVC and FEV1 values in these three curves should vary by no more than 5% or 150 mL, whichever is greater• The FEV1/FVC ratio should be taken from the technically acceptable curve with the largest sum of FVC and FEV1
BRONCHODILATION	<ul style="list-style-type: none">• Possible dosage protocols are 400 mcg short-acting beta₂-agonist, 160 mcg short-acting anticholinergic, or the two combined^b; FEV1 should be measured 10-15 minutes after a short-acting beta₂-agonist is given, or 30-45 minutes after a short-acting anticholinergic or a combination of both classes of drugs• Patients already on bronchodilator treatment, in whom spirometry is requested for monitoring purposes do not need to stop their regular treatment for spirometry
EVALUATION	<ul style="list-style-type: none">• Spirometry measurements are evaluated by comparison of the results with appropriate reference values based on age, height and sex• The presence of a post-bronchodilator FEV1/FVC < 0.7 confirms the presence of non-fully reversible airflow obstruction

^aMiller *et al.* Eur Respir J 2005; 26(2): 319; ^bPellegrino *et al.* Eur Respir J 2005; 26(5): 948.

As shown in **Figure 2.5**, forced spirometry measures: (1) the volume of air forcibly exhaled from the point of maximal inspiration (forced vital capacity, FVC); (2) the volume of air exhaled during the first second of this maneuver (forced expiratory volume in one second, FEV1); and (3) the ratio of these two measurements (FEV1/FVC). Spirometry measurements are evaluated by comparison with reference values^(367,370,371) based on age, height and sex (see below).

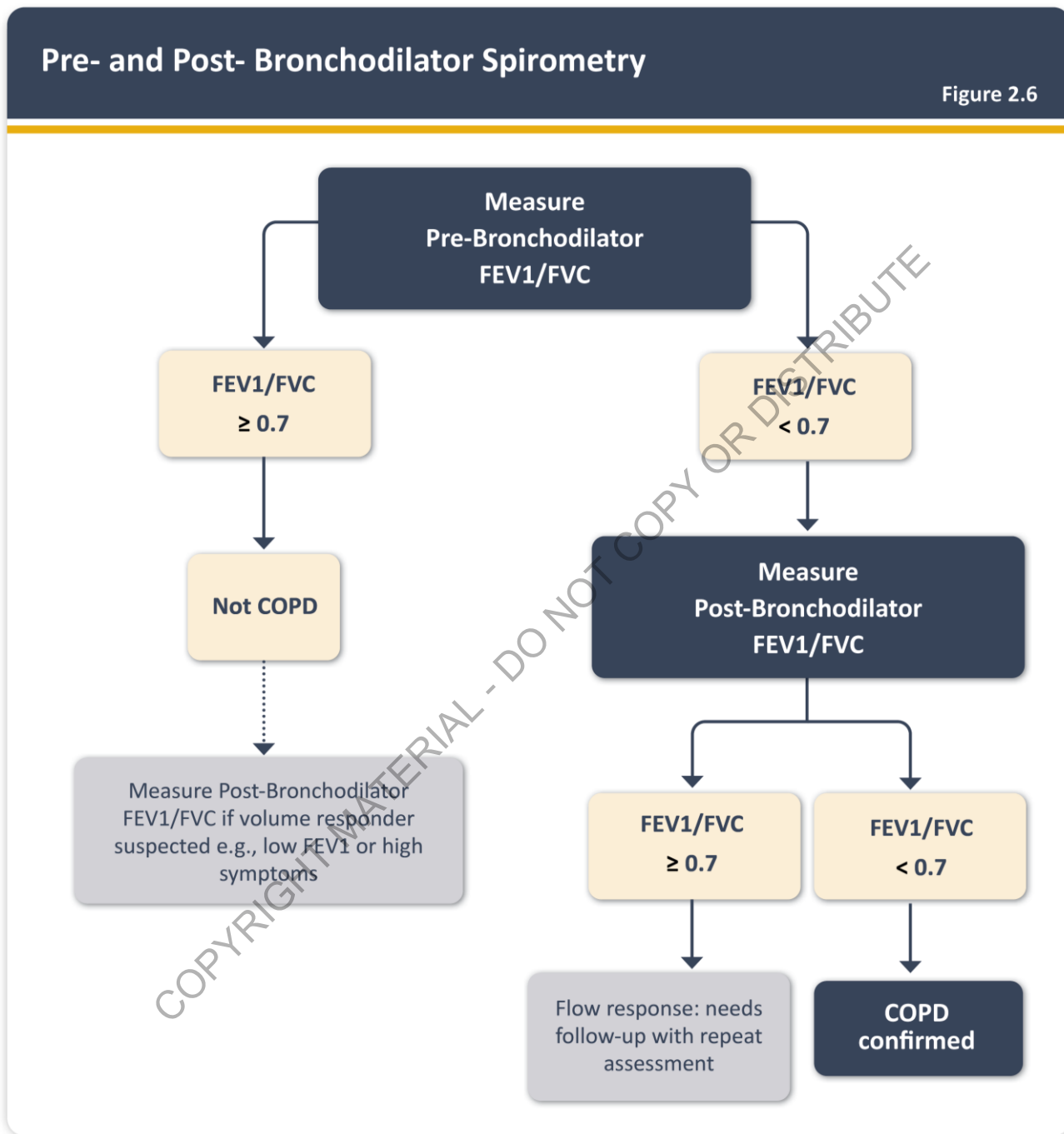
Figure 2.5A shows a normal spirometry tracing and **Figure 2.5B** shows a tracing obtained in a person with COPD. Patients with COPD typically show a decrease in both FEV1 (due to airflow obstruction) and (to a lesser degree) FVC (due to gas trapping).



Pre- or post-bronchodilator spirometry

In line with other National and International guidelines, GOLD has recommended using post-bronchodilator values when considering a diagnosis of COPD. Historically, post-bronchodilator values were considered more appropriate for confirming a diagnosis of fixed airflow obstruction as they were thought to be more reproducible, to be useful in excluding asthma and could identify volume responders to bronchodilators in whom the obstruction was revealed by bronchodilator-induced increase in FVC.⁽³⁷²⁾ However, it is now recognised that the bronchodilator response has little value in differentiating asthma from COPD,⁽³⁷³⁾ that pre-bronchodilator values are reproducible⁽³⁷⁴⁾ and obstruction only found on post-bronchodilator measurements is uncommon.⁽³⁷⁵⁾ Obtaining post-bronchodilator values is more time consuming and this may deter clinicians from performing spirometry. Pre-bronchodilator spirometry can be used as an initial test to investigate whether symptomatic patients have airflow obstruction (**Figure 2.6**). If the pre-bronchodilator spirometry does not show obstruction (see below for definition) performing post-bronchodilator spirometry is not necessary unless there is a very high clinical suspicion of COPD, in which case an FVC volume response

may reveal obstruction. Further tests to investigate the cause of the patient's symptoms and follow-up, including repeating the spirometry after an interval, may be required. If the pre-bronchodilator values show obstruction the diagnosis of COPD should be confirmed using post-bronchodilator measurements. Individuals with a pre-bronchodilator FEV1/FVC ratio that shows obstruction but a post-bronchodilator ratio that does not show obstruction have been shown to have an increased risk of future development of COPD, and should be followed closely.⁽³⁷⁶⁾



While post-bronchodilator spirometry is required for the diagnosis and assessment of COPD, assessing the degree of reversibility of airflow obstruction (e.g., measuring FEV1 before and after bronchodilator or corticosteroids) to inform therapeutic decisions is no longer recommended.⁽³⁷⁷⁾ The degree of reversibility in a single patient varies over time and has not been shown to differentiate the diagnosis from asthma, or to predict the response to long-term treatment with bronchodilators or corticosteroids.⁽³⁷⁸⁾ Accordingly, it is not necessary to stop inhaled medication before obtaining spirometry measurements during follow-up of patients. **Figure 2.7** shows the role of spirometry in patients with COPD.

- **Diagnosis**
- **Assessment of severity of airflow obstruction (for prognosis)**
- **Follow-up assessment**
 - Therapeutic decisions
 - Pharmacological in selected circumstances (e.g., discrepancy between spirometry and level of symptoms)
 - Consider alternative diagnoses when symptoms are disproportionate to degree of airflow obstruction
 - Non-pharmacological (e.g., interventional procedures)
 - Identification of rapid decline

Spirometric criteria to define airflow obstruction

The spirometric criterion for airflow obstruction selected by GOLD for the diagnosis of COPD remains a post-bronchodilator ratio of FEV1/FVC < 0.7. This criterion is simple and independent of reference values because it relates to variables measured in the same individual, and has been used in all the clinical trials that form the evidence base from which treatment recommendations are drawn. It should be noted that the use of a fixed FEV1/FVC ratio (< 0.7) to define airflow obstruction may result in over-diagnosis of COPD in the elderly,^(379,380) and under-diagnosis in approximately 1% of young adults,⁽³⁸⁰⁻³⁸²⁾ especially in mild disease, compared to using a cut-off based on the lower limit of normal (LLN) values for FEV1/FVC. If COPD is suspected in younger adults (age < 50 years) who have a repeated fixed ratio ≥ 0.7 , comparing the ratio to a predicted LLN or using z-scores (see below) may help when deciding how to best manage this small number of patients.

The LLN values are based on the normal distribution and classify the bottom 5% of the healthy population as abnormal. From a scientific or clinical perspective, it is difficult to determine which of these criteria will result in optimal COPD diagnostic accuracy. An equivalent approach to using the LLN is to use z-scores (the number of standard deviations by which the value of an observed value is above or below the mean value of what is being measured). A z-score of -1.645 is equivalent to the 5th centile. The Global Lung Initiative (GLI) has compared interpretation of spirometry results using z-scores with using a fixed ratio, and as with LLN, found that they lead to different classification of some patients^(383,384) but whether this is of clinical relevance remains uncertain.

LLN values and z-scores are highly dependent on the choice of valid reference equations. GLI predicted values are based on pre-bronchodilator measurements but postbronchodilator reference values were more successful at identifying individuals with mild COPD than prebronchodilator reference values in the SCAPIS (Swedish CardioPulmonary biolmage Study).⁽³⁸⁵⁾ There are no longitudinal studies available validating the use of the LLN, or studies using reference equations in populations where smoking is not the major cause of COPD. Using the fixed ratio is not inferior to LLN regarding prognosis.⁽³⁸⁶⁾

Importantly, the risk of misdiagnosis and over-treatment of individual patients using the fixed ratio as a diagnostic criterion is limited, as spirometry is only one biologic measurement to establish the clinical diagnosis of COPD in the appropriate clinical context (symptoms and risk factors). Diagnostic simplicity and consistency are crucial for the busy clinician. Thus, GOLD favors using the fixed ratio over LLN.

Assessment of the presence or absence of airflow obstruction based on a single measurement of the post-bronchodilator FEV1/FVC ratio should be confirmed by repeat spirometry on a separate occasion if the value is between 0.6 and 0.8, as in some cases the ratio may change as a result of biological variation when measured at a later interval.^(387,388) If the initial post-bronchodilator FEV1/FVC ratio is less than 0.6 it is very unlikely to rise spontaneously above 0.7.⁽³⁸⁷⁾

It is important to emphasize that airflow obstruction that is not fully reversible is not specific for COPD; the clinical context and risk factors should also be considered. Airflow obstruction that is not fully reversible may also be found in patients with asthma and other diseases.

Reference values for lung function interpretation

Interpretation of the severity of lung function impairment is dependent on having appropriate reference values. Previously reference values have taken account of race, as studies such as the Prospective Urban and Rural Epidemiological (PURE) study that analyzed pre-bronchodilator spirometry data from 153,996 healthy people with less than 5 pack-year smoking histories in 17 countries and observed wide variation by region.⁽⁴⁷⁾ Compared with individuals living in North America or Europe, people living in south Asia had FEV1 values that were on average 31% lower, adjusted for age, height and sex. Similarly, those living in southeast Asia, sub-Saharan Africa, East Asia, Middle East and South America had FEV1 values that were on average 24%, 21%, 13%, 11%, and 6% lower than individuals living in North America or Europe, respectively, independent of age, height, sex, and smoking status.⁽⁴⁷⁾ However, race-correction may have important consequences for patients from these areas and eliminating race-based reference values has been proposed⁽³⁷¹⁾ because they can lead to underestimation of disease severity and normalise the effects of malnutrition and childhood illness on lung development. In 2022, GLI published new race neutral equations (GLI-Global equations)⁽³⁸⁹⁾ and these are now the only reference equations officially endorsed by ATS and ERS.⁽²⁵⁵⁾ In a study of 369,077 participants in the National Health and Nutrition Examination Survey, U.K. Biobank, the Multi-Ethnic Study of Atherosclerosis, and the Organ Procurement and Transplantation Network the use of race-based and race-neutral equations generated similarly accurate predictions of respiratory outcomes in participants with lung diseases, including COPD.⁽³⁹⁰⁾ However, the study showed that changing to using race-neutral reference would lead to significant changes in occupational eligibility and disability compensation. Questions also remain about the validity of the GLI-Global equations as they are essentially based on a weighted average of racial and ethnic categories, were derived from a population that did not include participants from many countries or global regions, and ignore the observed population differences in body proportions.⁽³⁹¹⁻³⁹³⁾ In addition, lung reference values change over time and require periodic revision.⁽³⁹⁴⁾ Nevertheless, GOLD recommends using the GLI-Global equations as the reference standard for the assessment of lung function impairment in patients with COPD, despite their limitations.

Staging the severity of airflow obstruction

GOLD continues to recommend using the FEV1 as a percentage of the predicted value to stage the severity of airflow obstruction. The ERS and ATS recommend using z-scores rather than percent predicted values to stage severity and have proposed a three-level (four-tier) severity system that considered z-scores > -1.65 as normal, between -1.65 and -2.5 as mild, between -2.51 and -4 as moderate and < -4.1 as severe.⁽³⁷¹⁾ Using these thresholds inevitably leads to differences in the classification of some patients compared to using the percentage predicted⁽³⁹⁵⁾ but whether this has significant implications for management or prognosis remains unclear. The majority of COPD studies that form the evidence base for treatment recommendations, recruited and classified subjects using the GOLD stages based on percentage predicted values, and for the time being GOLD recommends continuing to use this method to assess severity of airflow limitation. The percentage of the predicted GLI-Global equation value can be determined using the online GLI calculator (gli-calculator.ersnet.org). In patients with airflow obstruction a low FEV1 or a rapid decline in FEV1 is associated with increased mortality.⁽³⁹⁶⁾

COVID-19

Performing spirometry and pulmonary function testing may lead to SARS-CoV-2 transmission as a result of coughing and droplet formation during the tests.^(397,398) During periods of high prevalence of COVID-19 in the community, spirometry should be restricted to patients requiring urgent or essential tests for the diagnosis of COPD, and/or to assess lung function status for interventional procedures or surgery. The ATS and ERS have provided recommendations regarding testing and precautions that should be taken.⁽³⁹⁷⁻⁴⁰¹⁾

When routine spirometry is not available, home measurement of peak expiratory flow (PEF) combined with validated patient questionnaires could be used to support or refute a possible diagnosis of COPD.⁽⁴⁰²⁻⁴⁰⁵⁾ However, PEF does not correlate well with the results of spirometry⁽⁴⁰⁶⁻⁴⁰⁸⁾ has low specificity⁽³⁶⁹⁾ and cannot differentiate obstructive and restrictive lung function abnormalities. When making a diagnosis of COPD, airflow obstruction could also be confirmed by giving patients a personal electronic portable spirometers,^(409,410) and instructing them in their use and observing them in their homes using video conferencing technology.

SCREENING AND CASE-FINDING

The role of screening spirometry for the diagnosis of COPD in the general population is controversial.^(411,412) In asymptomatic individuals without any significant exposures to tobacco or other risk factors, screening spirometry is probably not indicated; whereas in those with symptoms or risk factors (e.g., > 20 pack-years of smoking, recurrent chest infections, early life events), the diagnostic yield for COPD is relatively high and spirometry should be considered as a method for early case finding.⁽⁴¹³⁻⁴¹⁵⁾

Both FEV1 and FVC predict all-cause mortality independent of tobacco smoking, and abnormal lung function identifies a subgroup of smokers at increased risk for lung cancer. This has been the basis of an argument that spirometry should be employed as a global health assessment tool.^(125,416,417) A risk score based on routine data from electronic health records in primary care may facilitate case-finding and be cost-effective.^(418,419) However, data to support that population-based screening spirometry is effective in directing management decisions or in improving COPD outcomes in patients who are identified before the development of significant symptoms is weak.⁽⁴¹²⁾ This may reflect the design and application of current case finding instruments that have not been utilized to identify patients with undiagnosed COPD who are most likely to benefit from existing therapies.^(420,421) An RCT that used community case-finding to identify symptomatic individuals with underdiagnosed COPD or asthma explored the effects of early treatment. Symptomatic individuals with undiagnosed COPD who received treatment by a pulmonologist and an educator had fewer respiratory events over one year and showed improvements in symptoms, lung function, and disease-specific quality of life. These results suggest that such an approach, leading to early diagnosis and treatment of symptomatic COPD results in better clinical outcomes.^(420,421)

Additional methods for case finding have been developed that incorporate exposures, symptoms and health care utilization and simple peak flow measurement; one of these has been developed for low- and middle-income countries and has shown discriminatory properties.^(402,422) GOLD advocates active case finding^(413,423,424) i.e., performing spirometry in patients with symptoms and/or risk factors, but not screening spirometry. Systematic active case-finding in a primary care setting via mail-out of a screening questionnaire was also found to be an effective way to identify undiagnosed COPD patients.⁽⁴²⁵⁾ The potential use of spirometry in children, adolescents and young adults to identify individuals with poor lung development at risk of COPD and other chronic conditions later in life merits future investigation.⁽⁴²⁾

COPD case-finding tools have been created based on existing epidemiologic literature or expert opinion^(421,426,427) or with a multimodality approach.^(402,422) Increasingly, it appears that the combination of questionnaires with simple

physiological measurements enhances the operating characteristics and performance of these approaches.^(426,428,429) In a variety of settings case-finding has been able to identify previously undiagnosed COPD.^(425,428,430,431) In general, these tools identify a high proportion of patients with mild or minimally symptomatic disease, exhibiting modest sensitivity and specificity,⁽⁴³²⁾ or higher specificity but low sensitivity.⁽⁴³³⁾ COPD screening/case-finding in primary care has been demonstrated to have a small but significant impact on increasing rates of diagnoses and physician's clinical actions but with limited data suggesting a significant impact on patient outcomes.^(425,434-436) In the Veterans Affairs system, the use of a clinical decision support system algorithm that incorporates case-finding for COPD and AATD, improved COPD over- and under-diagnosis and screening rates of AATD in a primary care setting.⁽⁴³⁷⁾ It remains vital to critically assess how the introduction of case finding approaches can optimally improve health care utilization, and improve patient outcomes while ensuring that patients identified with these techniques have access to affordable and clinically and cost-effective interventions.^(2,438,439) In a prospective study in China the COPD Assessment in Primary Care to Identify Undiagnosed Respiratory Disease and Exacerbation Risk (CAPTURE) tool showed a good sensitivity to identify COPD patients who may require treatment because of increased symptoms, risk of exacerbations or hospitalization.⁽⁴⁴⁰⁾

Screening for COPD in targeted populations

The United States Preventative Service Task Force (USPSTF) recommended against screening for COPD in asymptomatic adults.⁽⁴⁴¹⁾ This recommendation was based upon a systematic review of data from asymptomatic or mildly symptomatic COPD patients enrolled in pharmacological or non-pharmacological clinical trials. This recommendation is not applicable to populations at increased risk for COPD (e.g., those undergoing annual low dose chest computed tomography (LDCT) for lung cancer detection, particularly when airways or parenchymal abnormalities are found incidentally) or with radiologically identified structural abnormalities found on chest imaging done for clinical respiratory complaints (e.g., emphysema, airway wall thickening, bronchiectasis, etc.).

Leveraging lung cancer imaging for COPD screening

Annual LDCT imaging of the chest is recommended by the USPSTF to diagnose lung cancer earlier among individuals aged 50 to 80 years with a ≥ 20 pack-year smoking history. Clinical trials have shown annual LDCT significantly improves survival.^(442,443) Lung cancer and COPD share common risk factors, and COPD is also an independent risk factor for lung cancer and represents the major comorbidity affecting survival in patients with lung cancer.^(442,444-446) Thoroughly assessing symptoms and performing spirometry in individuals undergoing LDCT for lung cancer screening therefore represents a unique opportunity to simultaneously screen patients for both the presence of unrecognized symptoms of COPD and airflow obstruction.

Studies that have evaluated patients for COPD symptoms and performed spirometry at lung cancer screening have reported airflow obstruction in 34-57% of individuals, emphysema in 68-73% and no prior diagnosis of COPD in 67%.^(445,447,448) Male sex, younger age, lower smoking duration and being asymptomatic were associated with detection of airflow obstruction without a prior diagnosis of COPD.^(448,449) Those without a prior diagnosis of COPD were less symptomatic, however, the prevalence of symptoms was still high and found in over 50% of individuals. The prevalence of the underdiagnosis of COPD in those undergoing lung cancer screening can approach 90% in some reports.^(417,450-455)

In a lung cancer screening cohort, over half of those with visually detected emphysema had airflow obstruction.⁽⁴⁵⁶⁾ Quantitative analysis of density can also be used to detect COPD with varying sensitivity and specificity depending on the threshold chosen. In the National Lung Cancer Screening Trial (NLST), among individuals > 65 years, a threshold of 1% quantitative emphysema was associated with a sensitivity of around 65% for women and 75% for men and a specificity of over 70% and 65% respectively.⁽⁴⁵⁷⁾ Deep learning approaches are also being investigated that could diagnose COPD from lung cancer screening CT scans with results varying depending on the method and cohort analyzed.⁽⁴⁵⁸⁾

Airflow obstruction or emphysema are markers of an increased risk for lung cancer. The severity of airflow obstruction and the presence of emphysema are both independent risk factors and may be useful indicators for triaging patients for more careful lung cancer surveillance. [\(417,442,443,451-455\)](#)

Leveraging incidental lung imaging abnormalities for COPD screening

Besides cigarette smoking other factors can increase the risk of COPD (e.g., developmental, genetic, environmental exposures, childhood infections, etc.) and these individuals may undergo chest imaging for evaluation of respiratory symptoms. These individuals have no or minimal exposure to cigarette smoking and are usually of younger age and distinct from the population undergoing annual LDCT for lung cancer screening. The CT scans themselves can be used to help identify individuals at increased risk for COPD in the non-lung cancer screened population and prompt consideration for spirometry. [\(417,451-455\)](#)

Emphysema is a hallmark of COPD and easily detected on chest imaging, either through visual inspection via a radiologist or through quantitative lung density. [\(456-458\)](#) Lung imaging may also identify other abnormalities that may indicate the presence of COPD including air trapping, airway wall thickening and mucus plugging. [\(214,449,450,459-461\)](#) These abnormalities may not only indicate the presence of airflow obstruction but indicate patients that might have a more rapid decline in lung function and worse quality of life. [\(462-465\)](#)

While quantitative analysis of LDCT data is often not available in clinical settings, the presence of emphysema and other airway abnormalities should raise clinical suspicion for COPD and lead to a detailed assessment of symptoms and consideration for pulmonary function testing if not previously performed.

There is currently a missed opportunity to perform spirometry in people at high risk of having COPD during lung cancer screening programs or when incidental lung abnormalities are found on imaging that may indicate the presence of COPD. The use of spirometry in targeted patients undergoing lung cancer screening or when incidental imaging abnormalities are found consistent with parenchymal or airway manifestations of airways disorders is recommended by GOLD. [\(466\)](#)

INITIAL ASSESSMENT

Once the diagnosis of COPD has been confirmed by spirometry, in order to guide therapy COPD assessment must focus on determining the following five fundamental aspects:

- ▶ Severity of airflow obstruction
- ▶ Nature and magnitude of current symptoms
- ▶ Previous history of moderate and severe exacerbations
- ▶ Blood eosinophil count
- ▶ Presence and type of other diseases (multimorbidity)

Severity of airflow obstruction

In the presence of FEV1/FVC ratio < 0.7 the assessment of **airflow obstruction severity** in COPD (note that this may be different from severity of the *disease*) is based on the post-bronchodilator value of FEV1 (% GLI-Global; see **Spirometry** section). The specific spirometric cut points are proposed for purposes of simplicity (**Figure 2.8**).

GOLD Grades and Severity of Airflow Obstruction in COPD (based on post-bronchodilator FEV1)

Figure 2.8

In COPD patients (FEV1/FVC < 0.7):

GOLD 1:	Mild	FEV1 ≥ 80% predicted
GOLD 2:	Moderate	50% ≤ FEV1 < 80% predicted
GOLD 3:	Severe	30% ≤ FEV1 < 50% predicted
GOLD 4:	Very Severe	FEV1 < 30% predicted

Symptoms

Because there is only a weak correlation between the severity of airflow obstruction (**Figure 2.8**) and the symptoms experienced by the patient or the impairment of their health status,^(467,468) formal assessment of symptoms using validated questionnaires is required.

Dyspnea questionnaire: the modified Medical Research Council (mMRC) dyspnea scale

The mMRC scale was the first questionnaire developed to measure breathlessness, which is a key symptom in many patients with COPD, although often unrecognized.⁽⁴⁶⁹⁾ (**Figure 2.9**) Of note, the mMRC score relates well to other multidimensional health status measures⁽⁴⁷⁰⁾ and predicts future mortality risk.^(471,472)

Modified MRC Dyspnea Scale

Figure 2.9

PLEASE TICK IN THE BOX THAT APPLIES TO YOU | ONE BOX ONLY | Grades 0 - 4

mMRC Grade 0	mMRC Grade 1	mMRC Grade 2	mMRC Grade 3	mMRC Grade 4
I only get breathless with strenuous exercise	I get short of breath when hurrying on the level or walking up a slight hill	I walk slower than people of the same age on the level because of breathlessness, or I have to stop for breath when walking on my own pace on the level	I stop for breath after walking about 100 meters or after a few minutes on the level	I am too breathless to leave the house or I am breathless when dressing or undressing
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Reference: ATS (1982) Am Rev Respir Dis. Nov;126(5):952-6.

Multidimensional questionnaires

It is now recognized that COPD impacts patients beyond dyspnea.⁽⁴⁷³⁾ For this reason, multidimensional questionnaires are recommended. The most comprehensive disease-specific health status questionnaires such as the Chronic Respiratory Questionnaire (CRQ)⁽⁴⁷⁴⁾ and St. George's Respiratory Questionnaire (SGRQ)⁽⁴⁷⁵⁾ are important research tools but they are too complex to use in routine practice. Shorter comprehensive measures, such as the COPD Assessment Test (CAT™) and the Clinical COPD Questionnaire (CCQ®) have been developed and are suitable for use in the clinic. Below we discuss the CAT™ and the SGRQ.

The CAT™*† is an 8-item questionnaire that assesses health status in patients with COPD (**Figure 2.10**).⁽⁴⁷⁶⁾ It was developed to be applicable worldwide and validated translations are available in a wide range of languages. The score ranges from 0 to 40, correlates very closely with the SGRQ, and has been extensively documented in numerous publications.⁽⁴⁷⁷⁾

* The COPD Assessment Test was developed by a multi-disciplinary group of international experts in COPD supported by GSK. COPD Assessment Test and the CAT™ logo is a trademark of the GlaxoSmithKline group of companies. © 2009 GlaxoSmithKline. All rights reserved. GSK activities with respect to the COPD Assessment Test™ are overseen by a governance board that includes independent external experts, one of whom chairs the board.

† The COPD Assessment Test CAT™ was designed to assess the impact of COPD on a person's health status. To facilitate its use in other chronic airway diseases, CAT™ has been renamed as Chronic Airways Assessment Test CAAT™.

For each item below, place a mark (x) in the box that best describes you currently. Be sure to only select one response for each question.

EXAMPLE: I am very happy	0 <input checked="" type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4 <input type="checkbox"/> 5	I am very sad	Score
I never cough	0 <input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4 <input type="checkbox"/> 5	I cough all the time	
I have no phlegm (mucus) in my chest at all	0 <input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4 <input type="checkbox"/> 5	My chest is completely full of phlegm (mucus)	
My chest does not feel tight at all	0 <input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4 <input type="checkbox"/> 5	My chest feels very tight	
When I walk up a hill or one flight of stairs I am not breathless	0 <input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4 <input type="checkbox"/> 5	When I walk up a hill or one flight of stairs I am very breathless	
I am not limited doing any activities at home	0 <input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4 <input type="checkbox"/> 5	I am very limited doing activities at home	
I am confident leaving my home despite my lung condition	0 <input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4 <input type="checkbox"/> 5	I am not at all confident leaving my home because of my lung condition	
I sleep soundly	0 <input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4 <input type="checkbox"/> 5	I don't sleep soundly because of my lung condition	
I have lots of energy	0 <input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4 <input type="checkbox"/> 5	I have no energy at all	

Reference: Jones et al. ERJ 2009; 34 (3); 648-54.

TOTAL SCORE:

The SGRQ is the most widely documented comprehensive measure; scores < 25 are uncommon in diagnosed COPD patients⁽¹⁸²⁾ and scores ≥ 25 are very uncommon in healthy persons.^(478,479) Therefore, it is recommended that a symptom score equivalent to SGRQ score ≥ 25 should be used as the threshold for considering regular treatment for symptoms including breathlessness, particularly since this corresponds to the range of severity seen in patients recruited to the trials that have provided the evidence base for treatment recommendations. The equivalent cut-point for the CAT™ is 10.⁽⁴⁸⁰⁾ An equivalent mMRC score cannot be calculated because a simple breathlessness cut-point cannot equate to a comprehensive symptom score cut-point. The great majority of patients with an SGRQ of ≥ 25 will have an mMRC of ≥ 1; however, patients with mMRC < 1 may also have a number of other COPD symptoms.⁽⁴⁸¹⁾ For this reason, the use of a comprehensive symptom assessment is recommended. However, because use of the mMRC is widespread, an mMRC of ≥ 2 is still included as a threshold for separating “less breathlessness” from “more breathlessness.” Nevertheless, users are cautioned that assessment of other symptoms is required.⁽⁴⁸¹⁾

Exacerbation risk

Exacerbations of COPD (ECOPD) are episodes of acute respiratory symptom worsening often associated with increased local and systemic inflammation (see **Chapter 4**).⁽⁴⁸²⁻⁴⁸⁵⁾ ECOPD are key events in the natural history of the disease because they impact significantly on the health status of the patient (often for a prolonged period of time), enhance the rate of lung function decline, worsen the prognosis of the patient and are associated with most of the healthcare costs of COPD.⁽⁴⁸⁶⁾ ECOPD rates vary greatly between patients⁽⁴⁸⁷⁾ and during follow-up.⁽⁴⁸⁸⁾ The best predictor of having

frequent exacerbations (defined as two or more exacerbations per year) is the previous history of exacerbations.⁽⁴⁸⁷⁾ Worsening of airflow obstruction is associated with an increasing prevalence of exacerbations, hospitalization^(424,489) and risk of death.^(182,490)

Blood eosinophil count

A number of studies have shown that blood eosinophil counts predict the magnitude of the effect of ICS (added on top of regular maintenance bronchodilator treatment) in preventing future exacerbations and blood eosinophil counts are recommended by GOLD to guide the use of ICS as part of pharmacological management (see **Chapter 3, Figure 3.7 & Figure 3.9**).⁽⁴⁹¹⁻⁴⁹⁶⁾

There is evidence that on average blood eosinophil counts are higher in COPD patients, although there is marked overlap with controls.^(497,498) Higher blood eosinophil counts in COPD patients are associated with increased lung eosinophil numbers and the presence of higher levels of markers of type-2 inflammation in the airways, although the concordance between blood and lung/airways T2 biomarkers is not strict.^(499,500) These differences in airway inflammation may explain the differential response to ICS treatment according to blood eosinophil counts.⁽⁵⁰¹⁾

The repeatability of blood eosinophil counts in a large primary care population appears reasonable,⁽⁵⁰²⁾ although greater variability is observed at higher thresholds.⁽⁵⁰³⁾ Better reproducibility is observed at the lower thresholds (e.g., 100 cells/ μ L).⁽⁵⁰⁴⁾ Blood eosinophil counts can help clinicians estimate the likelihood of a beneficial preventive response to the addition of ICS to regular bronchodilator treatment, and thus can be used as a biomarker in conjunction with clinical assessment when making decisions regarding ICS use.

Cohort studies have produced differing results with regard to the ability of blood eosinophils to predict future exacerbation outcomes, with either no relationship⁽⁵⁰⁵⁾ or a positive relationship reported.^(506,507) Differences between studies are likely to be related to different previous exacerbation histories and ICS use. There is insufficient evidence to recommend that blood eosinophils should be used to predict future exacerbation risk on an individual basis in COPD patients. Greater FEV1 decline was observed in mild to moderate COPD patients with higher blood eosinophil counts in a population where ICS use was low,⁽⁵⁰⁸⁾ highlighting the possible usefulness of blood eosinophil counts as a prognostic biomarker for lung function decline when not confounded by ICS use. In younger individuals without COPD, higher blood eosinophil counts are associated with increased risk of subsequent development of COPD.⁽⁵⁰⁹⁾

Multimorbidity

People with COPD often suffer other concomitant chronic diseases (multimorbidity). This can occur in patients with mild, moderate or severe airflow obstruction.⁽¹⁸²⁾ Multimorbidity influences mortality and hospitalizations independently of the severity of airflow obstruction,⁽⁵¹⁰⁾ and deserves specific treatment. Therefore, comorbid conditions should be looked for routinely, and treated appropriately if present, in any patient with COPD. Recommendations for the diagnosis, assessment of severity, and management of individual comorbid diseases are the same as for patients without COPD.

Frequent multimorbid diseases in COPD include cardiovascular disease,⁽⁴³⁾ metabolic syndrome, osteoporosis, depression and anxiety, likely in relation to shared risk factors (e.g., aging, smoking, alcohol, diet and inactivity).^(486,511-513) Besides, COPD itself may increase the risk for other comorbid diseases (e.g., COPD (particularly emphysema) and lung cancer).^(514,515) Whether the association between COPD and lung cancer is due to common risk factors (e.g., smoking), involvement of shared susceptibility genes and/or impaired clearance of carcinogens is unclear. COPD can also have significant extrapulmonary (systemic) effects including weight loss, nutritional abnormalities, and skeletal muscle dysfunction. The latter is characterized by both sarcopenia (loss of muscle cells) and abnormal function of the remaining cells.⁽⁵¹⁶⁾ Its causes are likely multifactorial (e.g., inactivity, poor diet, inflammation and/or hypoxia) and it can contribute to exercise intolerance and poor health status in patients with COPD. Importantly, skeletal muscle

dysfunction is a modifiable source of exercise intolerance by rehabilitation.⁽⁵¹⁷⁾ A more detailed description of the management of COPD and comorbidities is provided in **Chapter 5**.

Cardiovascular risk in COPD

Patients with COPD often suffer cardiovascular diseases and *vice versa*, although these may be ignored by the attending physician who focuses on her/his disease of interest (lung or heart).^(518,519) This has important clinical implications because the appropriate treatment of lung and heart diseases may be associated with better outcomes for the patient. It is important, however, to differentiate between clinically stable patients and patients suffering acute episodes of increased symptoms, so-called exacerbations of COPD (ECOPD).

Clinically stable COPD

The prevalence of cardiovascular diseases (CVD), including arterial hypertension, coronary artery disease, heart failure and arrhythmias is increased in patients with *clinically stable* COPD.^(331,519) CVD are a prominent cause of death in COPD, particularly in patients with mild-moderate airflow obstruction.⁽⁵²⁰⁾ Unfortunately, these CVD often go unnoticed and, therefore, untreated.^(518,519)

The mechanisms underlying the frequent co-existence of COPD and CVD are multiple. First, CVD and COPD share risk factors (e.g., aging, smoking), a concept that is now recognized as a *syndemic* occurrence.⁽³³¹⁾ Second, several abnormalities characteristic of COPD can contribute to CVD, including: 1) COPD is often associated with persistent systemic inflammation which, in turn, can cause endothelial dysfunction, platelet activation and coagulation disorders, all of which can then contribute to CVD;⁽⁵²¹⁾ 2) abnormal pulmonary gas exchange in patients with COPD can cause arterial hypoxemia and myocardial hypoxia, with impaired contractility and increased risk of arrhythmias; 3) lung hyperinflation in COPD reduces venous return and compresses the lung vessels, thus limiting cardiac output and oxygen delivery to tissues; 4) COPD-related exertional dyspnea results in decreased physical activity (which can be aggravated by anxiety/depression that are other frequent COPD comorbidities), a well-established cardiovascular risk factor. On the other hand, CVD can also contribute to worsening health status in patients with established COPD through several potential mechanisms, including: 1) alveolar and bronchial edema due to abnormal myocardial contractility; 2) post-capillary pulmonary hypertension; 3) reduced skeletal muscle oxygen delivery, further contributing to reduced physical activity in these patients.

From the above it follows that the presence of major CVD (arterial hypertension, coronary artery disease, heart failure, arrhythmia) needs to be investigated in any COPD patient^(522,523) and treated if present according to available guidelines.⁽⁵¹⁹⁾ Of note, the use of established CV risk scores in the general population, such as Framingham or QRisk, may underestimate CVD in COPD patients, and merits further research.^(522,524) Likewise, the inclusion of spirometric variables (e.g., FEV1) may augment the predictive value of the standard CV risk scores in use.^(522,524) This also merits research.

Acute exacerbations

Many COPD patients develop ECOPD episodes during the course of their disease that impact their health status and prognosis. The mechanisms and management of ECOPD are well described in **Chapter 4**. Yet it is worth noting that the cardiovascular risk during and after such episodes increases significantly, likely in relation to worsening of the factors that contribute to CVD during periods of clinical stability described above (systemic inflammation, abnormal pulmonary gas exchange, gas trapping and lung hyperinflation). On the other hand, the cardiovascular mechanisms that can influence lung function (reduced myocardial contractility leading to pulmonary edema, pulmonary hypertension and poor perfusion of systemic organs (including the diaphragm)) also worsen during ECOPD. As a result, during ECOPD the risk of an acute cardiovascular event, such as myocardial infarction, arrhythmias and stroke, increases further,⁽⁵²⁵⁾ particularly in those severe ECOPD that require hospitalization.⁽⁵²⁶⁾ Importantly, this risk remains high during the first few weeks after hospital discharge, and it can still remain significantly increased even one year

later. [\(523,525,527\)](#)

These considerations have several relevant implications for the management of ECOPD:

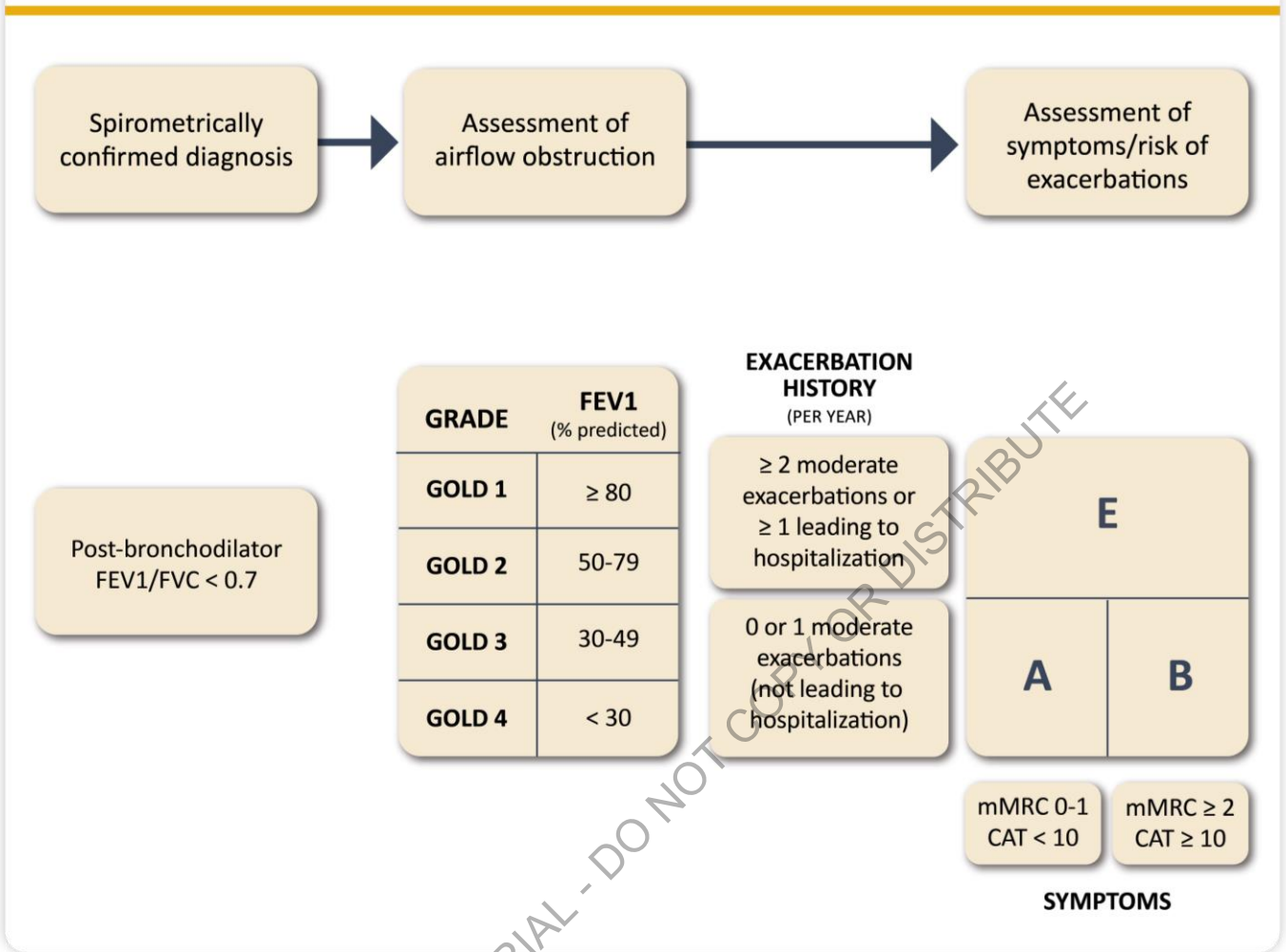
- 1) The current GOLD recommendations emphasize the importance of an appropriate *differential* diagnosis of ECOPD from other conditions that may mimic/aggravate them (e.g., heart failure). [\(528\)](#) Yet, if they do exist, they need to be treated appropriately.
- 2) It may be advisable to measure *routinely during* ECOPD markers of CVD, such as troponin and brain-natriuretic peptides. [\(522,523\)](#) The evidence supporting this proposal is still weak, but the observations discussed above support it. [\(525,526\)](#) If any of these markers are abnormal *during* the episode of ECOPD, appropriate further investigations and treatment are required following CVD recommendations.
- 3) Currently, there is no evidence to support the routine use of *preventive* cardiovascular treatment (e.g., aspirin) *during or following* an episode of ECOPD, but this again merits research. Similarly, β -blockers and statins need to be prescribed following their CV indications although these drugs did not show any benefit in clinically stable patients with COPD without CV indications. Importantly, COPD patients should not be denied β -blocker use if there is a CV indication.
- 4) Finally, although preventing ECOPD is already a main goal of COPD treatment because of their impact on the prognosis, lung function and health status of the patient, [\(519\)](#) the increased cardiovascular risk that occurs during and following the acute episode is another strong clinical argument to prevent these acute episodes, as discussed in detail in **Chapter 4**.

Combined initial COPD assessment

In 2011, GOLD proposed to move from a simple spirometric grading system for disease severity assessment and treatment to a combined assessment strategy based on the level of symptoms (mMRC or CAT™), the severity of airflow obstruction (GOLD grades 1-4), and the frequency of previous exacerbations. This classification was proposed to guide initial pharmacological treatment. The main step forward achieved by this combined assessment strategy was to incorporate patient-reported outcomes and highlight the importance of exacerbation prevention in the management of COPD. The initial version of the combined assessment relied on both the severity of airflow obstruction (GOLD grades 1-4) and the frequency of previous exacerbations to assess exacerbation risk.

The severity of airflow obstruction was subsequently removed from this combined assessment scheme considering its lower precision at the individual level (versus that at a population level) to predict outcomes and drive treatment decisions, while complexifying the use of the classification by clinicians. [\(468,490,529,530\)](#)

In the 2023 GOLD report, GOLD proposed a further evolution of the ABCD combined assessment tool that recognized the clinical relevance of exacerbations, independently of the level of symptoms of the patient. **Figure 2.11** presents this proposal. The A and B groups remained unchanged, but the C and D groups were merged into a single group termed “E” to highlight the clinical relevance of exacerbations. It was acknowledged that this proposal would have to be validated by appropriate clinical research.



ADDITIONAL INVESTIGATIONS

In cases where there is a marked discordance between the level of airflow obstruction and the perceived symptoms, a more detailed evaluation should be carried out to better understand lung mechanics (e.g., full lung function tests and exercise testing), lung structure (e.g., computed tomography) and/or comorbidities (e.g., ischemic heart disease) that might impact patient symptoms.

Physiological tests

Lung volumes

COPD patients exhibit gas trapping (a rise in residual volume) from the early stages of the disease, and as airflow obstruction worsens, static hyperinflation (an increase in total lung capacity) occurs, particularly during exercise (dynamic hyperinflation). These changes can be documented by body plethysmography, or less accurately by helium dilution lung volume measurement. These measurements help characterize the severity of COPD but are not essential to patient management.

Carbon monoxide diffusing capacity of the lungs (DLco)

The single breath DLco measurement⁽⁵³¹⁾ evaluates the gas transfer properties of the respiratory system. DLco is well-

standardized and with valid predicted values of practical utility.^(370,532-534) The advent of reliable portable systems capable of providing accurate determinations in the field, expands its potential use as a complement to the information provided by spirometry.⁽⁵³⁵⁾ DLco should be measured in any person with symptoms (dyspnea) disproportionate to the degree of airflow obstruction since reduced DLco values < 60% predicted are associated with increased symptoms, decreased exercise capacity, worse health status,⁽⁵³⁶⁻⁵³⁸⁾ and increased risk of death, independently of the severity of airflow obstruction and other clinical variables.⁽⁵³⁹⁻⁵⁴²⁾ In a clinical cohort of COPD diffusing capacity has been shown to be a strong predictor of COPD hospitalizations, independent of airflow obstruction and prior hospitalizations.⁽⁵⁴³⁾ Additionally, in COPD patients, low DLco values help preclude surgical lung resection in patients with lung cancer⁽⁵⁴⁴⁾ while in smokers without airflow obstruction, values < 80% predicted (as a marker of emphysema) signal an increased risk for developing COPD over time.⁽⁵⁴⁵⁾

Over time people with COPD have an accelerated decline in DLco compared to smokers without the disease, and this decline is significantly greater in women than men.^(546,547) However, DLco decline is slow, and years of follow up are often needed before a meaningful change in DLco is detected.

Oximetry and arterial blood gas measurement

Pulse oximetry can be used to evaluate a patient's arterial oxygen saturation and need for supplemental oxygen therapy at the point-of-care and should be used to assess all patients with clinical signs suggestive of respiratory failure or right heart failure. If peripheral arterial oxygen saturation is $\leq 92\%$, arterial blood gases should be measured due to the imperfect correlation between oxygen saturation detected via pulse oximetry as compared to arterial blood gas.⁽⁵⁴⁸⁾ Further, pulse oximetry does not provide information on PaCO₂ or pH, which may have potential therapeutic implications (e.g., non-invasive ventilation).

Exercise testing and assessment of physical activity

In some cases, patients may complain of minimal symptoms despite severe airflow obstruction. This may be due to reduced dyspnea perception⁽⁵⁴⁹⁾ and/or life-style adaptations (sedentarism) to reduce dyspnea generation. In these cases, exercise tests such as the 6-minute walking distance may reveal that the patients are severely constrained and do need more intense treatment (e.g., rehabilitation) than the initial evaluation would have suggested.

Further, objectively measured exercise impairment, assessed by a reduction in self-paced walking distance^(550,551) or during incremental exercise testing in a laboratory,⁽⁵⁵²⁾ is a powerful indicator of health status impairment and predictor of prognosis.⁽⁵⁵³⁾ Laboratory testing using cycle or treadmill ergometry can assist in identifying co-existing or alternative conditions e.g., cardiac diagnoses. Walking tests can be useful for assessing disability and risk of mortality⁽⁵⁵⁴⁾ and are used to assess the effectiveness of pulmonary rehabilitation. Both the paced shuttle walk test⁽⁵⁵⁵⁾ and the self-paced 6-minute walk test can be used.^(556,557) As the course length has a substantial impact on the distance walked, existing reference equations established for a 30-meter course cannot be applied to predict the distance achieved on shorter courses.⁽⁵⁵⁸⁾

Monitoring of physical activity may be more relevant regarding prognosis than evaluating only exercise capacity.⁽⁵⁵⁹⁾ This can be conducted using accelerometers or multi-sensor instruments.

Imaging

Chest X-ray

A chest X-ray is not useful to establish a diagnosis in COPD, but it is valuable in excluding alternative diagnoses and establishing the presence of significant comorbidities such as concomitant respiratory (pulmonary fibrosis, bronchiectasis, pleural diseases), skeletal (e.g., kyphoscoliosis), and cardiac diseases (e.g., cardiomegaly). Radiological changes associated with COPD may include signs of lung hyperinflation (flattened diaphragm and an increase in the volume of the retrosternal air space), hyperlucency of the lungs, and rapid tapering of the vascular markings.

Computed tomography (CT)

Computed tomography (CT) provides insights into the structural and pathophysiologic abnormalities present in COPD. This has led to enhanced understanding of disease phenotypes, severity, and outcomes.

CT and Emphysema

Emphysema distribution and severity can be readily assessed and can assist with decision making for lung volume reduction surgery (LVRS) or endobronchial valve placement. While historically this has been performed based on expert radiologist visual analysis, particularly for LVRS, increasingly quantitative analysis for emphysema extent, location and fissure integrity is now commonly used to assist with endobronchial valve therapy decision making. Endobronchial valve therapy has also expanded the pool of patients where CT evaluation is used more routinely as patients with post-bronchodilator FEV1 between 15%-45% and evidence of marked hyperinflation on plethysmography may benefit.^(560,561) The percentage of lung with low attenuation area defined as percentage of voxels with density ≤ -950 Hounsfield Units is the most common way to objectively quantify emphysema on CT and correlates with presence of emphysema on lung pathology and physiological measurements of airflow obstruction as well as increased risk for symptoms, exacerbations, risk of lung cancer, disease progression and death.^(457,542,562-564)

CT and Lung Nodules

While chest CT is not required for COPD diagnosis, more COPD patients are now undergoing CT as part of evaluation of pulmonary nodules detected on chest X-ray or assessment for concurrent lung disease. Recently, the number of patients who would potentially benefit from chest CT has also expanded. The American Cancer Society now suggests individuals aged 50-80 with 20 pack years smoking history, regardless of years since quitting should be considered for lung cancer with CT imaging, although which patients have this as a covered benefit varies widely across the world.

CT and Airways

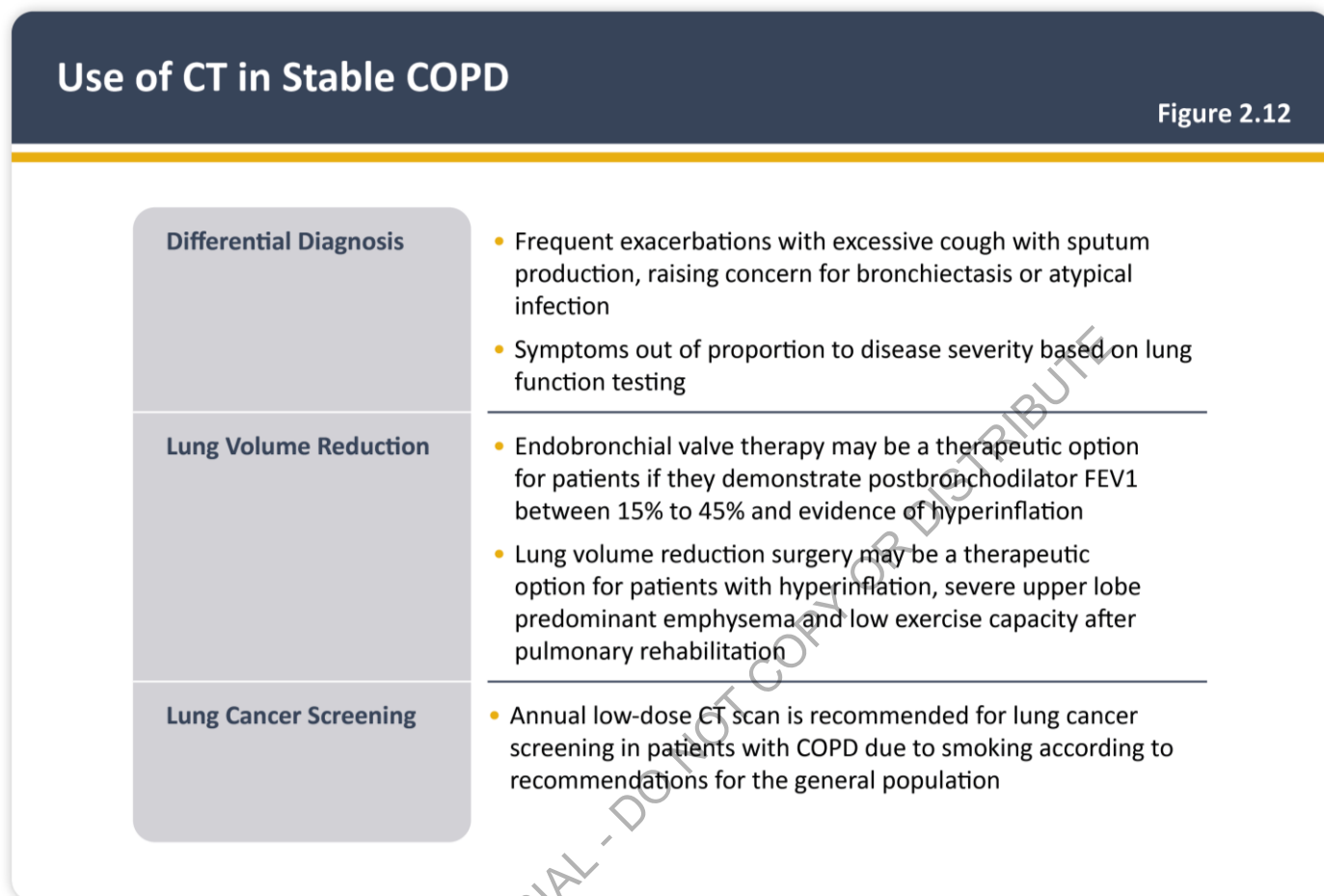
Additional CT features relevant to COPD include airway abnormalities. One well described feature includes bronchiectasis, which is visible on CT in roughly 30% of COPD patients. Bronchiectasis is associated with increased exacerbation frequency and mortality,⁽⁵⁶⁵⁾ although it is not yet known whether treatment according to bronchiectasis guidelines influences these outcomes. Airway mucus plugs can also be visualized on CT and systematically counted to create a mucus plug score. Higher scores have been associated with poorer lung function, higher CAT score, more frequent exacerbations and increased mortality, although there is poor overlap between presence of mucus plugs and mucus specific symptoms.^(213,215) As systematic scoring for mucus plugging is tedious, mucus plug scoring is not yet done routinely in clinical practice but is an area of intense research.

More detailed computer assisted CT analysis also enables quantification of the airways which have been associated with airflow obstruction, symptoms and exacerbations,^(563,566,567) although these metrics have been used more in the research setting. While segmental and subsegmental measures of wall thickness can be made directly, algorithms to measure and sum measures across multiple airways have also been studied. Measurements of small airways (<2 mm diameter) must be inferred by comparing inspiratory and expiratory to identify areas of non-emphysematous gas trapping. Validated algorithms are becoming increasingly available, even in the clinical setting, that can identify small airway abnormality through this method.^(568,569) Small airway abnormality may also be present even among individuals without detectable spirometric obstruction and identify individuals at increased risk for lung function decline.⁽⁵⁷⁰⁾

CT and COPD Related Morbidities

It should also be noted that CT imaging of the chest can provide additional information about COPD comorbidities including coronary artery calcium, pulmonary artery enlargement, bone density, muscle mass, interstitial lung abnormalities, hiatal hernias and liver steatosis. Such CT extracted features have been shown to be independently associated with all-cause mortality.⁽⁵⁶¹⁾ As technology advances, such information is likely to become increasingly available to clinicians to enhance patient management.

In summary, for now COPD patients with persistent exacerbations, symptoms out of proportion to disease severity on lung function testing or refractory to medical management, FEV1 less than 45% predicted with significant hyperinflation and gas trapping, or for those who meet criteria for lung cancer screening, chest CT imaging should be considered (**Figure 2.12**). [\(542,560,561,565,568-570\)](#)



Interstitial lung abnormalities (ILA)

Findings suggestive of parenchymal lung fibrosis or inflammation are common on chest CT imaging of both smokers and nonsmokers, and have been termed interstitial lung abnormalities (ILA) when discovered incidentally in patients without known interstitial lung disease (ILD). [\(571\)](#) The prevalence of ILA ranges from 4% to 9% among older (over 60 years) adults, and spans the spectrum from subclinical findings to clinical disease. [\(571\)](#) Among 4,360 COPD Gene participants, ILA was present in 8% of individuals, with half meeting criteria for suspected ILD, which was defined as definite fibrosis on CT, FVC less than 80% predicted or DLco less than 70% predicted. [\(271,572\)](#) Individuals with suspected ILD had increased respiratory symptoms and mortality. [\(572\)](#) Fibrotic ILA (i.e., those with traction bronchiectasis, architectural distortion and honeycombing) are more likely to progress and are associated with poor outcomes, especially when combined with emphysema. [\(573,574\)](#) Given the clinical relevance of ILA, multiple studies support clinical evaluation, risk stratification and follow up monitoring of individuals with these findings.

Alpha-1 antitrypsin deficiency (AATD)

The World Health Organization recommends that all patients with a diagnosis of COPD should be screened once for AATD, especially in areas with high AATD prevalence. [\(575,576\)](#) Although the classical patient is young (< 45 years) with panlobular basal emphysema, it has become recognized that delay in diagnosis has led to identification of some AATD patients when they are older and have a more typical distribution of emphysema (centrilobular apical). [\(577\)](#) A low concentration (< 20% normal) is highly suggestive of homozygous deficiency. Family members should be screened and,

together with the patient, referred to specialist centers for advice and management (see **Chapter 3**).

Composite scores

Several variables identify patients at increased risk for mortality including FEV₁, exercise tolerance assessed by walking distance or peak oxygen consumption, weight loss, and reduction of arterial oxygenation. The BODE (Body mass index, Obstruction, Dyspnea, and Exercise) method gives a composite score that is a better predictor of subsequent survival than any single component.^(578,579) Simpler alternatives that do not include an exercise test have been suggested but need validation across a wide range of disease severities and clinical settings to confirm that they are suitable for routine clinical use.^(580,581)

Biomarkers

There is rapidly increasing interest in the use of biomarkers in COPD. Biomarkers are characteristics (either clinical, functional, biologic and/or imaging) that are objectively measured and evaluated as an indicator of normal biological or pathogenic processes or pharmacological responses to therapeutic interventions. In general, such data has proven difficult to interpret, largely as a result of weak associations and lack of reproducibility between large patient cohorts.⁽⁵⁸²⁾

At present blood eosinophil counts (≥ 300 cells/ μ L) provide guidance to identify COPD patients at higher risk of exacerbations and more likely to benefit from preventive treatment with inhaled corticosteroids (see **Chapter 3**).⁽⁵⁸²⁾

Treatable traits

To address the heterogeneity and complexity of COPD in clinical practice, a strategy based on so-called 'Treatable Traits' (TTs) has been proposed.⁽⁵⁸³⁾ TTs can be identified based on phenotypic recognition and/or on deep understanding of critical causal pathways (endotypes) through validated biomarkers (e.g., high circulating eosinophil levels (a biomarker) identify COPD patients at risk of exacerbations (a TT) in whom treatment with inhaled corticosteroid is most effective).⁽⁵⁸⁴⁾ TTs can co-exist in the same patient⁽³⁶³⁾ and change with time (spontaneously or because of treatment). GOLD highlights the role of two key TTs (persistent dyspnea and exacerbations) in the follow up algorithm of pharmacological treatment (**Figure 3.9**) but there are many more pulmonary and extra-pulmonary traits, as well as behavioral/social risk factors, that merit individual attention and treatment if present.⁽³⁶³⁾

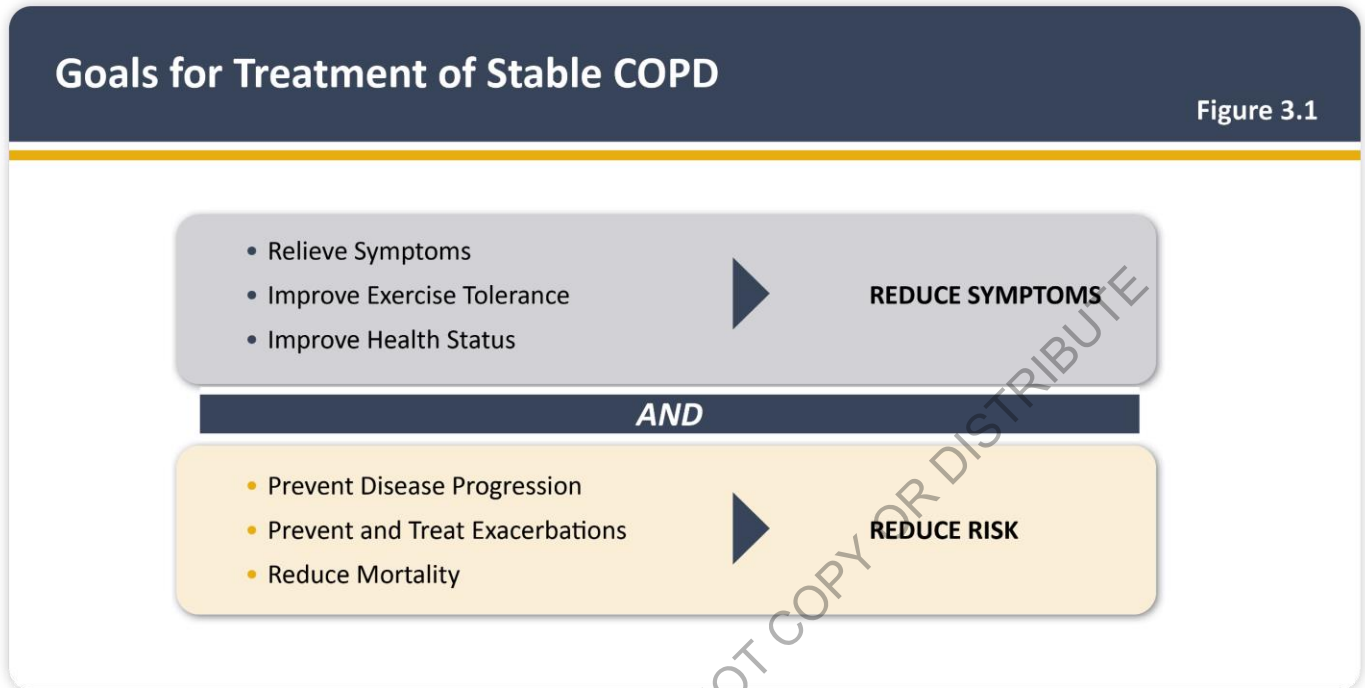
CHAPTER 3: PREVENTION & MANAGEMENT OF COPD

KEY POINTS:

- All individuals who smoke should be strongly encouraged and supported to quit. Nicotine replacement and pharmacotherapy reliably increase long-term smoking abstinence rates. Legislative smoking bans and counseling, delivered by healthcare professionals, improve quit rates. There is no evidence to support the effectiveness and safety of e-cigarettes as a smoking cessation aid at present.
- The main treatment goals are to reduce symptoms and future risk of exacerbations. The management strategy of stable COPD should be predominantly based on the assessment of symptoms and the history of exacerbations.
- Pharmacotherapy can reduce COPD symptoms, reduce the frequency and severity of exacerbations, and improve health status and exercise tolerance. Data suggest beneficial effects on rates of lung function decline and mortality.
- Each pharmacological treatment regimen should be individualized and guided by the severity of symptoms, risk of exacerbations, side-effects, comorbidities, drug availability and cost, and the patient's response, preference, and ability to use various drug delivery devices.
- Inhaler technique needs to be assessed regularly.
- COVID-19 vaccines are highly effective against SARS-CoV-2 infection and people with COPD should have the COVID-19 vaccination in line with national recommendations.
- Influenza vaccination and pneumococcal vaccination decrease the incidence of lower respiratory tract infections.
- The CDC recommends: the Tdap vaccination (dTaP/dTPa; pertussis, tetanus and diphtheria) for COPD patients who were not vaccinated in adolescence; routine use of shingles vaccine in all COPD patients; the new respiratory syncytial virus (RSV) vaccine for individuals over 60 years and/or with chronic heart or lung disease.
- Pulmonary rehabilitation with its core components, including exercise training combined with disease-specific education, improves exercise capacity, symptoms, and quality of life across all grades of COPD severity.
- In patients with severe resting chronic hypoxemia ($\text{PaO}_2 \leq 55$ mmHg or < 60 mmHg if there is *cor pulmonale* or secondary polycythemia), long-term oxygen therapy improves survival.
- In patients with stable COPD and resting or exercise-induced moderate desaturation, long-term oxygen treatment should not be prescribed routinely. However, individual patient factors must be considered when evaluating the patient's need for supplemental oxygen.
- In patients with severe chronic hypercapnia and a history of hospitalization for acute respiratory failure, long-term non-invasive ventilation may decrease mortality and prevent re-hospitalization.
- In select patients with advanced emphysema refractory to optimized medical care, surgical or bronchoscopic interventional treatments may be beneficial.
- Palliative approaches are effective in controlling symptoms in advanced COPD.

INTRODUCTION

The aim of COPD management is to reduce symptoms and future risk (**Figure 3.1**). COPD patients should have an assessment of the severity of their airflow obstruction, symptoms, history of exacerbations, exposure to risk factors and comorbidities (see **Chapter 2**) to guide management.



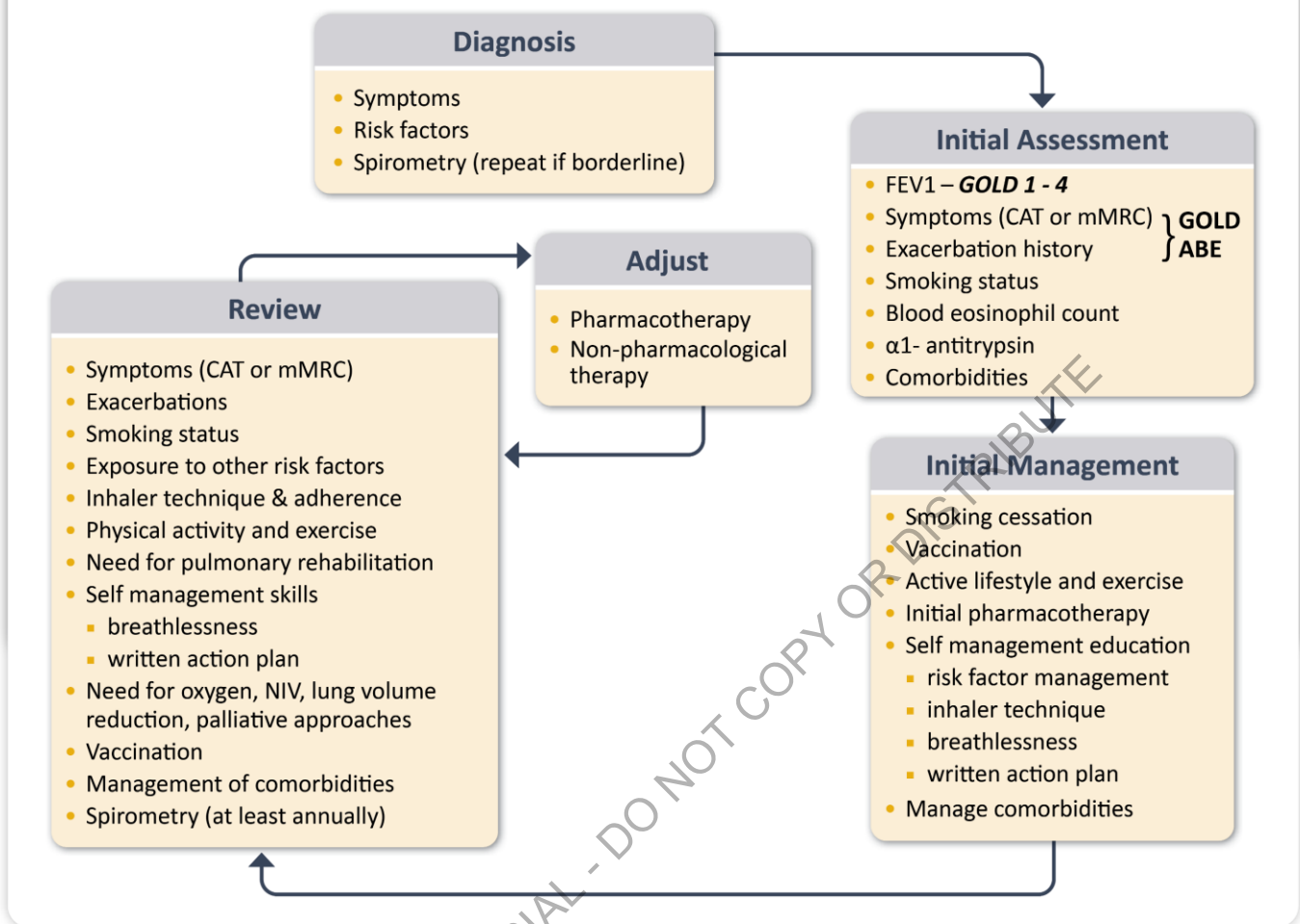
Pharmacological and non-pharmacological therapy should be adjusted as necessary (see below) and further reviews undertaken (**Figure 3.2**). This chapter contains recommendations on how to manage patients with COPD in clinical practice and summarizes the evidence about the effectiveness and safety of maintenance and prevention strategies in COPD on which the recommendations are based.

IDENTIFY AND REDUCE EXPOSURE TO RISK FACTORS

Identification and reduction of exposure to risk factors is important not only for the primary prevention of COPD but also as part of the management of a COPD patient. Cigarette smoking is the most commonly encountered and easily identifiable risk factor for COPD, and smoking cessation should be continually encouraged for all individuals who smoke. Reduction of total personal exposure to occupational dusts, fumes, and gases, and to household and outdoor air pollutants, should also be addressed (**Figure 3.3**).

Management of COPD

Figure 3.2



Identify & Reduce Risk Factor Exposure

Figure 3.3

- Smoking cessation interventions should be actively pursued in all people with COPD (**Evidence A**)
- Efficient ventilation, non-polluting cooking stoves and similar interventions should be recommended (**Evidence B**)
- Clinicians should advise patients to avoid continued exposures to potential irritants, if possible (**Evidence D**)

Smoking cessation

Smoking cessation is a key intervention for all COPD patients who continue to smoke. Healthcare providers are pivotal in delivering smoking cessation messages and interventions and should encourage patients to quit at every available opportunity (**Figure 3.4**).

A significant proportion of people with COPD continue to smoke despite knowing they have the disease (approximately 40% of those with COPD are current smokers), and continued smoking has a negative impact on prognosis and progression of the disease.⁽⁵⁸⁵⁾ Smoking cessation has the greatest capacity to influence the natural history of COPD, it also improves daily symptoms,⁽⁵⁸⁶⁾ and decreases the frequency of exacerbations.⁽⁵⁸⁷⁾

For smokers with COPD, the quitting may be more challenging than for smokers without COPD due to greater nicotine dependence, lower self-efficacy and lower self-esteem.⁽⁵⁸⁸⁻⁵⁹⁰⁾ In addition, it has been reported that depression is more common in smokers with COPD⁽⁵⁹¹⁾ and this could contribute to failed attempts to quit.^(591,592) Despite these adverse conditions, if effective time and resources are dedicated to smoking cessation, long-term quit rates of 14% to 27% have been reported.⁽⁵⁹²⁾

Brief Strategies to Help the Patient Willing to Quit

Figure 3.4

ASK	Systematically identify all tobacco users at every visit <i>Implement an office-wide system that ensures that, for EVERY patient at EVERY clinic visit, tobacco-use status is queried and documented</i>
ADVISE	Strongly urge all tobacco users to quit <i>In a clear, strong, and personalized manner, urge every tobacco user to quit</i>
ASSESS	Determine willingness and rationale of patient's desire to make a quit attempt. <i>Ask every tobacco user if he or she is willing to make a quit attempt at this time (e.g., within the next 30 days)</i>
ASSIST	Aid the patient in quitting <i>Help the patient with a quit plan; provide practical counseling; provide intra-treatment social support; help the patient obtain extra-treatment social support; recommend use of approved pharmacotherapy except in special circumstances; provide supplementary materials</i>
ARRANGE	Schedule follow-up contact <i>Schedule follow-up contact, either in person or via telephone</i>

As for all smokers, smoking cessation treatment for people with COPD should be adapted to the individual's needs and according to the level of tobacco dependence. There is evidence that a combination of counseling and pharmacotherapy is the most effective smoking cessation treatment for people with COPD. (592-594) The complexity of the smoking cessation process is largely determined by nicotine addiction. An accurate assessment of nicotine dependence should therefore be carried out for all patients. Some indicators of high nicotine dependence are: smoking within 30 min of waking up, smoking at night, consuming ≥ 20 cigarettes per day, a score of 7 to 10 on the Fagerström scale or 5 to 6 on the Heaviness of Smoking Index. (595,596)

In addition to individual approaches to smoking cessation, legislative smoking bans are effective in increasing quit rates and reducing harm from second-hand smoke exposure. (597)

Advice and counseling interventions

A five-step program for intervention (**Figure 3.4**) (598-600) provides a helpful strategic framework to guide healthcare providers interested in helping their patients stop smoking. (598,600,601) When possible, the patient should be referred to a comprehensive smoking cessation program that incorporates behavioral techniques that enhance patient motivation and confidence, patient education, and pharmacological and non-pharmacological interventions. Recommendations for treating tobacco use and dependence are summarized in **Figure 3.5**. (598) Because tobacco dependence is a chronic disease, (598,600) clinicians should recognize that relapse is common and reflects the chronic nature of dependence and addiction, and does not represent failure on the part of the patient or the clinician.

Treating Tobacco Use and Dependence

Figure 3.5

Major Findings & Recommendations from the Tobacco Use & Dependence Clinical Practice Guideline Panel:

- Tobacco dependence is a chronic condition that warrants repeated treatment until long-term or permanent abstinence is achieved
- Effective treatments for tobacco dependence exist and all tobacco users should be offered these treatments
- Clinicians and health care delivery systems must operationalize the consistent identification, documentation, and treatment of every tobacco user at every visit
- Brief smoking cessation counseling is effective and every tobacco user should be offered such advice at every contact with health care providers
- There is a strong dose-response relation between the intensity of tobacco dependence counseling and its effectiveness
- Three types of counseling have been found to be especially effective: practical counseling, social support of family and friends as part of treatment, and social support arranged outside of treatment
- First-line pharmacotherapies for tobacco dependence — varenicline, nortriptyline, bupropion sustained release, nicotine gum, nicotine inhaler, nicotine nasal spray, and nicotine patch— are effective and at least one of these medications should be prescribed in the absence of contraindications
- Financial incentive programs for smoking cessation may facilitate smoking cessation
- Tobacco dependence treatments are cost effective interventions

Counseling delivered by physicians and other health professionals significantly increases quit rates over self-initiated strategies. ⁽⁶⁰²⁾ Even brief (3-minute) periods of counseling urging a smoker to quit improve smoking cessation rates. ⁽⁶⁰²⁾

In patients with COPD a network meta-analysis showed a trend for smoking cessation counseling alone to be superior than usual care. ⁽⁶⁰³⁾ Another study reported a continuous one-year abstinence rate of 1.4% for usual care, 2.6% for minimal counseling (< 90 min), 6% for intensive counseling (≥ 90 min), and 12.3% for intensive counseling plus pharmacotherapy. ⁽⁵⁹³⁾ However, controversy remains as to whether more intensive individual counseling is more effective when combined with pharmacotherapy. ⁽⁶⁰³⁾

Household and outdoor air pollution

Reducing exposure to household and outdoor air pollution requires a combination of public policy, local and national resources, cultural changes, and protective steps taken by individual patients. Reduction of exposure to smoke from biomass fuel is a crucial goal to reduce the prevalence of COPD worldwide. Efficient ventilation, non-polluting cooking stoves and similar interventions are feasible and should be recommended. ^(8,9)

Occupational exposures

There are no studies that demonstrate whether interventions that reduce occupational exposures also reduce the burden of COPD, but it seems logical to advise patients to avoid ongoing exposures to potential irritants e.g., dusts, fumes and gases, if possible.

Climate change & COPD

Climate change has increased the frequency, intensity and geographic distribution of extreme weather events such as heatwaves, severe winter conditions, floods, droughts, hurricanes, thunderstorms, wildfires and dust storms. Excess deaths have been reported during heatwaves in all regions of the world, ⁽⁶⁰⁴⁻⁶¹⁰⁾ and during periods of cold weather. ⁽⁶¹¹⁻⁶¹⁴⁾ Epidemiological studies confirm the association between exposure to extreme, but not moderate, heat and mortality, ⁽⁶¹⁵⁻⁶¹⁷⁾ with the mortality impact of extreme high temperatures increasing with the length of the heat episode. ⁽⁶¹⁸⁾ Temperature thresholds for given health impacts are unique to particular locations, with greater effects of heat in large cities and colder regions where extreme temperatures were not previously common, and greater effects of falls in temperature in warmer regions that were unused to cold. ^(611,617) The effects of heat also vary with levels of atmospheric humidity and air pollution. ^(605,619,620)

Population studies have consistently found that people with COPD are at increased risk of death as a consequence of exposure to both heat and cold, ⁽⁶²¹⁻⁶²³⁾ with cold leading to a greater risk than heat. ^(624,625) As well as the effects on mortality, higher outdoor temperatures are associated with an increased risk of hospitalization for COPD ^(623,626-628) and lower outdoor temperatures are associated with an increased risk of exacerbations. ⁽⁶²⁹⁾

Most studies have examined the effect of outdoor air temperature on mortality and morbidity in COPD; however, many patients, particularly those with more severe disease, spend much of their time indoors. Indoor temperature and humidity vary significantly, despite similar outdoor conditions and are influenced by the building type, insulation, presence of heating, sun shades and ventilation, socioeconomic factors including the ability to afford heating, and behavioral factors such as cooking and bathing. ⁽⁶³⁰⁻⁶³²⁾ Indoor temperatures are often higher than outdoor including during heatwaves, ^(633,634) and high indoor humidity can exacerbate the adverse effects of heat by impeding natural

evaporative cooling. Lower indoor temperatures during cold periods are found in older properties, in those lacking heating systems and those that are expensive to heat.⁽⁶³⁵⁾ Even if heating is available, COPD patients may not heat their bedrooms at night and may keep windows open overnight even in winter.^(636,637)

Studies of the relationship between temperature, symptoms and lung function in COPD at an individual patient level have shown higher outdoor temperature is associated with increased dyspnea⁽⁶³⁸⁾ particularly on days that patients go outside.⁽⁶³⁹⁾ Higher indoor temperatures are associated with increased symptoms and SABA use⁽⁶³⁹⁾ and colder indoor and outdoor temperatures are also associated with increased cough and sputum, increased SABA use and a fall in FEV1.^(636,638-640) Over an autumn, winter and spring period (with average minimum outdoor temperature of 2.9°C and maximum of 10.1°C) health status was better in patients with at least 9 hours of indoor temperature $\geq 21^\circ\text{C}$.⁽⁶⁴¹⁾

Weather also has a significant impact on air quality. Ozone levels strongly correlate with temperature, as its generation depends on high temperatures and sunlight,⁽⁶⁴²⁾ and the generation and dispersion of air pollutants may be influenced by local patterns of wind, solar radiation and precipitation, especially in urban areas.⁽⁶⁴³⁾ Some studies have shown synergistic effects between heat and air pollution exposure on all-cause mortality, and hospital admissions in general populations,⁽⁶⁴⁴⁻⁶⁴⁶⁾ however, there are also studies showing no interaction.^(647,648) A synergistic effect of low temperatures and ozone concentrations on the general population has also been found in some countries (e.g., China and Hong Kong^(649,650)) but not in others^(621,644) Although not widely studied, there is conflicting evidence regarding the interactive effects of outdoor heat and pollution on respiratory outcomes.^(646,651,652) Several studies have looked at the interactive effects of pollution and temperature in people with COPD. There appears to be a greater effect of pollutants on COPD hospital admissions and emergency visits at low temperatures or during winter.⁽⁶⁵³⁻⁶⁵⁶⁾ Outdoor air pollutants, including PM_{2.5}, NO₂, and ozone do not appear to worsen the effect of outdoor temperature on symptoms,⁽⁶⁵⁷⁾ but the detrimental effect of higher indoor temperatures on symptoms appears to be potentiated by higher indoor concentrations of PM_{2.5} and NO₂.⁽⁶⁵⁷⁾ The conflicting findings regarding interactions between temperature and pollutants on symptoms and exacerbations in people with COPD may, in part, reflect differences in behaviors that affect exposure, such as avoiding going out, opening windows and using air conditioning.

The mechanisms by which heat exposure and cold adversely impact COPD are not well understood. However, on the basis of the evidence showing a relationship between high and low temperatures and morbidity and mortality, patients with COPD living in temperate and colder climates should, in line with WHO recommendations,⁽⁶⁵⁸⁾ ensure they keep bedroom temperatures above 18°C during cold weather. During heatwaves and periods of high temperature patients should ensure they keep adequately hydrated, keep out of the heat and try to keep living spaces < 32°C and sleeping spaces < 24°C as recommended by WHO.⁽⁶⁵⁹⁾ Prior identification and management of cardiovascular comorbidities is also important to reduce adverse outcomes.

There are significant differences in the carbon footprint of inhaler devices reflecting whether they contain a propellant gas, what they are made from, how they are manufactured and transported, and whether they can be reused or recycled. Selection and correct use and disposal of inhalers by patients can have important implications for global warming and climate change. Similarly, models of care should consider the environmental impact of healthcare facilities and the need for patients to travel.

Vaccinations

People with COPD should receive all recommended vaccinations in line with the relevant local guidelines (**Figure 3.6**).

Influenza vaccine

Influenza vaccination can reduce serious illness (such as lower respiratory tract infections requiring hospitalization)⁽⁶⁶⁰⁾ stroke,⁽⁶⁶¹⁾ and death in people with COPD.⁽⁶⁶²⁻⁶⁶⁵⁾ Only a few studies have evaluated exacerbations and they have shown significant reduction in the total number of exacerbations per vaccinated subject compared with those who received placebo.⁽⁶⁶²⁾ Vaccines containing either killed or live inactivated viruses are recommended⁽⁶⁶⁶⁾ as they are more effective in elderly people with COPD.⁽⁶⁶⁷⁾ The CDC recommends high-dose inactivated (HD-IIV3) and adjuvanted inactivated (aIIV3) influenza vaccines as acceptable options for influenza vaccination in older adults.⁽⁶⁶⁸⁾ Findings from a population-based study suggested that people with COPD, particularly the elderly, had decreased risk of ischemic heart disease when they were vaccinated with influenza vaccine over many years.⁽⁶⁶⁹⁾ Occurrence of adverse reactions is generally mild and transient.

Pneumococcal vaccines

Pneumococcal vaccinations, pneumococcal conjugated vaccine (PCV20 or PCV15) and pneumococcal polysaccharide vaccine (PPSV23), are approved for adults aged ≥ 65 years. They are also approved for adults aged 19–64 years if they have an underlying medical condition such as chronic lung disease (including COPD, emphysema, and asthma), cigarette smoking, solid organ transplant etc. The FDA recently approved PCV21⁽⁶⁷⁰⁾ which covers 11 unique serotypes not included in PCV20; many cases of adult disease are caused by subtypes not covered by other FDA-approved pneumococcal vaccines. Pneumococcal vaccination is universally recommended for adults in these age groups, if they have never received a pneumococcal conjugate vaccine previously, or if their previous pneumococcal vaccination history is unknown. The current recommendation is PCV15 followed by PPSV23 or one dose PCV20,⁽⁶⁷¹⁾ or one dose PCV21⁽⁶⁷⁰⁾ in adults who have indication for the vaccine (**Figure 3.6**).⁽⁶⁷¹⁾

Vaccination for Stable COPD

Figure 3.6

People with COPD should receive all recommended vaccinations in line with the relevant local guidelines:

- Yearly influenza vaccination (**Evidence B**)
- SARS-CoV-2 (COVID-19) vaccination based on WHO and CDC updated recommendations (**Evidence B**)
- Either one dose of 21-valent pneumococcal conjugate vaccine (PCV21) or one dose PCV20, as recommended by the CDC (**Evidence B**). Pneumococcal vaccination has been shown to reduce the incidence of community-acquired pneumonia and exacerbations for people with COPD (**Evidence B**)
- Respiratory syncytial virus (RSV) vaccination for individuals aged ≥ 60 years and/or with chronic heart or lung disease, as recommended by the CDC (**Evidence A**)
- Tdap (dTaP/dTPa) vaccination to protect against pertussis (whooping cough) for people with COPD that were not vaccinated in adolescence, as recommended by the CDC (**Evidence B**)
- Zoster vaccine to protect against shingles for people with COPD aged > 50 years, as recommended by the CDC (**Evidence B**)

Specific data on the effects of PPSV and PCV in people with COPD are limited.⁽⁶⁷²⁾ A systematic review of injectable vaccines in COPD patients identified twelve randomized studies for inclusion and observed injectable polyvalent pneumococcal vaccination provides significant protection against community-acquired pneumonia, although no evidence indicates that vaccination reduced the risk of confirmed pneumococcal pneumonia, which was a relatively rare event. Vaccination reduced the likelihood of a COPD exacerbation, and moderate-quality evidence suggests the benefits of pneumococcal vaccination in COPD patients. Evidence was insufficient for comparison of different pneumococcal vaccine types.⁽⁶⁷³⁾ PPSV23 has been shown to reduce the incidence of community-acquired pneumonia in COPD patients < 65 years, with an FEV1 < 40% predicted, or comorbidities (especially cardiac comorbidities).⁽⁶⁷⁴⁾ The PCV13 has been shown to exhibit at least the same or greater immunogenicity than the PPSV23 up to two years after vaccination in COPD patients.⁽⁶⁷⁵⁾ In a large RCT PCV13 demonstrated significant efficacy for the prevention of vaccine-type community-acquired pneumonia (45.6%) and vaccine-type invasive pneumococcal disease (75%) among adults ≥ 65 years and the efficacy persisted for at least 4 years.⁽⁶⁷⁶⁾ PCV20 covers up to 58% of those strains, while PCV21 covers up to 84% of strains responsible for invasive disease in adults.⁽⁶⁷⁷⁾

A study compared the effectiveness of PPSV23 and PCV13 in COPD patients over a 5-year follow-up cohort study. Although both vaccines have comparable clinical effects during the first year after vaccination, PCV13 showed persistent clinical effectiveness during the 5-year follow-up period. Pneumonia by year 5 after vaccination was registered in 47% of patients in the PPSV23 group, versus 3.3% of patients in the PCV13 group (p < 0.001). Similar effects were shown in the reduction of COPD exacerbations.⁽⁶⁷⁸⁾

Pneumococcal vaccine can be co-administered with influenza vaccine in an adult immunization program, as concomitant administration (PCV15 or PPSV23 and QIV [Fluarix], PCV20 and adjuvanted QIV [Fluad]) has been demonstrated to be immunogenic and safe.⁽⁶⁷⁹⁾

Respiratory syncytial virus (RSV) vaccine

The US Centers for Disease Control (CDC) estimates that every year, respiratory syncytial virus (RSV) causes approximately 60,000–160,000 hospitalizations and 6,000–10,000 deaths among older adults in the USA.^(680,681) RSV infection in adults may have a significant impact not only in the respiratory system but also on other organs. In a cross-sectional study over 5 RSV seasons, nearly one-quarter of hospitalized adults aged ≥ 60 years with RSV infection experienced an acute cardiac event (most frequently acute heart failure), including 1 in 12 adults (8.5%) with no documented underlying cardiovascular disease.⁽⁶⁸²⁾ In a report from the UK, RSV was associated with 8.7% of outpatient managed COPD exacerbations.⁽⁶⁸³⁾

The Advisory Committee on Immunization Practices' (ACIP) and the European Commission recommend use of RSV bivalent prefusion F protein-based vaccine,⁽⁶⁸⁴⁾ and prefusion F protein vaccine⁽⁶⁸⁵⁾ for all individuals aged ≥ 75 years and for those ≥ 60 years at high risk of severe RSV illness due to chronic heart or lung disease, immune compromise, or living in a nursing home or long-term care facility.⁽⁶⁸⁶⁾ Recent analysis of follow-up demonstrated that one dose of adjuvanted prefusion F protein-based vaccine was efficacious in preventing RSV-related disease in participants aged ≥ 60 years during 2 full RSV seasons.⁽⁶⁸⁷⁾ In another study of 2,987 adults ≥ 60 years, RSV vaccination reduced the likelihood of RSV-associated hospitalization. Moreover, the study demonstrated protection in a population at high risk of severe RSV disease, including adults aged ≥ 75 years and immunocompromised individuals.⁽⁶⁸⁸⁾ The safety of RSV vaccinations was demonstrated in a recent CDC publication.⁽⁶⁸⁹⁾

Other vaccines

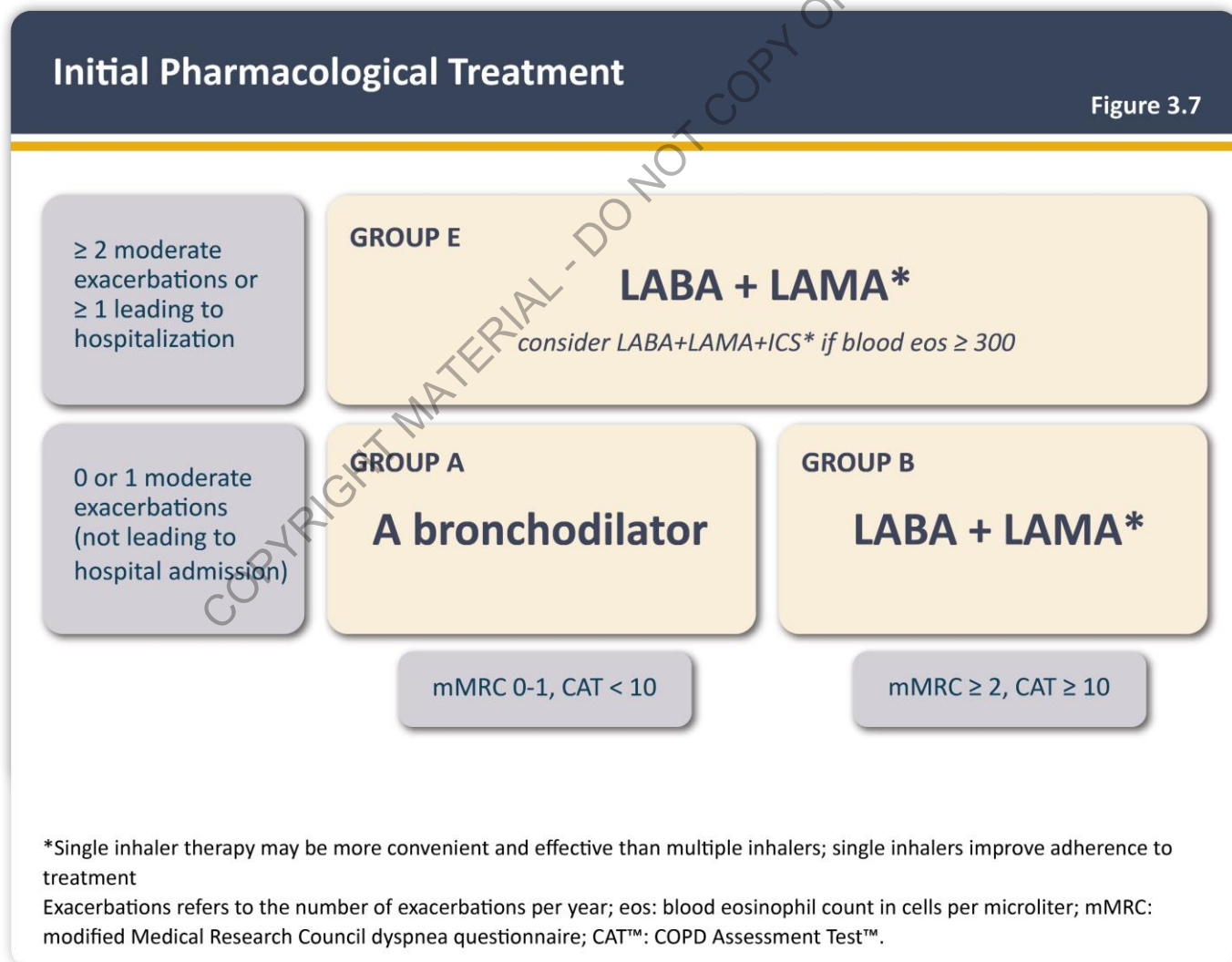
COPD patients are at increased risk of pertussis (whooping cough).⁽⁶⁹⁰⁾ As such, in adults with COPD the CDC recommends the Tdap vaccination (also called dTaP/dTPa) to protect against pertussis, in addition to tetanus and diphtheria, in those who were not vaccinated in adolescence and also the routine use of shingles vaccine.^(691,692)

People with COPD should have the COVID-19 vaccinations in line with national recommendations.⁽⁶⁹³⁾ COVID-19 vaccines are highly effective against SARS-CoV-2 infection requiring hospitalization, ICU admission, or an emergency department or urgent care clinic visit, including those with chronic respiratory disease.^(693,694)

PHARMACOLOGICAL TREATMENT OF STABLE COPD

We propose a tailored approach to initiate treatment based on the level of symptoms and risk for exacerbations. Treatment can be escalated/de-escalated based on the presence of the predominant symptoms (treatable traits) of breathlessness and exercise limitation, and the continued occurrence of exacerbations whilst on maintenance therapy. The basis for these recommendations was partly derived from evidence generated from randomized controlled trials. However, as these recommendations are intended to support clinician decision-making, they also incorporate expert advice based on clinical experience.

Initial pharmacotherapy should be based on the patient's GOLD group (**Figure 3.7**). Patients should be offered guidance and follow up on self-management of breathlessness, and stress management, and be given a written action plan (**Figure 3.13**). Comorbidities should be managed as per specific guidelines, irrespective of the presence of COPD (**Figure 3.2**).



Patients should be reviewed after a suitable interval (shorter in more severe patients and longer in less severe patients) and their current level of symptoms (using either the CAT or mMRC scores) and exacerbation frequency assessed. The effect of treatment and possible adverse effects should be evaluated, and comorbidities reassessed.

Inhaler technique, adherence to prescribed therapy (both pharmacological and non-pharmacological), smoking status and continued exposure to risk factors should be regularly checked. Physical activity should be encouraged and referral for pulmonary rehabilitation considered in severe patients. The need for oxygen therapy, non-invasive ventilatory support, lung volume reduction and palliative approaches should be considered individually, and the action plan should be updated accordingly. Spirometry should be repeated at least annually. If the patient is already receiving bronchodilator treatment, the latter should not be interrupted for performing spirometry.

We no longer refer to asthma and COPD overlap (ACO), instead we emphasize that asthma and COPD are different disorders, although they may share some common treatable traits and clinical features (e.g., eosinophilia, some degree of reversibility). Asthma and COPD may coexist in an individual patient. If a concurrent diagnosis of asthma is suspected, pharmacotherapy should primarily follow asthma guidelines.

Algorithms for the initiation and follow-up of pharmacological treatment

Further information on the evidence that underpins these recommendations is given later in **Chapter 3** in the section entitled “**Overview of the evidence: Pharmacotherapy**”.

Initial pharmacological management

A proposal for the **INITIATION** of pharmacological management of COPD according to the individualized assessment of symptoms and exacerbation risk following the ABE scheme, and also accounting for blood eosinophil count, is shown in **Figure 3.7**. It is an attempt to provide clinical guidance. There is no high-quality evidence such as randomized controlled trials to support initial pharmacological treatment strategies in newly diagnosed COPD patients.

Group A

▶ All Group A patients should be offered bronchodilator treatment based on its effect on breathlessness. This can be either a short- or a long-acting bronchodilator. If available and affordable a long-acting bronchodilator is the preferred choice except in patients with very occasional breathlessness.

▶ This should be continued if benefit is documented.

Group B

▶ Treatment should be initiated with a LABA+LAMA combination. It has been shown in a RCT that in patients with ≤ 1 moderate exacerbation in the year before the study and a CAT™ ≥ 10 LABA+LAMA is superior to a LAMA with regard to several endpoints.⁽⁶⁹⁵⁾ Therefore, providing there are no issues regarding availability, cost and side-effects LABA+LAMA is the recommended initial pharmacological choice.

▶ If a LABA+LAMA combination is not considered appropriate, there is no evidence to recommend one class of long-acting bronchodilators over another (LABA or LAMA) for initial relief of symptoms in this group of patients. In the individual patient, the choice should depend on the patient’s perception of symptom relief.

▶ Group B patients are likely to have comorbidities that may add to their symptomatology and impact their prognosis,

and these possibilities should be investigated and treated, if present, by following national and international guidelines. [\(696,697\)](#)

Group E

- ▶ A Cochrane systematic review and network meta-analysis comparing dual combination therapy versus mono long-acting bronchodilators showed that the LABA+LAMA combination was the highest ranked treatment group to reduce COPD exacerbations. [\(698\)](#) Therefore, provided there are no issues regarding availability, cost and side-effects LABA+LAMA is the preferred choice for initial therapy in group E patients.
- ▶ Use of LABA+ICS in COPD is not encouraged. If there is an indication for an ICS, then LABA+LAMA+ICS has been shown to be superior to LABA+ICS and is therefore the preferred choice. [\(496,699\)](#)
- ▶ Consider LABA+LAMA+ICS in group E if eos \geq 300 cells/ μ L (practical recommendation). As detailed later in this chapter, the effect of ICS on exacerbation prevention is correlated to blood eosinophil count. There are no direct data in the literature concerning initiation of triple therapy in newly diagnosed patients. However, we think available studies performed mostly in treated patients provide a rationale for considering this treatment option as initial therapy for patients with a high eosinophil count (\geq 300 cells/ μ L).
- ▶ If patients with COPD have concomitant asthma they should be treated like patients with asthma. Under these circumstances the use of an ICS is mandatory.

Rescue short-acting bronchodilators should be prescribed to all patients for immediate symptom relief.

Following implementation of therapy, patients should be reassessed for attainment of treatment goals and identification of any barriers for successful treatment (**Figure 3.8**). Following review of the patient's response to treatment initiation, adjustments may be needed.

This is guided by the principles of first **review** and **assess**, then **adjust** if necessary (**Figure 3.8**):

▶ Review

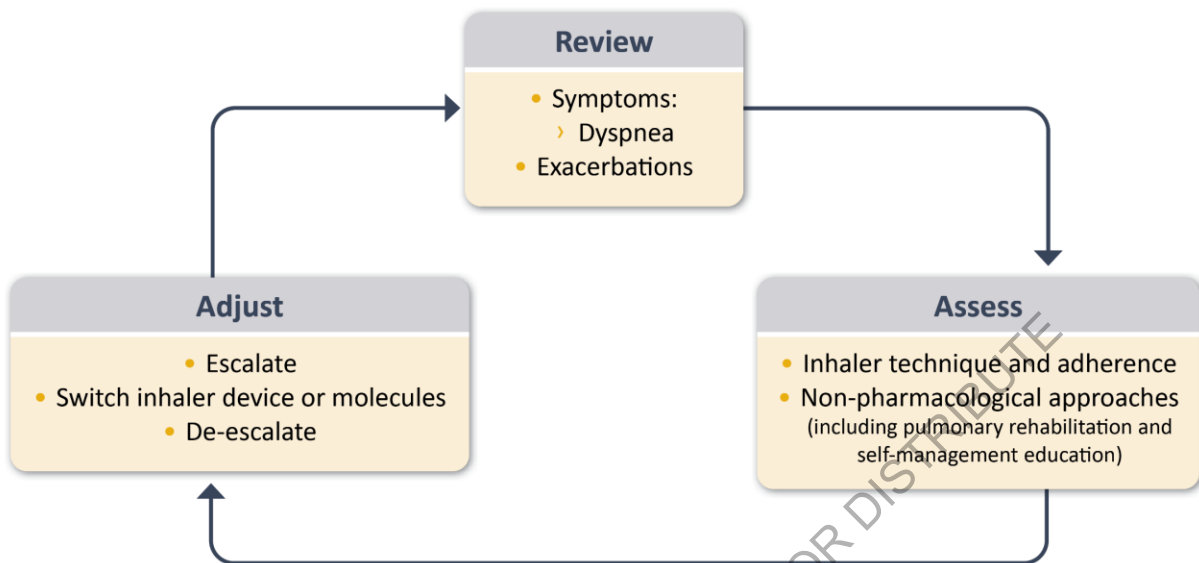
- Review symptoms (dyspnea) and exacerbation risk (previous history, blood eosinophils).

▶ Assess

- Assess inhaler technique and adherence, and the role of non-pharmacological approaches (covered earlier in this chapter).

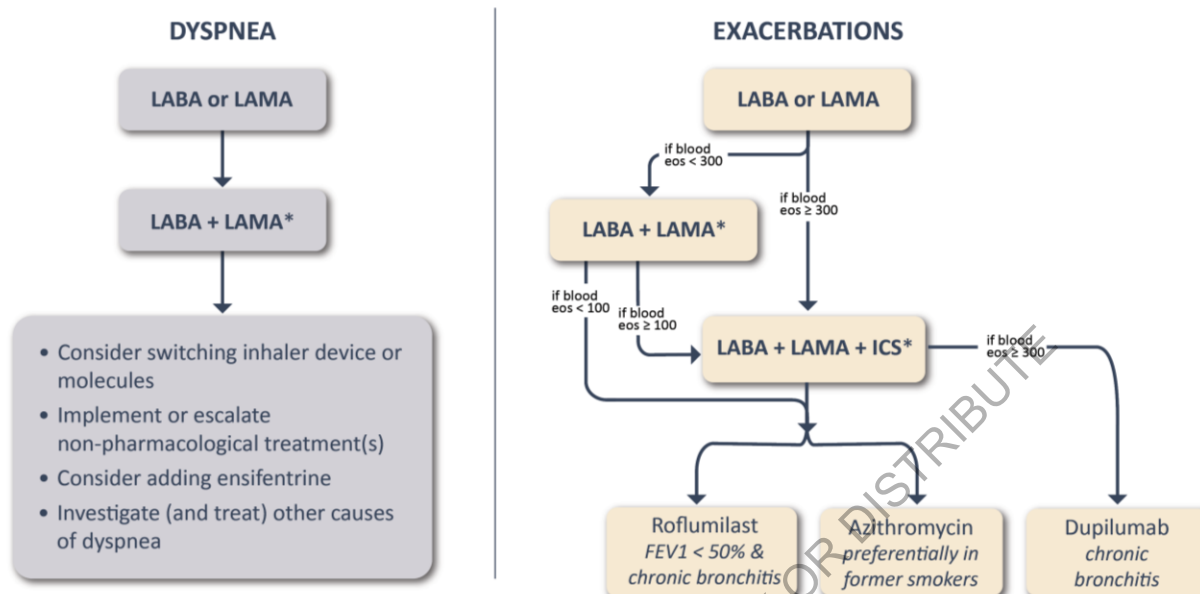
▶ Adjust

- Adjust pharmacological treatment, including escalation or de-escalation. Switching inhaler device or molecules within the same class (e.g., using a different long-acting bronchodilator) may be considered as appropriate. Any change in treatment requires a subsequent **review** of the clinical response, including side effects.



Follow-up pharmacological management

A separate algorithm is provided for **FOLLOW-UP** treatment, where the management is based on two key treatable traits: persistence of dyspnea and occurrence of exacerbations (**Figure 3.9**).^(501,700-702) These follow-up recommendations are designed to facilitate management of patients taking maintenance treatment(s), whether early after initial treatment or after years of follow-up. These recommendations incorporate the evidence from clinical trials and the use of peripheral blood eosinophil counts as a biomarker to guide the use of ICS therapy for exacerbation prevention (see more detailed information regarding blood eosinophil counts as a predictor of ICS effects later in **Chapter 3**).



*Single inhaler therapy may be more convenient and effective than multiple inhalers; single inhalers improve adherence to treatment. Consider de-escalation of ICS if pneumonia or other considerable side-effects. In case of blood eos ≥ 300 cells/ μ l de-escalation is more likely to be associated with the development of exacerbations. Exacerbations refers to the number of exacerbations per year.

Figure 3.9 presents suggested escalation and de-escalation strategies based on available efficacy and safety data. The response to treatment escalation should always be reviewed. Patients, in whom treatment modification is considered, in particular de-escalation, should be under close medical supervision. We are fully aware that treatment escalation has not been systematically tested; trials of de-escalation are also limited and only include ICS.

The follow-up pharmacological treatment algorithm (Figure 3.9) can be applied to any patient who is already taking maintenance treatment(s) irrespective of the GOLD group allocated at treatment initiation. If response to initial treatment is appropriate, maintain it. If not:

- Check adherence, inhaler technique and possible interfering comorbidities.
- The need to target primarily dyspnea/activity limitation or to prevent further exacerbations should be evaluated in each patient. Consider the predominant treatable trait to target (dyspnea or exacerbations).
 - Use the exacerbation pathway if both exacerbations and dyspnea need to be targeted.
- If a change in treatment is considered necessary, then select the corresponding algorithm for dyspnea (Figure 3.9 left column) or exacerbations (Figure 3.9 right column)
- Identify which box corresponds to the patient’s current treatment and follow the suggested algorithm.

Dyspnea

► For patients with persistent breathlessness or exercise limitation on **bronchodilator** monotherapy, (703) the use of two long-acting bronchodilators is recommended.

► If the addition of a second long-acting bronchodilator does not improve symptoms, we suggest:

Be sure to read and understand the paragraph entitled Important Purpose & Liability Disclaimer

- Considering switching inhaler device or molecules.
- Implementing or escalating non-pharmacological treatment(s) e.g., pulmonary rehabilitation.
- Considering adding ensifentrine if available.

▶ At all stages, dyspnea due to other causes (not COPD) should be investigated and treated appropriately. Inhaler technique and adherence should be considered as causes of inadequate treatment response. Rehabilitation should also be considered.

Exacerbations

▶ For patients with persistent exacerbations on **bronchodilator** monotherapy, escalation to LABA+LAMA is recommended.

▶ In patients who develop further exacerbations on **LABA+LAMA** therapy we suggest escalation to **LABA+LAMA+ICS**. A beneficial response after the addition of ICS may be observed at blood eosinophil counts ≥ 100 cells/ μL , with a greater magnitude of response more likely with higher eosinophil counts. ⁽⁴⁹⁶⁾

▶ If patients treated with **LABA+LAMA** and eosinophil counts < 100 cells/ μL still have exacerbations the following options may be considered:

- Among those who are not currently smoking, consider adding azithromycin. ^(704,705) Consideration to the development of resistant organisms should be factored into decision-making.
- Among those with FEV1 $< 50\%$, symptoms of chronic bronchitis and history of prior severe exacerbation, consider adding roflumilast. ⁽⁷⁰⁶⁻⁷⁰⁸⁾

▶ If patients treated with **LABA+LAMA+ICS** (or those with eosinophil counts < 100 cells/ μL) still have exacerbations the following options may be considered:

- Among those with eosinophils ≥ 300 cells/ μL and symptoms of chronic bronchitis, consider adding dupilumab. ^(700,701)
- Among those who are not currently smoking, consider adding azithromycin. ^(704,705) Consideration to the development of resistant organisms should be factored into decision-making.
- Among those with FEV1 $< 50\%$, symptoms of chronic bronchitis and history of prior severe exacerbation, consider adding roflumilast. ⁽⁷⁰⁶⁻⁷⁰⁸⁾

▶ Patients treated with **LABA+LAMA+ICS** should not have the ICS component withdrawn unless the inhaled corticosteroids were started inappropriately, there has been no response to ICS, they experience significant side-effects, or severe or recurrent pneumonia. The risks and benefits of discontinuing ICS should be considered. If blood eosinophils are ≥ 300 cells/ μL de-escalation is more likely to be associated with the development of exacerbations. ^(709,710)

Patients on treatment with LABA+ICS

▶ If a patient with COPD and **no features of asthma** has been treated – for whatever reason – with LABA+ICS and is well controlled in terms of symptoms and exacerbations, continuation with LABA+ICS is an option (**Figure 3.22**). However, if the patient has:

- **Further exacerbations:** treatment should be escalated to LABA+LAMA+ICS if the blood eosinophil count is ≥ 100 cells/ μL or switched to LABA+LAMA if it is < 100 cells/ μL .

- **Major symptoms:** change to LABA+LAMA or LABA+LAMA+ICS depending on previous treatment response to ICS (see 'Management of Patients Currently on LABA+ICS' on Page 88 and **Figure 3.22** for further information).

Managing inhaled therapy

Most of the drugs used to treat COPD are inhaled. Thus, appropriate use of inhaler devices is crucial to optimize the benefit-risk ratio of inhaled therapy. Achieving this goal requires choosing the appropriate device, providing education, checking inhaler use regularly and, whenever necessary, adapting education and device (**Figure 3.10**).

Key Points for Inhalation of Drugs

Figure 3.10

- When a treatment is given by the inhaled route, the importance of education and training in inhaler device technique cannot be over-emphasized
- The choice of inhaler device has to be individually tailored and will depend on access, cost, prescriber, and most importantly, patient's ability and preference
- It is essential to provide instructions and to demonstrate the proper inhalation technique when prescribing a device, to ensure that inhaler technique is adequate and to re-check at each visit that patients continue to use their inhaler correctly
- Inhaler technique (and adherence to therapy) should be assessed before concluding that the current therapy is insufficient

There are currently at least 33 different inhaled therapies containing different bronchodilators (both short- and long-acting) and inhaled corticosteroids (ICS) alone or in combinations (**Figure 3.18**). In addition, at least 22 different inhaler devices are available,⁽⁷¹¹⁾ including nebulizers, metered-dose inhalers (MDIs) used with or without valved holding chamber (VHC)/spacers, breath-actuated MDIs (BAIs), soft mist inhalers (SMIs) and dry powder inhalers (DPIs)⁽⁷¹²⁾ In multi-dose DPIs, the powder is contained in a reservoir or in individual blisters.⁽⁷¹²⁾ More information about inhalation devices is available on the Asthma + Lung UK website.⁽⁷¹³⁾

Devices differ in their size and portability. They also differ in the number of steps required to prepare them,⁽⁷¹⁴⁾ in the force needed to load or actuate them,⁽⁷¹⁵⁾ in the time taken to deliver the drug, and in the need for cleaning and maintenance, as well as in the inspiratory manoeuvre required to use them effectively.⁽⁷¹²⁾ Increased steps reduces the ease of use and likelihood that patients use the inhaler correctly.⁽⁷¹⁶⁾ There may also be quite significant differences in the carbon footprint of devices reflecting whether or not they contain a propellant gas, what they are made from, how they are manufactured and transported, and whether they can be reused or recycled.⁽⁷¹⁷⁾ The proper use of an inhaler has a positive environmental impact through the reduction of exacerbations and their CO₂ footprint (especially when hospitalization is required).⁽⁷¹⁷⁾ Smart inhalers incorporate sensors that detect the date and time of use, and for some inspiratory flow and inspired volume. These allow the identification of problems and feedback in real time⁽⁷¹⁸⁾ and can provide objective data on adherence and technique.^(719,720)

Particles > 5 microns (μm) are most likely to be deposited in the oropharynx. For drug delivery to the lower respiratory tract and lungs, particle size (mass-median aerodynamic diameter) can be fine (2-5 μm) or extra-fine (< 2 μm), which influences the total respirable fraction (particles < 5 μm) and the amount and site of drug deposition (more peripheral deposition with extra-fine particles).⁽⁷¹²⁾ Inspiratory flow, flow acceleration, and inhaled volume are important factors

for patients to successfully inhale drug particles from handheld devices into the lower respiratory tract.^(712,721) MDIs and SMIs require a slow and deep inspiration while DPIs require forceful inspiration. Each DPI has a unique internal resistance and patients must create turbulent energy within the device during inhalation to disaggregate the powder into fine particles. Prescribers should check visually that the patient can inhale forcefully through the device and, if there is doubt, either check the inspiratory flow objectively^(722,723) or switch to an MDI+/-spacer/VHC or SMI depending on drug availability and patient's characteristics. Suboptimal peak inspiratory flow and inhalation technique errors were associated with higher COPD-related healthcare utilization and costs in patients on DPI maintenance therapy.⁽⁷²⁴⁾

Randomized controlled trials have not identified superiority of one device/formulation and there is no evidence for superiority of nebulized therapy over hand-held devices in patients who are able to use these devices properly.⁽⁷¹²⁾ However, patients included in these trials are usually those who master inhalation technique and receive proper education and follow-up regarding this issue, and therefore may not be reflective of normal clinical practice. Fixed-dose triple inhaled combination therapy in one inhaler may help improve health status compared to treatment using multiple inhalers.⁽⁷²⁵⁾

Ability to use delivery system correctly

Specific instructions are available for each type of device.^(712,713) On average more than two thirds of patients make at least one error in using an inhalational device.⁽⁷²⁶⁻⁷²⁹⁾ Observational studies in these patients show that, although the type and frequency of inhalation errors vary between devices depending on their characteristics, there is no device obviating the need to explain, demonstrate and regularly check inhalation technique.⁽⁷³⁰⁻⁷³⁶⁾ The main errors in delivery device use relate to problems with inspiratory flow, inhalation duration, coordination, dose preparation, exhalation maneuver prior to inhalation and breath-holding following dose inhalation.⁽⁷³⁷⁾

Patients' ability to use inhalers correctly is affected by their cognitive ability, manual dexterity and coordination skills, the inspiratory flow that they can achieve, the use of different types of device, and previous education on inhaler technique.^(727,738) Poor inhaler technique and errors using devices are more common with advancing age,⁽⁷³⁹⁾ but this is likely to be mainly due to cofounders such as cognitive impairment or reduced manual dexterity.^(740,741) pMDIs require sufficient hand strength to actuate the inhaler, and although BAIs are triggered by inhalation they still require priming which needs a degree of strength.⁽⁷⁴⁵⁾ Patients with poor dexterity may struggle to load a DPI, particularly if capsules require extraction from foil, insertion into the device or puncturing prior to administration.⁽⁷¹⁵⁾ Tremor may result in shaking of the device and loss of the dose.⁽⁷⁴²⁾

If there is any doubt that the patient will not be able to use a pMDI correctly they should be prescribed a VHC/spacer; however, these are not a panacea and there is evidence that fewer older patients using a pMDI and VHC find them easy to use compared to a pMDI alone.⁽⁷⁴³⁾ Currently available VHCs range in volume from < 50 to 750 mL⁽⁷⁴⁴⁾ but VHC with volumes from 150 to 250 mL have been shown to be as effective as those with larger volumes⁽⁷⁴⁵⁾ and are more portable. As well as reducing difficulties caused by poor co-ordination and inspiratory maneuvers with pMDIs, VHCs increase pulmonary and reduce oropharyngeal deposition, which is particularly important to minimize the risk of oropharyngeal candidiasis with corticosteroid containing pMDIs.⁽⁷¹²⁾

Leaflets included in device packages are insufficient to provide proper education of patients regarding inhaler use. Other strategies and tools including physical training and use of video or web-based education have proven effective to improve inhaler technique in some but not all patients on the short-term, but effects appear to wane over time.⁽⁷¹⁶⁾ Using the "teach-back" approach (patients being asked to show how the device has to be used) appears to be particularly effective.⁽⁷⁴⁶⁾ Pharmacist-, physician-, physiotherapist- and nurse-led interventions⁽⁷⁴⁷⁾ as well as lay health coaching⁽⁷⁴⁸⁾ can improve inhalation technique and adherence in COPD patients. As in asthma, digital inhalers could contribute to improved adherence and inhaler technique in patients with COPD.⁽⁷⁴⁹⁾

Choice of inhaler device

If a patient is currently taking inhaled therapy and able to use their current device correctly, new therapy is best prescribed in the same device. If a new device is required, either because the patient is not using their current device correctly or the drug is not available in the same device, a systematic iterative process should be used to select a delivery system and ensure the patient can use it.

The choice of an inhaler device depends on drug availability, characteristics of the device, the patient's abilities and preferences, and the knowledge of healthcare professionals caring for the patient about devices and their correct usage. The final choice should be made jointly by the prescriber and the patient using a shared decision-making approach. **Figure 3.11** summarises the main principles that should be considered to guide the individualized selection of the appropriate device for a given patient.

Basic Principles for Appropriate Inhalation Device Choice

Figure 3.11

- Availability of the drug in the device.
- Patients' beliefs, satisfaction with current and previous devices and preferences need to be assessed and considered.
- The number of different device types should be minimized for each patient.
- Device type should not be switched in the absence of clinical justification nor without proper information, education and medical follow-up.
- Shared decision-making is the most appropriate strategy for inhalation device choice.
- Patient's cognition, dexterity and strength must be taken into account.
- Patient's ability to perform the correct specific inhalation maneuver for the device must be assessed:
 - Dry powder inhalers are appropriate only if the patient can make a forceful and deep inhalation. Check visually that the patient can inhale forcefully through the device - if there is doubt assess objectively or choose alternative device.
 - Metered-dose inhalers and, to a lesser extent, soft mist inhalers require coordination between device triggering and inhalation and patients need to be able to perform a slow and deep inhalation. Check visually that the patient can inhale slowly and deeply from the device - if there is doubt consider adding a spacer/VHC or choose an alternative device.
 - For patients unable to use an MDI (with or without spacer/VHC), SMI or DPI a nebulizer should be considered.
- Other factors to consider include size, portability, cost.
- Smart inhalers may be useful if there are issues with adherence/persistence or inhalation technique (for devices that can check it).
- Physicians should prescribe only devices they (and the other members of the caring team) know how to use.

Appropriate education must be provided by health care professionals, including physical, video- or be-based demonstration of the proper technique and live verification that the patient masters this technique. It is crucial to check regularly (ideally, at each visit) that patients continue to use their device correctly. Lack of placebo devices within clinical areas is often a limitation and barrier to providing quality inhaler technique instruction to patients. Encouraging a patient to bring their own devices to clinic is a useful alternative.

NON-PHARMACOLOGICAL TREATMENT OF STABLE COPD

Non-pharmacological treatment is complementary to pharmacological treatment and should form part of the comprehensive management of COPD.

After receiving a diagnosis of COPD a patient should be given further information about the condition. Physicians should emphasize the importance of a smoke free environment, empower adherence to prescribed medication, ensure proper inhaler technique, promote physical activity, prescribe vaccinations, and refer patients to pulmonary rehabilitation.

Algorithms for the initiation and follow-up of non-pharmacological treatment

Some relevant non-pharmacological measures based on the patient's GOLD A, B, E group **AT DIAGNOSIS** are summarized in **Figure 3.12**.

Non-Pharmacological Management of COPD*			
Patient Group	Essential	Recommended	Depending on Local Guidelines
A	Smoking cessation (can include pharmacological treatment)	Physical activity	Influenza vaccination COVID-19 vaccinations Pneumococcal vaccination Pertussis vaccination Shingles vaccination RSV vaccination
B and E	Smoking cessation (can include pharmacological treatment) Pulmonary rehabilitation	Physical activity	Influenza vaccination COVID-19 vaccinations Pneumococcal vaccination Pertussis vaccination Shingles vaccination RSV vaccination

*Can include pharmacological treatment

Recommendations for **FOLLOW UP** non-pharmacological treatments are based on a patient's treatable traits e.g., symptoms and exacerbations (Figure 3.13).

Follow-up of Non-Pharmacological Treatment

Figure 3.13

1. If response to initial treatment is appropriate, maintain it and offer:

- Influenza vaccination every year and other recommended vaccinations according to guidelines
- Self-management education
- Assessment of behavioral risk factors such as smoking cessation (if applicable) and environmental exposures

Ensure

- Maintenance of exercise program and physical activity
- Adequate sleep and a healthy diet

2. If not, consider the predominant treatable trait to target

DYSPNEA

- Self-management education (written action plan) with integrated self-management regarding:
 - Breathlessness, energy conservation techniques, and stress management strategies
- Pulmonary rehabilitation (PR) program and/or maintenance exercise program post PR

EXACERBATIONS

- Self-management education (written action plan) that is personalized with respect to:
 - Avoidance of aggravating factors
 - How to monitor/manage worsening of symptoms
 - Contact information in the event of an exacerbation
- Pulmonary rehabilitation (PR) program and/or maintenance exercise program post PR

All patients with advanced COPD should be considered for end of life and palliative care support to optimize symptom control and allow patients and their families to make informed choices about future management.

Rehabilitation, Education & Self-Management

Pulmonary rehabilitation

Pulmonary rehabilitation is defined as “a comprehensive intervention based on thorough patient assessment followed by patient-tailored therapies that include, but are not limited to, exercise training, education, self-management intervention aiming at behavior change, designed to improve the physical and psychological condition of people with chronic respiratory disease and to promote the long-term adherence to health-enhancing behaviors.”^(750,751)

Patients with high symptom burden and risk of exacerbations (Groups B and E), should be encouraged to take part in a formal rehabilitation program that includes setting patient goals and is designed and delivered in a structured manner, taking into account the individual's COPD characteristics and comorbidities.^(750,752,753) This includes patients who are older, female, more deprived, or have a comorbidity of diabetes, asthma, or painful condition and currently appear less likely to be referred for pulmonary rehabilitation.⁽⁷⁵⁴⁾

Pulmonary rehabilitation should be considered as part of integrated patient management, and usually includes a range of healthcare professionals to ensure optimum coverage of the many aspects involved.⁽⁷⁵²⁾ Optimum benefits are achieved from programs lasting 6 to 8 weeks. Available evidence indicates that there are no additional benefits from extending pulmonary rehabilitation to 12 weeks.⁽⁷⁵³⁾ Supervised exercise training at least twice weekly is recommended, and this can include any regimen from endurance training, interval training, resistance/strength training; upper and lower limbs ideally should be included as well as walking exercise; flexibility, inspiratory muscle training and neuromuscular electrical stimulation can also be incorporated. In all cases the rehabilitation intervention (content, scope, frequency, and intensity) should be individualized to maximize personal functional gains.⁽⁷⁵⁵⁾ If a center based pulmonary rehabilitation program is complimented with a physical activity promotion program, clinically significant improvements in physical activity are observed.^(756,757) The importance of long-term behavior change to improve physical functionality, and reduce the psychological impact of COPD, should be emphasized to the patient.

Assessment and follow-up of pulmonary rehabilitation

Baseline and outcome assessments of each participant in a pulmonary rehabilitation program should be made to specify individual maladaptive behaviors (including motivation), physical and mental health impediments to training, goals, barriers and capabilities and to quantify gains and to target areas for improvement.

Assessments should include:

- ▶ Detailed history and physical examination
- ▶ Measurement of post-bronchodilator spirometry
- ▶ Assessment of exercise capacity
- ▶ Measurement of health status and impact of breathlessness
- ▶ Assessment of inspiratory and expiratory muscle strength and lower limb strength in patients who suffer from muscle wasting
- ▶ Discussion about individual patient goals and expectations

The first two assessments are important for establishing entry suitability and baseline status but are not used in outcome assessment.

Exercise tolerance can be assessed by cycle ergometry or treadmill exercise with the measurement of a number of physiological variables, including maximum oxygen consumption, maximum heart rate, and maximum work performed. Standardized self-paced, timed walking tests (e.g., 6-minute walking distance) are useful in clinical practice as they require minimal facilities and are relevant to routine functioning. Shuttle walking tests provide more complete information than an entirely self-paced test, and are simpler to perform than a treadmill test.⁽⁷⁵⁸⁾ Walking tests do require at least one practice session before data can be interpreted.

It is important not to limit assessment only to these outcome measures but gather information on each patient's ultimate goal (relevant or valued outcomes), such as their desired achievements in work, home and leisure by the end of the program.

Several detailed questionnaires for assessing health status are available, including some specifically designed for patients with respiratory disease. Health status can also be assessed by generic instruments, although these are less sensitive to change than the disease specific questionnaires such as the CAT™, CRQ or SGRQ. The *Hospital Anxiety and Depression Scale (HADS)*⁽⁷⁵⁹⁾ and the *Primary Care Evaluation of Mental Disorders (PRIME-MD) Patient Questionnaire*⁽⁷⁶⁰⁾ have been used to improve identification and treatment of anxious and depressed patients.

Education, self-management and integrative care

Patient “education” often takes the form of providers giving information and advice, and assumes that knowledge will lead to behavior change. Although enhancing patient knowledge is an important step towards behavior change, didactic group sessions are insufficient for promoting self-management skills. Topics such as smoking cessation, correct use of inhaler devices, early recognition of exacerbation, decision-making and taking action, and when to seek help, surgical interventions, considering advance directives, and others will be better dealt with using self-management interventions. Personalized education and training that considers specific issues relating to the individual patients, and that aims to enhance long-term functionality and appropriate health behaviors, is likely to benefit patients more. These are addressed under self-management.

Education

Patients may have individual and/or group education sessions. During group sessions, patients engage in active, participatory-based learning of program content. During one-on-one interactions, a motivational communication style should be used, as this approach empowers patients to take greater responsibility for their health and wellbeing, where physicians and other healthcare professionals only serve as guides in the behavior change process.

Topics considered appropriate for an education program include: smoking cessation; basic information about COPD; general approach to therapy and specific aspects of medical treatment (respiratory medications and inhalation devices); strategies to help minimize dyspnea; advice about when to seek help; decision-making during exacerbations; and advance directives and end-of-life issues. The intensity and content of these educational messages will vary depending on the severity of the patient’s disease, although the specific contributions of education to the improvements seen after pulmonary rehabilitation remain unclear.⁽⁷⁶¹⁾ Implicit in this description is the provision of “self-management support/coaching”, which refers to the strategies, techniques and skills used by healthcare providers to arm patients with the knowledge, confidence and skills required to self-manage their disease effectively. However, the individual patient’s evaluation and risk assessment with respect to exacerbations, patient’s needs, preferences, and personal goals should inform the personalized design of the self-management education plan.

Self-management

Self-management education and coaching by healthcare professionals should be a major component of the “Chronic Care Model” within the context of the healthcare delivery system.

The aim of self-management interventions is to motivate, engage and coach patients to positively adapt their health behavior(s) and develop skills to better manage their COPD on a day-to-day basis.⁽⁷⁶²⁾ Physicians and healthcare providers need to go beyond pure education/advice-giving (didactic) approaches to help patients learn and adopt sustainable self-management skills. The basis of enabling patients to become active partners in their ongoing care is to build knowledge and skills. It is important to recognize that patient education alone does not itself change behavior or even motivate patients, and it has had no impact on improving exercise performance or lung function,^(763,764) but it can play a role in improving skills, ability to cope with illness, and health status.⁽⁷⁵⁰⁾

Integrative care

COPD is a complex disease that requires the input of multiple care providers who need to work together closely. In principle, use of a formal structured program that determines how each component is delivered should make care more efficient and effective, but the evidence for this is divided.

Delivery of pulmonary rehabilitation, education & self-management: in-person versus virtual

The COVID-19 pandemic and resulting need for social distancing forced the healthcare system to implement remote solutions and telehealth to ensure delivery of appropriate care. However, the use and acceptance of telehealth solutions in the post-pandemic context is still being elucidated. To date the most studied telehealth modalities in COPD are pulmonary rehabilitation and self-management interventions.

Pulmonary rehabilitation has the highest quality studies in the COPD-telehealth field with well-defined and reported exercise training programs, and comparing telerehabilitation with usual care and/or center-based rehabilitation, which has been established as the gold-standard in a 2021 Cochrane review.⁽⁷⁶⁵⁾ A clinical practice guideline reported that telerehabilitation can achieve similar clinical outcomes as face-to-face, center-based pulmonary rehabilitation, and recommended that adults with stable chronic respiratory disease, particularly COPD, should be offered the choice of a center-based pulmonary rehabilitation or telerehabilitation (strong recommendation, moderate quality evidence).⁽⁷⁵¹⁾

Key to the delivery of an effective pulmonary rehabilitation program, with demonstrated proven benefits for COPD, is the inclusion of lower extremity endurance exercise training. For most people telerehabilitation still involves a face-to-face, center-based assessment to complete a comprehensive pre-rehabilitation evaluation. Telerehabilitation does create a means to provide pulmonary rehabilitation services and, like center-based rehabilitation, it requires appropriately trained staff and adequate infrastructure. However, considering issues such as lack of trained medical personnel, and the appeal of technology, there is a need to ensure that telehealth pulmonary rehabilitation is not misused.

A 2022 Cochrane review reported that a self-management intervention both improved quality of life and reduced hospital admissions.⁽⁷⁶⁶⁾ Tele-education and self-management using information communication technology could have the potential to ease the working life of health practitioners and transform the way patients are monitored, and healthcare is delivered.

Despite the many advances in self-management, delivering self-management at distance using digital technology still raises many unanswered questions and important limitations. No studies to date have been designed to demonstrate whether there is any additional benefit of telehealth-supported self-management compared to self-management interventions not using information communication technologies.⁽⁷⁶⁷⁾

Oxygen therapy and ventilatory support

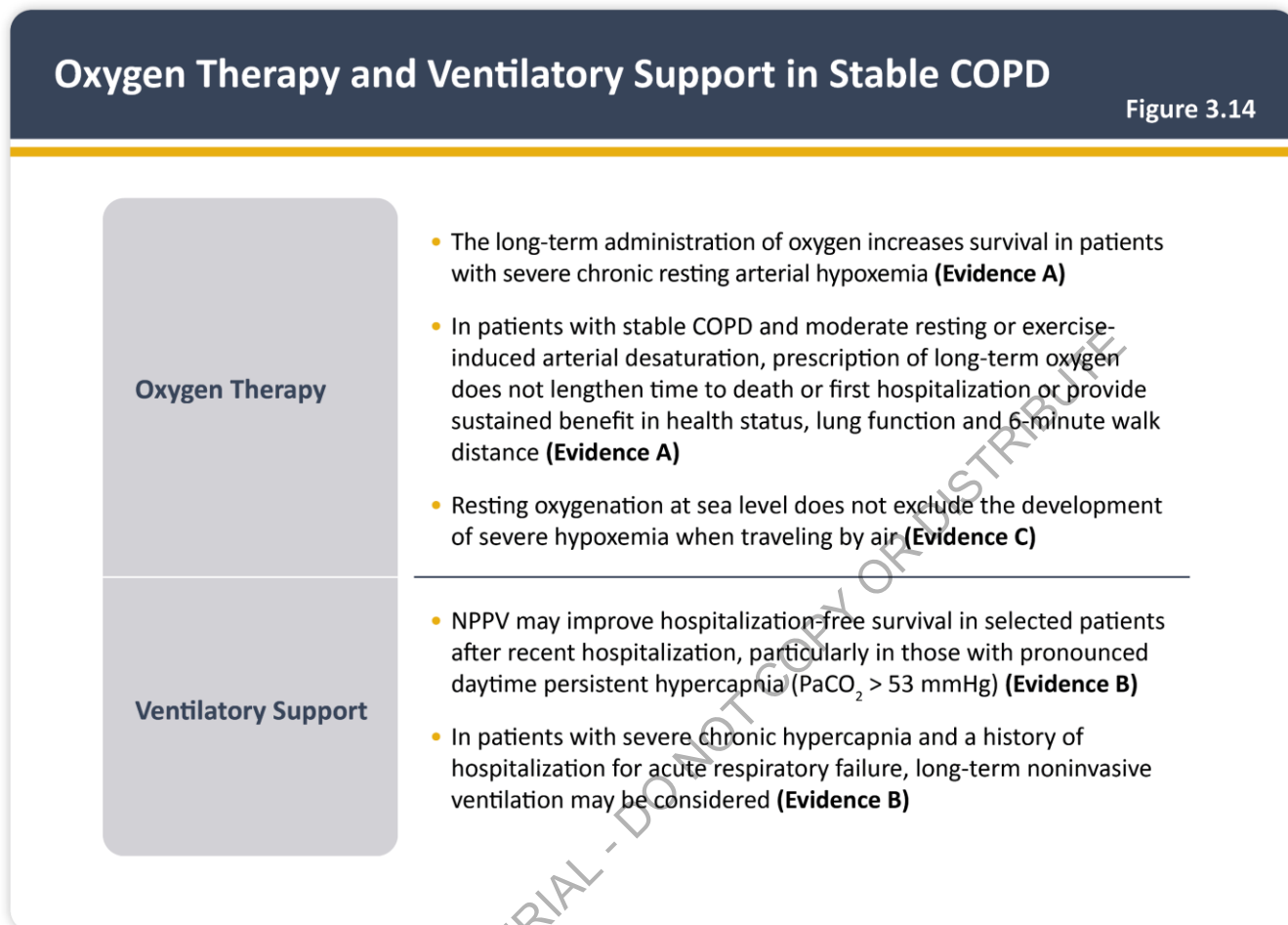
Oxygen therapy

The long-term administration of oxygen (> 15 hours per day) to patients with chronic respiratory failure has been shown to increase survival in patients with severe resting hypoxemia.⁽⁷⁶⁸⁾

Ekström and colleagues⁽⁷⁶⁹⁾ reported that among patients with severe hypoxemia agreeing to participate in a study, long-term oxygen therapy used for 24 hours per day did not result in a lower risk of hospitalization or death within one year compared to therapy for 15 hours per day, but the generalizability of this finding is unclear.

Long-term oxygen therapy does not lengthen time to death or first hospitalization or provide sustained benefit for any of the measured outcomes in patients with stable COPD and resting or exercise-induced moderate arterial oxygen

desaturation.⁽⁷⁷⁰⁾ Breathlessness may be relieved in COPD patients who are either mildly hypoxemic, or non-hypoxemic but do not otherwise qualify for home oxygen therapy, when oxygen is given during exercise training; however, studies have shown no improvement of breathlessness in daily life and no benefit on health-related quality of life (**Figure 3.14**).⁽⁷⁷⁰⁻⁷⁷²⁾ There are contradictory studies although the majority do not demonstrate changes.⁽⁷⁷³⁾



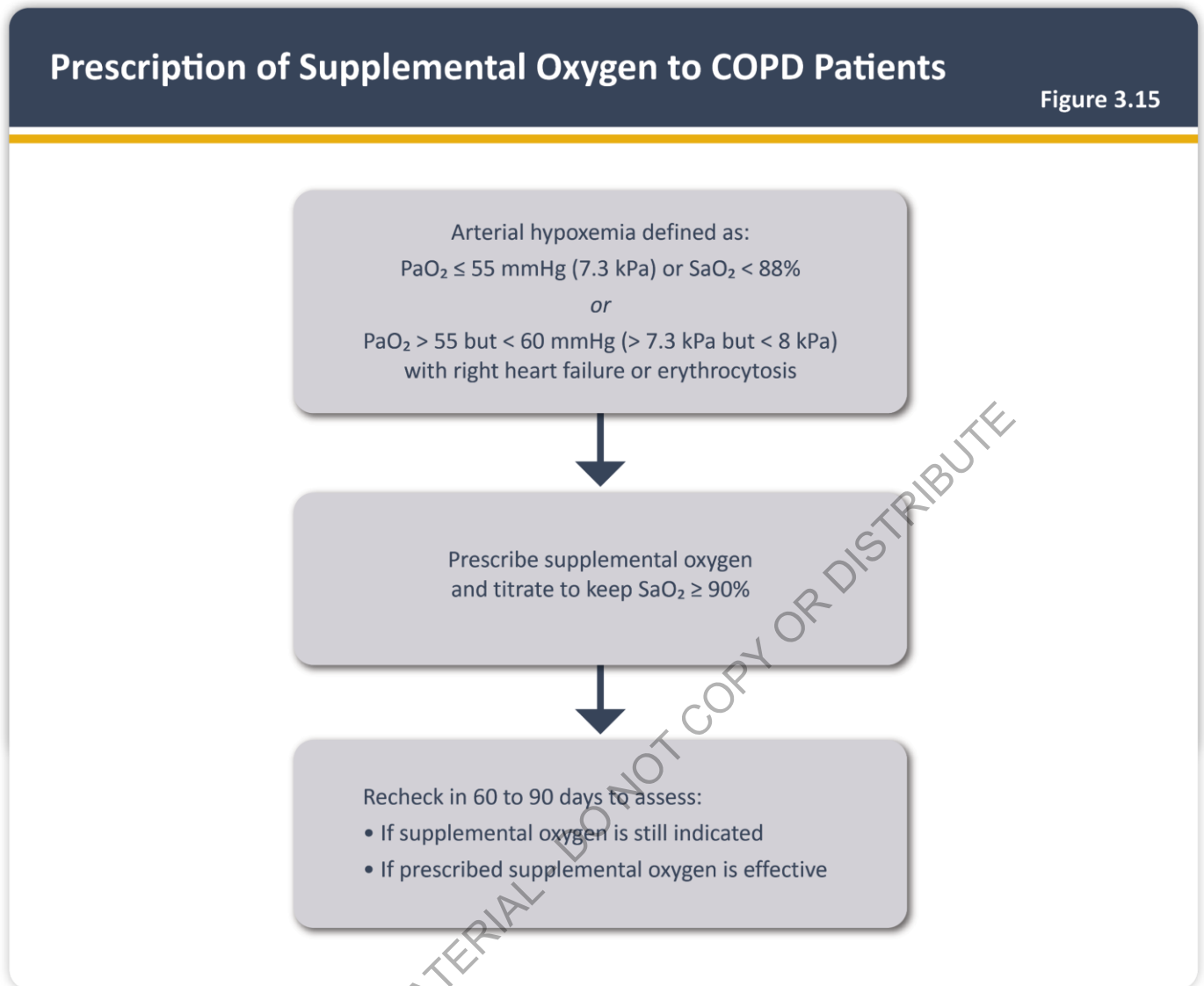
Although air travel is safe for most patients with chronic respiratory failure who are on long-term oxygen therapy,⁽⁷⁷⁴⁾ patients should ideally maintain an in-flight PaO_2 of at least 6.7 kPa (50 mmHg). Studies indicate that this can be achieved in those with moderate to severe hypoxemia at sea level by supplementary oxygen at 3 liters/min by nasal cannula or 31% by Venturi facemask.⁽⁷⁷⁵⁾ Those with a resting oxygen saturation $> 95\%$ and 6-minute walk oxygen saturation $> 84\%$ may travel without further assessment,⁽⁷⁷⁶⁾ although it is important to emphasize that resting oxygenation at sea level does not exclude the development of severe hypoxemia when travelling by air.⁽⁷⁷⁴⁾ Careful consideration should be given to any comorbidity that may impair oxygen delivery to tissues (e.g., cardiac impairment, anemia). Also, walking along the aisle may profoundly aggravate hypoxemia.⁽⁷⁷⁷⁾

Long-term oxygen therapy (LTOT) is indicated for stable patients who have:

- ▶ PaO_2 at or below 55 mmHg (7.3 kPa) or SaO_2 at or below 88%, with or without hypercapnia confirmed twice over a three-week period; or
- ▶ PaO_2 between 55 mmHg (7.3 kPa) and 60 mmHg (8.0 kPa), or SaO_2 of 88%, if there is evidence of pulmonary hypertension, peripheral edema suggesting congestive cardiac failure, or polycythemia (hematocrit $> 55\%$).

Once placed on LTOT the patient should be re-evaluated after 60 to 90 days with repeat arterial blood gas (ABG) or oxygen saturation measurements while inspiring room air and the level of oxygen flow that had been prescribed to determine if oxygen is still indicated and if so, therapeutic. An appropriate algorithm for the prescription of oxygen to

COPD patients is shown in **Figure 3.15**.



Ventilatory support

Noninvasive ventilation (NIV) is occasionally used in patients with stable very severe COPD.⁽⁷⁷⁸⁾ NIV may be considered of some use in a selected group of patients, particularly in those with pronounced daytime hypercapnia and recent hospitalization, although a systematic review was unable to support or refute this.⁽⁷⁷⁹⁾ In contrast, in patients with both COPD and obstructive sleep apnea there are clear indications for continuous positive airway pressure (CPAP).^(780,781)

During exacerbations of COPD

NIV in the form of noninvasive positive pressure ventilation (NPPV) is the standard of care for decreasing morbidity and mortality in patients hospitalized with an exacerbation of COPD and acute respiratory failure⁽⁷⁸²⁻⁷⁸⁵⁾ (see also **Chapter 4**).

Stable patient

In patients with both COPD and obstructive sleep apnea there are clear benefits associated with the use of continuous positive airway pressure (CPAP) to improve both survival and the risk of hospital admissions.^(780,781)

Whether to use NPPV chronically at home to treat patients with acute on chronic respiratory failure following

hospitalization remains undetermined and outcome may be affected by persistent hypercapnia.⁽⁷⁸⁶⁾ A multicenter prospective RCT of COPD patients with persistent hypercapnia (PaCO₂ > 53 mmHg) after 2-4 weeks of hospital discharge because an acute episode of exacerbation, compared the effects of home NIV plus oxygen compared to home oxygen alone on time to readmission or death.⁽⁷⁸⁶⁾ Results showed that adding home NIV to oxygen therapy significantly prolonged the time to readmission or death within 12 months.⁽⁷⁸⁶⁾ A systematic review and meta-analysis of these studies confirms that NIV decreases mortality and risk of hospitalization. The best candidate subgroups (by recent hospitalization history or PaCO₂) remain unclear.⁽⁷⁸⁵⁾

Two previous retrospective studies^(787,788) and two of three RCTs^(786,789-792) reported reductions in re-hospitalization and improved survival with using NPPV post-hospitalization. Two studies reported decreases in mortality and hospitalization rates while another showed no benefit of NPPV for survival.⁽⁷⁹⁰⁾ Several factors may account for discrepancies: differences in patient selection, underpowered studies, NPPV settings incapable of achieving adequate ventilation, and poor adherence with NPPV therapy.⁽⁷⁹³⁾ NPPV when indicated should be instituted and monitored under the direction of personnel familiar with the process and the devices utilized.^(794,795)

A meta-analysis suggested that in patients with chronic hypercapnic respiratory failure long-term treatment with HFNC may reduce acute exacerbations and improve SGRQ scores compared to standard care, but its effect on mortality and hospitalizations is uncertain.^(796,797)

MONITORING AND FOLLOW-UP

Routine follow-up of COPD patients is essential. Lung function may worsen over time, even with the best available care. Symptoms, exacerbations and objective measures of airflow obstruction should be monitored to determine when to modify management and to identify any complications and/or comorbidities that may develop.

Symptoms

At each visit, information on symptoms since the last visit should be collected, including cough and sputum, breathlessness, fatigue, activity limitation, and sleep disturbances, including insomnia. Questionnaires such as the COPD Assessment Test (CAT™)⁽⁴⁷⁶⁾ can be used; trends and changes are more valuable than single measurements.

Exacerbations

The frequency, severity, type and likely causes of all exacerbations⁽⁷⁹⁸⁾ should be monitored. Sputum volume and presence or absence of sputum purulence should be noted. Specific inquiry into response to previous treatment, unscheduled visits to providers, telephone calls for assistance, and use of urgent or emergency care facilities is important. Hospitalizations should be documented, including the facility, duration of stay, and any use of critical care or mechanical ventilatory support.

Adherence and appropriate use of prescribed treatments

This is a key action in the chronic management of COPD patients that should be mandatory in each clinical visit. The following aspects need careful and personalized attention:

- ▶ Dosages of prescribed medications
- ▶ Adherence to the regimen
- ▶ Inhaler technique
- ▶ Effectiveness of the current regime
- ▶ Side effects

Treatment modifications should be recommended (**Figure 3.7**).

Smoking status

At each visit, the current smoking status and smoke exposure should be determined followed by appropriate action.

Measurements

Decline in FEV1 can be tracked by spirometry performed at regular intervals (e.g., yearly) to identify patients who are declining quickly, although other lung function parameters reflecting hyperinflation and gas transfer may also be informative.

A timed walking test (6-minute walking distance or shuttle-walking test) provides additional information regarding prognosis.^(799,800) Measurement of oxygenation at rest in an arterial blood gas sample may help identify patients who will benefit from supplemental oxygen to improve both symptoms and survival in those with severe resting hypoxemia.

Imaging

If there is a clear worsening of symptoms, imaging may be indicated. When exacerbations are repeatedly characterized by purulent sputum, patients should be investigated for bronchiectasis.

Comorbidities

Symptoms that may indicate the development or worsening of a comorbid condition such as lung cancer, obstructive sleep apnea, congestive heart failure, ischemic heart disease, osteoporosis or depression/anxiety etc. should be recorded. If present, an appropriate diagnostic work-up should follow (see also **Chapter 5**).

Telehealth, remote monitoring and follow-up

The COVID-19 pandemic has dramatically changed how outpatient care is delivered in health care practices. Telehealth may offer a bridge to care, and now offers a chance to consider virtual and hybrid virtual/in-person care models, with a goal of improved healthcare access, outcomes, and affordability.⁽⁸⁰¹⁾ However, incorporation of virtual care into ambulatory care should be based on evidence.

From a recent Cochrane review⁽⁸⁰²⁾ on telehealth for remote monitoring and consultations for patients with COPD, different models have been reviewed based on RCTs:

- ▶ Remote monitoring (linked to a healthcare professional) plus usual care versus usual care alone (as reported by trialists).
- ▶ Remote consultation (e.g., real-time contact with a health professional) plus usual care versus usual care alone (e.g., face-to-face visit for a check-up in a health service with a health professional, or as reported by trialists).
- ▶ Remote monitoring or remote consultation versus usual care (e.g., where tele healthcare has replaced an element of usual face-to-face care).

For most of the studies included in the review (24 RCTs) remote monitoring interventions required participants to transfer measurements using a remote device for subsequent health professional review (asynchronous) as opposed to only 5 RCTs that transferred data and allowed review by health professionals in real time (synchronous).⁽⁸⁰²⁾ The results of this systematic review demonstrate the paucity of evidence of superiority of these models compared to usual care, i.e., exacerbations, hospitalization, health status and mortality. While there was no evidence of harm, it is still unclear which COPD severity subgroups would benefit, or possibly be harmed, by telehealth interventions. Telehealth interventions may be beneficial as an additional health resource based on professional assessment, and

depending on individual needs, although the long-term effects remain unknown.

Information is provided below on how i) to prepare for the remote visit; ii) to set up the visit agenda with the patient; and a standardized checklist is provided for follow-up of COPD patients, whether in-person, by phone or in a virtual/online setting, in **Appendix 1** at the end of the GOLD report.

The principles of good record keeping and clinical practice should always apply: i) treat patients with dignity; ii) respect people's right to privacy and confidentiality; iii) listen to the patient's needs and act in their best interest; and iv) base your recommendations on the best available evidence.

Triage and prioritizing process

The process of triage should help decide: i) whether to offer an in-person as opposed to a remote (telephone or virtual/online) consultation, and ii) who to prioritize.

Remote follow-up could be considered in the following situations:

- Patient or caregiver can understand the process and provide information clearly;
- Regular COPD follow-up or patient followed for a known condition;
- Medical records and laboratory test results are accessible to the healthcare professionals;
- Prescription and access to medication is possible and follow-up to the prescription can be arranged if necessary.

In-person follow-up should be prioritized in these situations:

- Patient and caregiver have difficulty providing information;
- Patient needs immediate attention due to the presence of severe medical symptoms;
- Changes in patient's symptoms require a differential diagnosis work-up with the need for a physical exam and/or laboratory testing;
- Patient treatment can only be given in person and cannot be given at home.

Prioritization of in-person visits should take into consideration the COPD patient disease severity (symptom burden and risk of exacerbations), recent emergency department visit and/or hospital admission, associated significant comorbidities, age, and/or living alone at home.

Consideration and instruction for remote COPD follow-up

Ensure documentation of the whole visit (in writing) as you would normally do for an in-person follow-up. The documentation should reflect that this is a remote follow-up (telephone or virtual/online) and should be specific about how the information was obtained.

1. Start the call by
 - a. Introducing yourself and, if necessary, any other health care professional(s) who may be with you (e.g., case manager, student, resident, etc.);
 - b. Verifying who you are speaking with (patient name and date of birth), and patient consent to receive remote follow-up;
 - c. If applicable, informing patient that the speakerphone is on;
2. Welcome the patient to the call
 - a. Verify technical issues;
 - b. Ask the patient if (s)he can hear you well;

- c. Describe what to do if the connection fails;
3. Explain that this is a remote visit and give the reason why;
4. **Check if there are others listening** to the conversation, and if patient consents to all those present;
5. **Set the agenda** (agree on elements to be discussed, time allotted, etc.);
6. **Conduct the follow-up visit** using the instructions below in the COPD Follow-up Checklist and remember to keep the focus on the main issues raised by the patient;
7. End and summarize the visit
 - a. Ask the patient to summarize what the discussion and main issues have been, reinforce any action plan or intervention you have agreed upon (if any homework);
 - b. Set up a date for follow-up;
 - c. Agree upon ending the meeting.

SUPPORTIVE, PALLIATIVE, END-OF-LIFE & HOSPICE CARE

Symptom control and palliative care

Palliative care is a broad term that encompasses approaches to symptom control as well as management of terminal patients close to death. The goal of palliative care is to prevent and relieve suffering, and to support the best possible quality of life for patients and their families, regardless of the stage of disease or the need for other therapies.⁽⁸⁰³⁾ COPD is a highly symptomatic disease and has many elements such as fatigue, dyspnea, depression, anxiety, insomnia that require symptom-based palliative treatments. There is evidence that people with COPD are less likely to receive such services compared to patients with lung cancer.^(804,805) Palliative care expands traditional disease-model medical treatment to increase the focus on the goals of enhancing quality of life, optimizing function, helping with decision-making about end-of-life care, and providing emotional and spiritual support to patients and their families.⁽⁸⁰³⁾ Palliative approaches are essential in the context of end-of-life care as well as hospice care (a model for delivery of end-of-life care for patients who are terminally ill and predicted to have less than 6 months to live). Increasingly, palliative care teams are available for consultation for hospitalized patients.⁽⁸⁰⁶⁾ Availability for outpatient palliative care consultation is less common, and has been shown to improve quality of life, reduce symptoms and even prolong survival for patients with advanced lung cancer.⁽⁸⁰⁵⁾ Key points for palliative, end-of-life and hospice care in COPD are summarized in **Figure 3.16**.

- All clinicians managing patients with COPD should be aware of the effectiveness of palliative approaches to symptom control and use these in their practice **(Evidence D)**
- End of life care should include discussions with patients and their families about their views on resuscitation, advance directives and place of death preferences **(Evidence D)**
- Opiates, neuromuscular electrical stimulation (NMES), oxygen and fans blowing air onto the face can relieve breathlessness **(Evidence C)**
- Nutritional supplementation should be considered in malnourished patients with COPD **(Evidence B)** as it may improve respiratory muscle strength and overall health status **(Evidence B)**
- Fatigue can be improved by self-management education, pulmonary rehabilitation, nutritional support and mind-body interventions **(Evidence B)**

Therapy relevant to all people with COPD

Even when receiving optimal medical therapy many people with COPD continue to experience distressing breathlessness, impaired exercise capacity, fatigue, and suffer panic, anxiety and depression.⁽⁸⁰⁷⁾ Some of these symptoms can be improved by wider use of palliative therapies that in the past have often been restricted to end-of-life situations.

Palliative treatment of dyspnea

Relieving dyspnea during daily life activities to limit disability, improve quality of life, and reduce medical resource use is a major goal of COPD care. Multiple therapeutic approaches can be considered to target the variety of involved mechanisms; they are dominated by inhaled bronchodilators, self-management education (where patients learn breathing techniques) and pulmonary rehabilitation that includes exercise training. The roles of oxygen therapy, high-flow nasal therapy (HFNT) and non-invasive ventilation (NIV) for palliation of dyspnea are debated.⁽⁸⁰⁸⁾

Opiates,⁽⁸⁰⁹⁻⁸¹¹⁾ neuromuscular electrical stimulation (NMES),^(811.812) chest wall vibration (CWV)⁽⁸¹¹⁾ and fans blowing air onto the face^(811.813.814) can relieve breathlessness. Morphine may improve health status in COPD patients⁽³⁴³⁾ and no worsening in sleepiness was reported in one study when used for breathlessness in COPD.⁽⁸¹⁵⁾ Immediate-release morphine extended exercise endurance time in over half of the patients with advanced COPD in one study.⁽³⁴³⁾ However, in another RCT oral extended-release morphine (8 mg/day or 16 mg/day for one week) did not improve dyspnea compared with placebo in patients with mMRC breathlessness scale scores of 3 or 4.⁽⁸¹⁶⁾ Further research is required to determine what patient characteristics predict response to opioid therapy,⁽⁸¹⁷⁾ however one cross-sectional study found greater benefit in those with worse baseline dyspnea and higher BMI.⁽⁸¹⁸⁾ The optimal formulation and administration route remain under discussion.^(811.819)

Oxygen may offer some benefit even if the patient is not hypoxemic ($SpO_2 > 92\%$) **(Figure 3.14)**.⁽⁸²⁰⁾ Pulmonary rehabilitation is effective and in severe cases NIV can also reduce daytime breathlessness. Acupuncture and acupressure are other non-pharmacological approaches in patients with advanced COPD that may improve breathlessness and quality of life.^(448.821) Refractory dyspnea may be more effectively managed with a multidisciplinary integrated palliative and respiratory care service.⁽⁸²²⁾

There is no evidence for a beneficial effect of benzodiazepines⁽⁸²³⁾ and there is not enough data to recommend distractive auditory stimuli (music), relaxation, counseling and support, with or without breathing relaxation training, or psychotherapy.⁽⁸²⁴⁾

Nutritional support

Low BMI and particularly low fat-free mass is associated with worse outcomes in people with COPD.⁽⁸²⁵⁾ In malnourished people with COPD, nutritional supplementation promotes significant weight gain and leads to significant improvements in respiratory muscle strength and overall health-related quality of life.⁽⁸²⁶⁾ Nutritional antioxidant supplementation (vitamin C and E, zinc, and selenium) has been shown to improve antioxidant deficits, quadriceps strength, and serum total protein, without further improvement in quadriceps endurance. Only in malnourished patients has nutritional supplementation demonstrated significant improvements for 6-minute walk test, respiratory muscle strength and health status.⁽⁸²⁷⁾ A 12-month nutritional intervention in muscle wasted patients had no effect on physical capacity but physical activity was significantly higher.⁽⁸²⁸⁾

Panic, anxiety & depression

The causes of depression and anxiety symptoms in people with COPD are multifactorial and include behavioral, social and biological factors.⁽⁸²⁹⁾ Pulmonary rehabilitation may help reduce anxiety symptoms. The efficacy of antidepressants in people with COPD has been inconclusive, possibly as a result of methodological issues in the published trials. Cognitive behavioral therapy and mind-body interventions (e.g., mindfulness-based therapy, yoga, and relaxation) can reduce anxiety and depression; mind-body interventions also improve physical outcomes such as lung function, dyspnea, exercise capacity and fatigue in people with COPD and psychological problems.⁽⁸³⁰⁾

Fatigue

Fatigue in people with COPD can be improved by self-management education, pulmonary rehabilitation, nutritional support and mind-body interventions.⁽⁸³¹⁾

End-of-life and hospice care

In many patients, the disease trajectory in COPD is marked by a gradual decline in health status and increasing symptoms, punctuated by acute exacerbations that are associated with an increased risk of dying.⁽⁸³²⁾ Although mortality rates following hospitalization for an acute exacerbation of COPD are declining,⁽⁸³³⁾ reported rates still vary from 23%⁽⁸³⁴⁾ to 80%.⁽⁸³⁵⁾ Progressive respiratory failure, cardiovascular diseases, malignancies and other diseases are the primary cause of death in people with COPD hospitalized for an exacerbation.⁽⁸³⁵⁾ In qualitative studies, as well as describing the high symptom burden, people with COPD and their families describe a need for a better understanding of their condition and the psychological impact of living and dying with COPD.⁽⁸³⁶⁾ Palliative care is a broad term that includes approaches to symptom control as well as management of terminal patients close to death. Palliative care, end-of-life care, and hospice care are important components of the care of patients with advanced COPD.

End-of-life care should also include discussions with patients and their families about their views on resuscitation, advance directives and place of death preferences.⁽⁸³⁷⁾ At an individual level, prediction of 6-month survival in people with COPD is unreliable and therefore early discussion of these issues is important together with phased introduction of supportive care.⁽⁸³⁸⁾ Hospitalization may be a trigger to initiate discussion of advance care planning. Patients and their families live with uncertainty about the timing of death and fear of death will result from worsening dyspnea and suffocation.⁽⁸³⁹⁾ Good advance care planning can reduce anxiety for patients and their families by talking about death and dying and offering emotional support. It can also ensure that care is consistent with their wishes and avoids unnecessary, unwanted and costly invasive approaches.^(840,841)

For patients with very advanced or terminal illness, hospice services may provide additional benefit. Hospice services

often focus on patients with severe disability or symptom burden and may provide these services within the patient's home or in hospice beds in dedicated hospice units or other institutions such as hospitals or nursing homes. Organizations such as the National Hospice and Palliative Care Organization⁽⁸⁴²⁾ provide guidance for selecting patients with non-cancer diseases like COPD for access to hospice services (for example, disabling dyspnea at rest that is poorly responsive to bronchodilators and progression of advanced disease demonstrated by increasing hospitalizations or emergency department visits).^(804,805) These guidelines discuss the difficulties in accurately predicting the prognosis of patients with advanced COPD, but recognize the appropriateness of providing hospice services for some of these patients.⁽⁸⁰³⁾

Therapeutic interventions that reduce COPD mortality

COPD is the third leading cause of death worldwide, causing 3.23 million deaths in 2019. As we move towards targeting subgroups of COPD patients for specific therapy, it is important to know which modifiable factors (treatable traits) are associated with mortality. A large clinical database study of COPD in primary care has demonstrated that the highest magnitude of risk of all-cause mortality, COPD- and CVD-related mortality, was in individuals with increased severity and frequency of COPD exacerbations, GOLD groups B and D, and those with lower FEV1 (particularly GOLD 3 and 4).⁽⁸⁴³⁾ We are still learning about the mechanisms that cause death in patients with COPD. Demonstrating benefits of therapeutic modalities on mortality in RCTs has been difficult, requiring large populations and/or long follow-up duration and/or highly selected populations with a high but preventable risk of death during follow-up. In addition, the low number of events makes the analysis of disease specific mortality (e.g., respiratory or cardiovascular) in most trials difficult. **Figure 3.17** presents a summary of pharmacological and non-pharmacological therapies with evidence of efficacy in reducing the mortality of COPD patients.

Pharmacological therapy

Previous studies such as the TORCH clinical trial⁽⁸⁴⁴⁾ and the SUMMIT trial⁽⁸⁴⁵⁾ failed to provide evidence for the efficacy of a LABA+ICS combination compared to placebo in reducing mortality (primary outcome) in COPD patients. These trials had no requirement for a history of previous exacerbations. In the largest LAMA treatment trial UPLIFT, the intention to treat analysis, i.e., 30 days after completion of the study period, did not demonstrate a reduction in mortality (secondary outcome) compared to placebo. The majority of patients included in this study utilized an ICS.

Evidence has emerged from two large randomized clinical trials, IMPACT⁽⁴⁹⁶⁾ and ETHOS,⁽⁶⁹⁹⁾ that fixed-dose inhaled triple combinations (LABA+LAMA+ICS), reduce all-cause mortality compared to dual inhaled long-acting bronchodilation therapy. Together these results suggest a beneficial effect of fixed-dose triple inhaled therapy versus fixed-dose LABA+LAMA combinations on mortality in symptomatic COPD patients with a history of frequent and/or severe exacerbations who were previously receiving maintenance therapy with triple therapy, LABA+ICS or single or dual long-acting bronchodilators. These trials were enriched for symptomatic patients (CAT ≥ 10) with a history of frequent (≥ 2 moderate exacerbations) and/or severe exacerbations (≥ 1 exacerbation requiring a hospital admission) (**Figure 3.17**).

Evidence Supporting a Reduction in Mortality with Pharmacotherapy and Non-pharmacotherapy in COPD Patients

Figure 3.17

Therapy	RCT*	Treatment effect on mortality	Patient characteristics
Pharmacotherapy			
LABA+LAMA+ICS ¹	Yes	Single inhaler triple therapy compared to dual LABD therapy relative risk reduction: IMPACT: HR 0.72 (95% CI: 0.53, 0.99) ^{1a} ETHOS: HR 0.51 (95% CI: 0.33, 0.80) ^{1b}	Symptomatic people with a history of frequent and/or severe exacerbations
Non-pharmacological Therapy			
Smoking cessation ²	Yes	HR for usual care group compared to intervention group (smoking cessation) HR 1.18 (95% CI: 1.02, 1.37) ²	Asymptomatic or mildly symptomatic
Pulmonary rehabilitation ^{3#}	Yes	Old trials: RR 0.28 (95% CI 0.10, 0.84) ^{3a} New trials: RR 0.68 (95% CI 0.28, 1.67) ^{3b}	Hospitalized for exacerbations of COPD (during or ≤ 4 weeks after discharge)
Long-term oxygen therapy ⁴	Yes	NOTT: ≥ 19 hours of continuous oxygen vs ≤ 13 hours: 50% reduction ^{4a} MRC: ≥ 15 hours vs no oxygen: 50% reduction ^{4b}	PaO ₂ ≤ 55 mmHg or < 60 mmHg with <i>cor pulmonale</i> or secondary polycythemia
Noninvasive positive pressure ventilation ⁵	Yes	12% in NPPV (high IPAP level) and 33% in control HR 0.24 (95% CI 0.11, 0.49) ⁵	Stable COPD with marked hypercapnia
Lung volume reduction surgery ⁶	Yes	0.07 deaths/person-year (LVRS) vs 0.15 deaths/person-year (UC) RR for death 0.47 (p = 0.005) ⁶	Upper lobe emphysema and low exercise capacity

*RCT with pre-specified analysis of the mortality outcome (primary or secondary outcome); #Inconclusive results likely due to differences in pulmonary rehabilitation across a wide range of participants and settings.

1. a) IMPACT trial (Lipson et al. 2020) and b) ETHOS trials (Martinez et al. 2021); 2. Lung Health Study (Anthonisen et al. 2005); 3. a) Puhan et al. (2011) and b) Puhan et al. 2016; 4. a) NOTT (NOTT, 1980) and b) MRC (MRC, 1981); 5. Kohlein trial (Kohlein et al. 2014); 6. NETT trial (Fishman et al. 2003)

ICS: inhaled corticosteroid; IPAP: inspiratory positive airway pressure; LABA: long-acting beta-agonist; LABD: long-acting bronchodilator; LAMA: long-acting anti-muscarinic; LTOT: long-term oxygen therapy; NPPV: noninvasive positive pressure ventilation; LVRS: lung volume reduction surgery; UC: usual treatment control group.

Non-pharmacological therapy

Smoking cessation. From the Lung Health Study, a randomized clinical trial (RCT) that included asymptomatic or mildly symptomatic COPD patients treated with a 10-week smoking cessation intervention program and followed up to 14.5 years, the overall mortality rate was reduced in the smoking cessation intervention group compared to the usual care group.⁽⁸⁴⁶⁾

Pulmonary rehabilitation (PR). A systematic review of RCTs reported a reduction in mortality for patients who had PR initiated during hospitalization or 4 weeks after discharge compared to those who did not have PR.⁽⁸⁴⁷⁻⁸⁵⁰⁾ These results have been corroborated by real-world evidence, from a large population-based cohort of 190,000 patients hospitalized for COPD, in whom initiation of PR within 90 days of discharge, while rare, was associated with a statistically significant reduced mortality.⁽⁸⁵¹⁾

Long term oxygen therapy (LTOT). Survival benefit of LTOT in COPD demonstrated in two studies in the early 1980s laid the foundation for long-term domiciliary management of hypoxemia. The Nocturnal Oxygen Therapy Trial (NOTT)(≥ 19 hours of continuous oxygen compared to ≤ 13 hours)⁽⁸⁵²⁾ and the Medical Research Council (MRC)(≥ 15

hours compared to no oxygen),⁽⁸⁵³⁾ two RCTs in COPD patients with resting PaO₂ ≤ 55 mmHg or < 60 mmHg with *cor pulmonale* or secondary polycythemia showed a survival benefit. No significant benefit of LTOT was found in patients with moderate desaturation.⁽⁸⁵⁴⁾

Non-invasive positive pressure ventilation (NPPV). Recent meta-analyses^(785,855) have shown positive results of long-term NPPV in patients with stable COPD. Although RCT results have been inconsistent on survival, larger trials with mortality as the primary outcome, enrolling patients with marked hypercapnia and applying higher IPAP levels demonstrated a reduction of mortality.^(790,856)

Lung transplantation and lung volume reduction surgery (LVRS). Because of the absence of randomized trials, observational data has been used to estimate the survival benefit of lung transplantation, relative to remaining “untransplanted.” The survival benefit of transplantation varied by disease group, with a 2-year expected benefit in 2/5 of transplanted COPD patients.⁽⁸⁵⁷⁾

LVRS has been shown to prolong survival compared to medical therapy in a very select group of patients with severe COPD, predominantly upper lobe emphysema, and low exercise capacity post-rehabilitation.⁽³¹³⁾ Among patients with non-upper-lobe emphysema and high exercise capacity post-rehabilitation, mortality was higher in the surgery group than in the medical-therapy group.

In summary, available data suggest that several pharmacological and non-pharmacological treatments may reduce mortality. Further analyses or studies may help to determine whether specific patient subgroups demonstrate a greater survival benefit.

Overview of the evidence: Pharmacotherapy

Pharmacotherapies for smoking cessation

Pharmacological treatments for smoking cessation include controller medications aimed at achieving long-term abstinence (nicotine patch, bupropion, and varenicline) and those that rapidly relieve acute withdrawal symptoms (short-acting nicotine).

Nicotine replacement products

Nicotine replacement therapy (nicotine gum, inhaler, nasal spray, transdermal patch, sublingual tablet, or lozenge) reliably increases long-term smoking abstinence rates^(598,600,602,858,859) and is significantly more effective than placebo. Nicotine replacement therapy often causes irritation at the site through which it is administered, and can cause non-ischemic chest pain and palpitations, therefore medical contraindications to nicotine replacement therapy include recent myocardial infarction or stroke.^(602,860,861) The contraindication to nicotine replacement therapy after acute coronary syndrome remains unclear and the evidence suggests that this treatment can and should be started > 2 weeks after a cardiovascular event.⁽⁸⁶²⁾ Continuous chewing of nicotine gum produces secretions that are swallowed rather than absorbed through the buccal mucosa resulting in little absorption and potentially causing nausea.

Vaping/E-cigarettes

There is a perception that vaping with electronic cigarettes (e-cigarettes, vapes) is safer than smoking and therefore an effective nicotine replacement therapy for smoking cessation. The efficacy of vaping with regard to smoking cessation remains controversial.⁽⁸⁶³⁻⁸⁶⁷⁾ E-cigarettes provide a vaporized and doseable method of nicotine inhalation and have increased in usage as an alternative to cigarettes for those wishing to quit, but also as a rising trend in younger individuals who have never smoked. E-cigarettes may contain not only nicotine but also other chemicals, such

as vegetable glycine, propylene glycol, various flavoring agents, volatile carbonyls, diacetyl, reactive oxygen species, furones and metals. The long-term health effects in general smokers, but more importantly in high-risk populations such as COPD, are largely unknown.

What is known has been reported mainly as individual, or series of, case reports of the acute effects of e-cigarettes, including vaping-associated lung injury. Severe acute lung injury, eosinophilic pneumonia, alveolar hemorrhage, respiratory bronchiolitis and other forms of lung abnormalities have been reportedly linked to e-cigarette use, and occasionally death.⁽⁸⁶⁸⁻⁸⁷¹⁾ A review of studies on the pulmonary effects of e-cigarettes reported that e-cigarette aerosol is cytotoxic to pulmonary cells, induces acute and chronic inflammation, impairs immune responses against viral and bacterial pathogens, impairs mucociliary clearance, induces oxidative stress, causes DNA damage and increases airway hyperresponsiveness *in vitro* and *in vivo*. Adding nicotine to the e-liquid increased mucociliary dysfunction, oxidative stress, emphysema and airway hyperreactivity.⁽⁸⁷²⁾

The U.S. Centers for Disease Control (CDC) and the U.S. Food and Drug Administration (FDA) investigated an outbreak of e-cigarette, or vaping, product use-associated lung injury (EVALI). Laboratory data showed that vitamin E acetate, an additive in some THC-containing e-cigarettes, was strongly linked to the EVALI outbreak.⁽⁸⁷³⁾ Following the identification of vitamin E acetate as a primary cause of EVALI there was a decline in new cases.

Neutrophilic inflammation of the airways, airways irritability, ciliary paresis and increased mucus hypersecretion are seen in animal models and *in vitro* human airway studies and are similar to changes induced by cigarette smoke and recognised features of COPD.⁽⁸⁷⁴⁻⁸⁷⁸⁾ These data are summarized in a review by Gotts and colleagues,⁽⁸⁷⁹⁾ although it is likely to be many years before the long-term risks of vaping, including risks of cancer, are clarified, particularly in people with COPD and/or whether vaping is an independent risk factor for developing COPD.⁽⁸⁶⁸⁻⁸⁷¹⁾ In a large prospective cohort study, an increased risk of respiratory disease among former and current e-cigarette users was observed even when adjusted for cigarette and other combustible tobacco product use, demographic characteristics, and chronic health conditions.⁽⁸⁸⁰⁾ There is additional evidence that in older adults at risk of or with COPD, e-cigarette users have greater nicotine dependence, poorer lung-related health outcomes (more chronic bronchitis and exacerbations), and are less likely to reduce or quit smoking conventional cigarettes.⁽⁸⁸¹⁾

A meta-analysis of five RCTs has suggested that e-cigarettes are superior to nicotine replacement therapy for achieving 6 months continuous abstinence from smoking tobacco.⁽⁸⁸²⁾ Nevertheless, based on the available evidence and the lack of knowledge about the long-term effects of e-cigarettes on respiratory health, it is not possible to recommend this intervention for smoking cessation in patients with COPD.⁽⁸⁸³⁾

Pharmacological products

Results of a meta-analysis comparing simple controller pharmacotherapy (nicotine replacement therapy, bupropion, nortriptyline and varenicline) with placebo in smokers with COPD showed that all pharmacotherapy groups (except nortriptyline) increased the chances of smoking cessation compared with placebo.⁽⁵⁹²⁾ Prolonged abstinence rates in the pharmacotherapy groups ranged from 14% to 27%, and in the placebo group from 5% to 9%.⁽⁵⁹²⁾

A study in patients with COPD showed higher continuous abstinence rates during weeks 9 to 24 with varenicline (58.3%) and bupropion (55.6%) compared with nicotine patch (38.2%).⁽⁸⁸⁴⁾ Varenicline and bupropion showed similar efficacy, however, the group receiving varenicline compared with bupropion smoked more cigarettes per day.⁽⁸⁸⁴⁾

Pharmacotherapy to treat stable COPD

Pharmacotherapy for COPD is currently focused on symptoms and exacerbations. FEV1 decline has been considered a surrogate for the natural course of the disease. In this context, studies have been performed to evaluate if pharmacotherapy may have an impact on the change of FEV1 over time. Individual clinical trials have not been

sufficiently conclusive to show that pharmacotherapy can reduce the rate of FEV1 decline.⁽⁸⁸⁵⁻⁸⁸⁹⁾ However, a systematic review combining data from 9 studies demonstrated a reduction in the rate of FEV1 decline of 5.0 mL/year in active treatment arms compared with placebo arms.⁽⁸⁹⁰⁾ The difference between long-acting bronchodilator containing treatment arms and placebo arms was 4.9 mL/year. The difference between inhaled corticosteroid containing treatment arms and placebo arms was 7.3 mL/year. Although we need to be aware of the potential benefit of pharmacotherapy in reducing the rate of lung function decline, further research is needed to know which patients are likely to benefit.

The classes of medications commonly used to treat COPD are shown in **Figure 3.18**. The choice within each class depends on the availability and cost of medication, and the clinical response balanced against side effects. Each treatment regimen needs to be individualized as the relationship between severity of symptoms, airflow obstruction, and severity of exacerbations can differ between patients. The WHO has defined a minimum set of interventions for the management of stable COPD in primary care.⁽⁸⁹¹⁾

Bronchodilators

Bronchodilators are medications that increase FEV1 and/or change other spirometric variables (**Figure 3.19**). They act by altering airway smooth muscle tone and the improvements in expiratory flow reflect widening of the airways rather than changes in lung elastic recoil. Bronchodilators tend to reduce dynamic hyperinflation at rest and during exercise,^(306,892) and improve exercise performance. The extent of these changes, especially in patients with severe and very severe COPD, is not easy to predict from the improvement in FEV1 measured at rest.^(893,894)

Bronchodilator dose-response (FEV1 change) curves are relatively flat with all classes of bronchodilators.⁽⁸⁹⁵⁻⁹⁰¹⁾ Increasing the dose of either a beta₂-agonist or an anticholinergic by an order of magnitude, especially when given by a nebulizer, appears to provide subjective benefit in acute episodes⁽⁹⁰²⁾ but is not necessarily helpful in stable disease.⁽⁹⁰³⁾ Bronchodilator medications in COPD are most often given on a regular basis to prevent or reduce symptoms. Toxicity is also dose-related (**Figure 3.18**). Use of short acting bronchodilators on a regular basis is not generally recommended.

Maintenance Medications in COPD*

Figure 3.18

Generic Drug Name	Inhaler Type	Nebulizer	Oral/Injectable Delivery	Duration of Action
BETA₂-Agonists				
Short-acting (SABA)				
Fenoterol	MDI	✓	tablet, solution	variable
Levalbuterol	MDI	✓		variable
Salbutamol (albuterol)	MDI & DPI	✓	syrup, tablet	variable
Terbutaline	DPI		tablet	variable
Long-acting (LABA)				
Arformoterol		✓		12 hours
Formoterol	DPI	✓		12 hours
Indacaterol	DPI			24 hours
Olodaterol	SMI			24 hours
Salmeterol	MDI & DPI			12 hours
Anticholinergics				
Short-acting (SAMA)				
Ipratropium bromide	MDI	✓		6-8 hours
Oxipropium bromide	MDI	✓		7-9 hours
Long-acting (LAMA)				
Aclidinium bromide	DPI			12 hours
Glycopyrronium bromide	DPI		solution	variable
Tiotropium	DPI, SMI, MDI			24 hours
Umeclidinium	DPI			24 hours
Glycopyrronium		✓		12 hours
Revefenacin		✓		24 hours
Combination Short-Acting Beta₂-Agonist Plus Anticholinergic in One Device (SABA+SAMA)				
Fenoterol/ipratropium	SMI	✓		6-8 hours
Salbutamol/ipratropium	SMI, MDI	✓		variable
Combination Long-Acting Beta₂-Agonist Plus Anticholinergic in One Device (LABA+LAMA)				
Formoterol/acclidinium	DPI			12 hours
Formoterol/glycopyrronium	MDI			12 hours
Indacaterol/glycopyrronium	DPI			12-24 hours
Vilanterol/umeclidinium	DPI			24 hours
Olodaterol/tiotropium	SMI			24 hours
Methylxanthines				
Aminophylline			solution, injectable	variable
Theophylline (SR)			tablet, capsule, elixir, solution, injectable	variable
Combination of Long-Acting Beta₂-Agonist Plus Corticosteroid in One Device (LABA+ICS)				
Formoterol/beclometasone	MDI, DPI			12 hours
Formoterol/budesonide	MDI, DPI			12 hours
Formoterol/mometasone	MDI			12 hours
Salmeterol/fluticasone propionate	MDI, DPI			12 hours
Vilanterol/fluticasone furoate	DPI			24 hours
Triple Combination in One Device (LABA+LAMA+ICS)				
Fluticasone/umeclidinium/vilanterol	DPI			24 hours
Beclometasone/formoterol/glycopyrronium	MDI, DPI			12 hours
Budesonide/formoterol/glycopyrrolate	MDI			12 hours
Phosphodiesterase-3 and/or -4 Inhibitors				
Roflumilast			tablet	24 hours
Ensifentrine		✓		12 hours
Mucolytic Agents				
Erdosteine			capsule, suspension	12 hours
Carbocysteine†			capsule, packet, solution, syrup	6-8 hours
N-acetylcysteine†		✓	solution, tablet	2-6 hours
Biologics				
Dupilumab			injectable	2 weeks

*This list is not exhaustive. Not all formulations are available in all countries. In some countries other formulations and dosages may be available. †Dosing regimens are under discussion. MDI = metered dose inhaler; DPI = dry powder inhaler; SMI = soft mist inhaler. Note that glycopyrrolate & glycopyrronium are the same compound.

- Inhaled bronchodilators in COPD are central to symptom management and commonly given on a regular basis to prevent or reduce symptoms **(Evidence A)**
- Inhaled bronchodilators are recommended over oral bronchodilators **(Evidence A)**
- Regular and as-needed use of SABA or SAMA improves FEV1 and symptoms **(Evidence A)**
- Combinations of SABA and SAMA are superior compared to either medication alone in improving FEV1 and symptoms **(Evidence A)**
- LABAs and LAMAs are preferred over short-acting agents except for patients with only occasional dyspnea **(Evidence A)**, and for immediate relief of symptoms in patients already on long-acting bronchodilators for maintenance therapy
- LABAs and LAMAs significantly improve lung function, dyspnea, health status, and reduce exacerbation rates **(Evidence A)**
- LAMAs have a greater effect on exacerbation reduction compared with LABAs **(Evidence A)** and decrease hospitalizations **(Evidence B)**
- When initiating treatment with long acting bronchodilators the preferred choice is a combination of a LABA and a LAMA. In patients with persistent dyspnea on a single long-acting bronchodilator treatment should be escalated to two **(Evidence A)**.
- Combination treatment with a LABA and a LAMA increases FEV1 and reduces symptoms compared to monotherapy **(Evidence A)**
- Combination treatment with a LABA+LAMA reduces exacerbations compared to monotherapy **(Evidence B)**
- Combinations can be given as single inhaler or multiple inhaler treatment. Single inhaler therapy may be more convenient and effective than multiple inhalers
- Ensilfenrine significantly improves lung function **(Evidence A)**, dyspnea **(Evidence A)** and health status **(Evidence B)**
- Theophylline exerts a small bronchodilator effect in stable COPD **(Evidence A)** and that is associated with modest symptomatic benefits **(Evidence B)**

Beta₂-agonists

The principal action of beta₂-agonists is to relax airway smooth muscle by stimulating beta₂-adrenergic receptors, which increases cyclic AMP and produces functional antagonism to bronchoconstriction. There are short-acting (SABA) and long-acting (LABA) beta₂-agonists. The effect of SABAs usually wears off within 4 to 6 hours.^(897,898) Regular and as-needed use of SABAs improve FEV1 and symptoms.⁽⁹⁰⁴⁾ LABAs show duration of action of 12 or more hours and do not preclude additional benefit from as-needed SABA therapy.⁽⁹⁰⁵⁾

Formoterol and salmeterol are twice-daily LABAs that significantly improve FEV1 and lung volumes, dyspnea, health status, exacerbation rate and number of hospitalizations,⁽⁹⁰⁶⁾ but have no effect on mortality or rate of decline of lung function. Indacaterol is a once daily LABA that improves breathlessness,^(907,908) health status⁽⁹⁰⁸⁾ and exacerbation rate.⁽⁹⁰⁸⁾ Some patients experience cough following the inhalation of indacaterol. Oladaterol and vilanterol are additional once daily LABAs that improve lung function and symptoms.^(909,910)

Adverse effects

Stimulation of beta₂-adrenergic receptors can produce resting sinus tachycardia and has the potential to precipitate cardiac rhythm disturbances in susceptible patients. Exaggerated somatic tremor is troublesome in some older patients treated with higher doses of beta₂-agonists, regardless of route of administration. Although hypokalemia can occur, especially when treatment is combined with thiazide diuretics,⁽⁹¹¹⁾ and oxygen consumption can be increased under resting conditions in patients with chronic heart failure,⁽⁹¹²⁾ these metabolic effects decrease over time (i.e., show tachyphylaxis). Mild falls in partial pressure of oxygen (PaO₂) can occur after administration of both SABAs and LABAs⁽⁹¹³⁾ but the clinical significance of these changes is uncertain. Despite prior concerns related to the use of beta₂-agonists in the management of asthma, no association between beta₂-agonist use and loss of lung function or increased mortality has been reported in COPD.^(906,914,915)

Antimuscarinic drugs

Antimuscarinic drugs block the bronchoconstrictor effects of acetylcholine on M3 muscarinic receptors expressed in airway smooth muscle.⁽⁹¹⁶⁾ Short-acting antimuscarinics (SAMAs), namely ipratropium and oxitropium, also block the inhibitory neuronal receptor M2, which potentially can cause vagally induced bronchoconstriction.⁽⁹¹⁷⁾ Long-acting muscarinic antagonists (LAMAs), such as tiotropium, aclidinium, glycopyrronium bromide (also known as glycopyrrolate), umeclidinium and revefenacin have prolonged binding to M3 muscarinic receptors, with faster dissociation from M2 muscarinic receptors, thus prolonging the duration of bronchodilator effect.⁽⁹¹⁶⁾

A systematic review of RCTs concluded that ipratropium, a short acting muscarinic antagonist, alone provided small benefits over short-acting beta₂-agonist in terms of lung function, health status and requirement for oral steroids.⁽⁹¹⁸⁾ Among LAMAs, some are administered once a day (tiotropium, umeclidinium, revefenacin), others twice a day (aclidinium), and some are approved for once daily dosing in some countries and twice daily dosing in others (glycopyrrolate).^(916,919) LAMA treatments improve symptoms, including cough and sputum and health status.^(916,920,921) They also improve the effectiveness of pulmonary rehabilitation^(922,923) and reduce exacerbations and related hospitalizations.⁽⁹²⁰⁾ Clinical trials have shown a greater effect on exacerbation rates for LAMA treatment (tiotropium) versus LABA treatment.^(924,925)

Adverse effects

Inhaled anticholinergic drugs are poorly absorbed which limits the troublesome systemic effects observed with atropine.^(916,926) Extensive use of this class of agents in a wide range of doses and clinical settings has shown them to be very safe. The main side effect is dryness of mouth.^(917,927) Although occasional urinary symptoms have been reported, there are no data to prove a true causal relationship.⁽⁹²⁸⁾ Some patients using ipratropium report a bitter, metallic taste. An unexpected small increase in cardiovascular events in COPD patients regularly treated with ipratropium bromide has been reported.^(929,930) In a large, long-term clinical trial in COPD patients, tiotropium added to other standard therapies had no effect on cardiovascular risk.⁽⁸⁸⁹⁾ Although there were some initial concerns regarding the safety of tiotropium delivery via the Respimat[®]⁽⁹³¹⁾ inhaler, the findings of a large trial observed no difference in mortality or exacerbation rates when comparing tiotropium in a dry-powder inhaler and the Respimat[®] inhaler.⁽⁹³²⁾ There are less safety data available for the other LAMAs, but the rate of anti-cholinergic side effects for drugs in this class appears to be low and generally similar. Use of solutions with a facemask can precipitate acute glaucoma, probably as a direct result of the contact between the solution and the eye.⁽⁹³³⁻⁹³⁵⁾

Methylxanthines

Controversy remains about the exact effects of xanthine derivatives. They may act as non-selective phosphodiesterase inhibitors, but have also been reported to have a range of non-bronchodilator actions, the significance of which is disputed.⁽⁹³⁶⁻⁹³⁸⁾ Data on duration of action for conventional, or even slow-release, xanthine preparations are lacking in COPD.

Theophylline, the most commonly used methylxanthine, is metabolized by cytochrome P450 mixed function oxidases. Clearance of the drug declines with age. Many other physiological variables and drugs modify theophylline metabolism. Enhanced inspiratory muscle function has been reported in patients treated with methylxanthines,⁽⁹³⁶⁾ but whether this reflects a reduction in gas trapping or a primary effect on the respiratory skeletal muscles is not clear. All studies that have shown efficacy of theophylline in COPD were performed with sustained-release preparations.

There is evidence for a modest bronchodilator effect compared with placebo in stable COPD.⁽⁹³⁹⁾ Addition of theophylline to salmeterol produces a greater improvement in FEV1 and breathlessness than salmeterol alone.^(940,941) Earlier studies reported contradictory evidence regarding the effect of low-dose theophylline on exacerbation rates.^(942,943) A study that investigated the effectiveness of adding low-dose theophylline to ICS in COPD patients at increased risk of exacerbation showed no difference compared with placebo in the number of COPD exacerbations over a one-year period.⁽⁹⁴⁴⁾ A large placebo-controlled trial showed no effect of oral theophylline alone or in combination with prednisolone 5 mg daily on exacerbations of severe COPD.⁽⁹⁴⁵⁾

Adverse effects

Toxicity is dose-related, which is a particular problem with xanthine derivatives because their therapeutic ratio is small and most of the benefit occurs only when near-toxic doses are given.^(937,939) Methylxanthines are non-specific inhibitors of all phosphodiesterase enzyme subsets, which explains their wide range of toxic effects. Problems include atrial and ventricular arrhythmias (which can prove fatal) and *grand mal* convulsions (which can occur irrespective of prior epileptic history). Other side effects include headaches, insomnia, nausea, and heartburn, and these may occur within the therapeutic range of serum levels of theophylline. These medications have significant interactions with commonly used medications such as erythromycin (but not azithromycin), certain quinolone antibiotics (ciprofloxacin, but not ofloxacin), allopurinol, cimetidine (but not ranitidine), serotonin uptake inhibitors (fluvoxamine) and the 5-lipoxygenase inhibitor zileuton.

Combination bronchodilator therapy

Combining bronchodilators with different mechanisms and durations of action may increase the degree of bronchodilation with a lower risk of side-effects compared to increasing the dose of a single bronchodilator.^(946,947) Combinations of SABAs and SAMAs are superior compared to either medication alone in improving FEV1 and symptoms.⁽⁹⁴⁸⁾ Treatment with formoterol and tiotropium in *separate inhalers* has a bigger impact on FEV1 than either component alone.⁽⁹⁴⁹⁾ There are numerous combinations of a LABA and LAMA in a *single inhaler* available (**Figure 3.18**). These combinations improve lung function compared to placebo;⁽⁹⁴⁶⁾ this improvement is consistently greater than long-acting bronchodilator monotherapy effects although the magnitude of improvement is less than the fully additive effect predicted by the individual component responses.⁽⁹⁵⁰⁾ Single inhalers improve adherence to treatment.⁽⁹⁵¹⁾ In studies where patient reported outcomes (PROs) are the primary endpoint or in pooled analyses, combination bronchodilators have a greater impact on PROs compared to monotherapies.⁽⁹⁵²⁻⁹⁵⁵⁾ In one clinical trial, combination LABA+LAMA treatment had the greatest improvement in quality of life compared to placebo or its individual bronchodilator components in patients with a greater baseline symptom burden.⁽⁹⁵⁶⁾ A clinical trial showed that LABA+LAMA improved lung function and symptoms versus long-acting bronchodilator monotherapy in symptomatic patients with low exacerbation risk and not receiving inhaled corticosteroids.⁽⁹⁵⁵⁾ The LABA+LAMA combination demonstrated favorable improvements compared with the monotherapies for the majority of outcomes irrespective of baseline HRQoL.⁽⁹⁵⁷⁾ These clinical trials deal with group mean data, but symptom responses to LABA+LAMA combinations are best evaluated on an individual patient basis. A lower dose, twice daily regimen for a LABA+LAMA has also been shown to improve symptoms and health status in COPD patients⁽⁹⁵⁸⁾ (**Figure 3.19**). These findings have been shown in people across different ethnic groups (Asian as well as European).⁽⁹⁵⁹⁾

Most studies with LABA+LAMA combinations have been performed in patients with a low rate of exacerbations. One study in patients with a history of exacerbations indicated that a combination of long-acting bronchodilators is more

effective than long-acting bronchodilator monotherapy for preventing exacerbations.⁽⁹⁶⁰⁾ Another large study found that combining a LABA with a LAMA did not reduce exacerbation rate as much as expected compared with a LAMA alone.⁽⁹⁶¹⁾ Another study in patients with a history of exacerbations showed that a combination LABA+LAMA decreased exacerbations to a greater extent than an LABA+ICS combination.⁽⁹⁶²⁾ However, another study in a population with high exacerbation risk (≥ 2 exacerbations and/or 1 hospitalization in the previous year) reported that LABA+ICS decreased exacerbations to a greater extent than a LABA+LAMA combination at higher blood eosinophil concentrations.⁽⁴⁹⁶⁾ A large observational pharmaco-epidemiological study found similar effectiveness of LABA+LAMA and LABA+ICS but a significantly higher risk of pneumonia in those treated with LABA+ICS.⁽⁹⁶³⁾

Anti-inflammatory agents

To date, exacerbations (e.g., exacerbation rate, patients with at least one exacerbation, time-to-first exacerbation) represent the main clinically relevant endpoint used for efficacy assessment of drugs with anti-inflammatory effects (Figure 3.20).

Inhaled corticosteroids (ICS)

General considerations

In vitro evidence suggests that COPD-associated inflammation has limited responsiveness to corticosteroids. Moreover, some drugs including beta₂-agonists, theophylline or macrolides may partially facilitate corticosteroid sensitivity in COPD.^(964,965) The clinical relevance of this effect has not yet been fully established.

In vivo data suggest that the dose-response relationships and long-term (> 3 years) safety of ICS in people with COPD are unclear and require further investigation.⁽⁹⁶²⁾ Because the effects of ICS in COPD can be modulated by the concomitant use of long-acting bronchodilators, these two therapeutic options are discussed separately.

Both current and ex-smokers with COPD benefit from ICS use in terms of lung function and exacerbation rates, although the magnitude of the effect is lower in heavy or current smokers compared to light or ex-smokers.^(496,966)

Efficacy of ICS (alone)

Most studies have found that regular treatment with ICS alone does not modify the long-term decline of FEV1 nor mortality in people with COPD.⁽⁹⁶⁷⁾ Studies and meta-analyses assessing the effect of regular treatment with ICS alone on mortality in people with COPD have not provided conclusive evidence of benefit.⁽⁹⁶⁷⁾ In the TORCH trial, a trend toward higher mortality was observed for patients treated with fluticasone propionate alone compared to those receiving placebo or salmeterol plus fluticasone propionate combination.⁽⁸⁴⁴⁾ However, an increase in mortality was not observed in COPD patients treated with fluticasone furoate in the Survival in Chronic Obstructive Pulmonary Disease with Heightened Cardiovascular Risk (SUMMIT) trial.⁽⁹⁶⁸⁾ In moderate COPD, fluticasone furoate alone or in combination with vilanterol was associated with slower decline in FEV1 compared with placebo or vilanterol alone by on average 9 mL/year.⁽⁹⁶⁹⁾ A number of studies have investigated whether there is a relationship between ICS treatment and risk of lung cancer with conflicting results.⁽⁹⁷⁰⁾

<p>Inhaled Corticosteroids</p>	<ul style="list-style-type: none"> Regular treatment with ICS increases the risk of pneumonia especially in those with severe disease (Evidence A) An ICS combined with a LABA is more effective than the individual components in improving lung function and health status and reducing exacerbations in patients with exacerbations and moderate to very severe COPD (Evidence A) We do not encourage the use of a LABA+ICS combination in COPD. If there is an indication for an ICS the combination LABA+LAMA+ICS has been shown to be superior to LABA+ICS and is therefore the preferred choice Triple inhaled therapy of LABA+LAMA+ICS improves lung function, symptoms and health status, and reduces exacerbations, compared to LABA+ICS, LABA+LAMA or LAMA monotherapy (Evidence A). Recent data suggest a beneficial effect of triple inhaled therapy versus fixed-dose LABA+LAMA combinations on mortality in symptomatic COPD patients with a history of frequent and/or severe exacerbations If patients with COPD have features of asthma, treatment should always contain an ICS Independent of ICS use, there is evidence that a blood eosinophil count < 2% increases the risk of pneumonia (Evidence C) Combinations can be given as single or multiple inhaler therapy. Single inhaler therapy may be more convenient and effective than multiple inhalers
<p>Oral Glucocorticoids</p>	<ul style="list-style-type: none"> Long-term use of oral glucocorticoids has numerous side effects (Evidence A) with no evidence of benefits (Evidence C)
<p>PDE Inhibitors</p>	<ul style="list-style-type: none"> In patients with chronic bronchitis, severe to very severe COPD and a history of exacerbations: <ul style="list-style-type: none"> Roflumilast improves lung function and reduces moderate and severe exacerbations (Evidence A) Enfetrine improves lung function (Evidence A) but an effect on exacerbations has not been evaluated in patients at increased exacerbation risk
<p>Antibiotics</p>	<ul style="list-style-type: none"> Long-term azithromycin and erythromycin therapy reduces exacerbations over one year (Evidence A) Preferentially, but not only in former smokers with exacerbations despite appropriate therapy, azithromycin can be considered (Evidence B) Treatment with azithromycin is associated with an increased incidence of bacterial resistance (Evidence A) and hearing test impairments (Evidence B)
<p>Mucoregulators & Antioxidant Agents</p>	<ul style="list-style-type: none"> Regular treatment with mucolytics such as erdosteine, carbocysteine and NAC reduces the risk of exacerbations in select populations (Evidence B) Antioxidant mucolytics are recommended only in selected patients (Evidence A)
<p>Biologics</p>	<ul style="list-style-type: none"> In patients with moderate to severe COPD with a history of exacerbations, chronic bronchitis and higher blood eosinophil counts (≥ 300 cells/μL): <ul style="list-style-type: none"> Dupilumab reduces exacerbations, improves lung function and quality of life (Evidence A)
<p>Other Anti-Inflammatory Agents</p>	<ul style="list-style-type: none"> Statin therapy is not recommended for prevention of exacerbations (Evidence A) Simvastatin does not prevent exacerbations in COPD patients at increased risk of exacerbations and without indications for statin therapy (Evidence A). However, observational studies suggest that statins may have positive effects on some outcomes in patients with COPD who receive them for cardiovascular and metabolic indications (Evidence C) Leukotriene modifiers have not been tested adequately in COPD patients

ICS in combination with long-acting beta agonist (LABA+ICS)

In patients with moderate to very severe COPD and exacerbations, an ICS combined with a LABA is more effective than either component alone in improving lung function, health status and reducing exacerbations.^(971,972) Clinical trials powered on all-cause mortality as the primary outcome failed to demonstrate a statistically significant effect of LABA+ICS combination therapy on survival.^(844,968)

Factors to Consider when Initiating ICS Treatment

Figure 3.21

Factors to consider when adding ICS to long-acting bronchodilators:

(note the scenario is different when considering ICS withdrawal)

STRONGLY FAVORS USE

History of hospitalization(s) for exacerbations of COPD[#]
≥ 2 moderate exacerbations of COPD per year[#]
Blood eosinophils ≥ 300 cells/μL
History of, or concomitant asthma

FAVORS USE

1 moderate exacerbation of COPD per year[#]
Blood eosinophils 100 to < 300 cells/μL

AGAINST USE

Repeated pneumonia events
Blood eosinophils < 100 cells/μL
History of mycobacterial infection

[#]despite appropriate long-acting bronchodilator maintenance therapy (see Figures 3.7 & 3.18 for recommendations); *note that blood eosinophils should be seen as a continuum; quoted values represent approximate cut-points; eosinophil counts are likely to fluctuate.

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Blood eosinophil count

A number of studies have shown that blood eosinophil counts predict the magnitude of the effect of ICS (added on top of regular maintenance bronchodilator treatment) in preventing future exacerbations.⁽⁴⁹¹⁻⁴⁹⁶⁾ There is a continuous relationship between blood eosinophil counts and ICS effects; no and/or small effects are observed at lower eosinophil counts, with incrementally increasing effects observed at higher eosinophil counts.⁽⁵⁰¹⁾ Data modeling indicates that ICS containing regimens have little or no effect at a blood eosinophil count < 100 cells/μL,⁽⁴⁹¹⁾ therefore, this threshold can be used to identify patients with a low likelihood of treatment benefit with ICS. In addition, lower blood and sputum eosinophils are associated with greater presence of proteobacteria,^(278,283,973) notably haemophilus, and increased bacterial infections and pneumonia.⁽⁹⁷⁴⁾ Lower blood eosinophil counts therefore may identify individuals with microbiome profiles associated with increased risk of clinical worsening due to pathogenic bacterial species. The threshold of a blood eosinophil count ≥ 300 cells/μL identifies the top of the continuous relationship between eosinophils and ICS, and can be used to identify patients with the greatest likelihood of treatment benefit with ICS.

Sources of evidence include: 1) *post-hoc* analyses comparing LABA+ICS versus LABA^(491,492,494); 2) pre-specified analyses comparing triple therapy versus LABA+LAMA or LAMA^(493,495,496); and 3) other analyses comparing LABA+ICS versus LABA+LAMA⁽⁹⁷⁵⁾ or studying ICS withdrawal.^(709,710,976)

The treatment effect of ICS containing regimens (LABA+LAMA+ICS and LABA+ICS vs LABA+LAMA) is higher in patients with high exacerbation risk (≥ 2 exacerbations and / or 1 hospitalization in the previous year).^(493,496,962) Thus, the use of blood eosinophil counts to predict ICS effects should always be combined with clinical assessment of exacerbation risk (as indicated by the previous history of exacerbations). Other factors (smoking status, ethnicity, geographical location) could influence the relationship between ICS effect and blood eosinophil count but remains to be further explored.

Factors to consider when initiating ICS treatment in combination with one or two long-acting bronchodilators are shown in **Figure 3.21**.⁽⁵⁸⁴⁾

Adverse effects

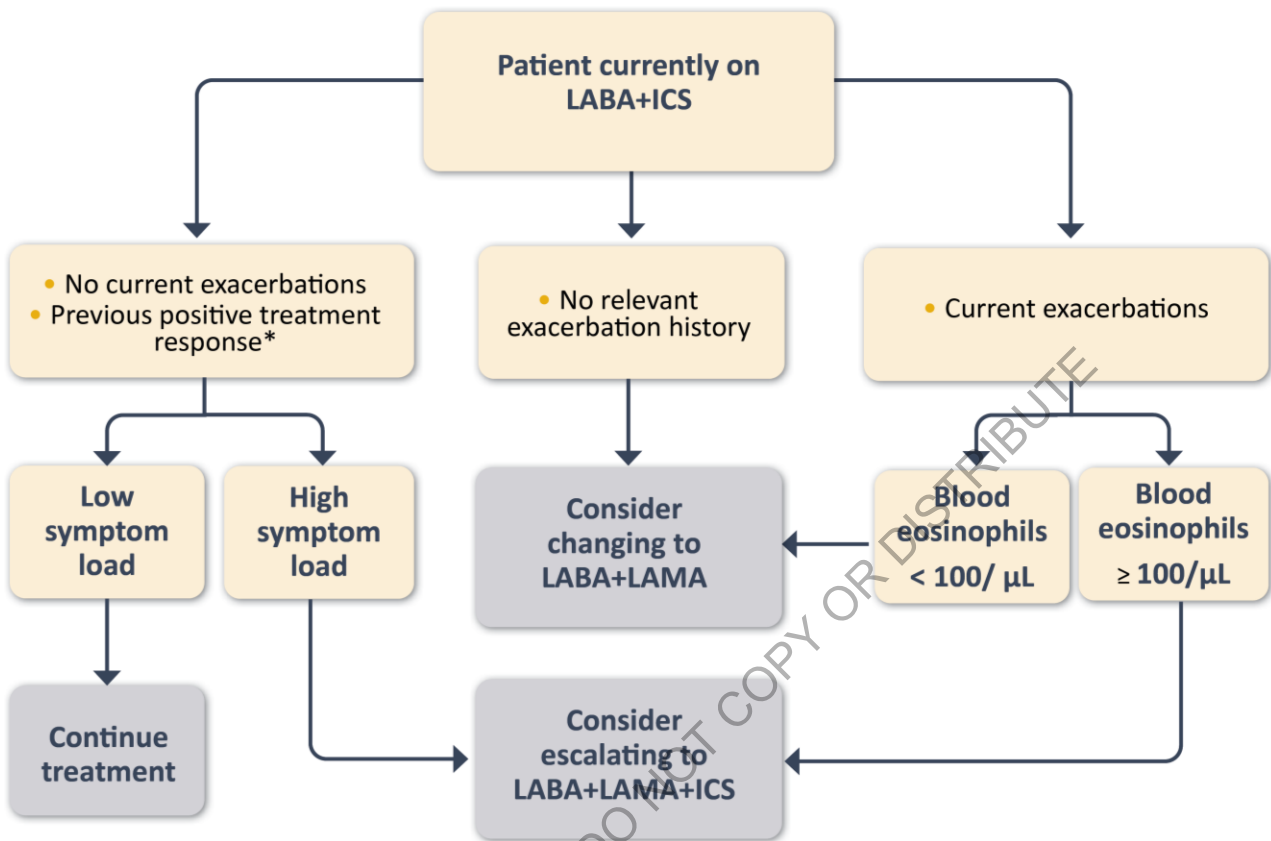
There is high quality evidence from RCTs that ICS use modifies the airway microbiome⁽⁹⁷⁷⁾ and is associated with higher prevalence of oral candidiasis, hoarse voice, skin bruising and pneumonia.⁽⁹⁶⁷⁾ This excess risk has been confirmed in ICS studies using fluticasone furoate, even at low doses.⁽⁹⁷⁸⁾ Patients at higher risk of pneumonia include those who currently smoke, are aged ≥ 55 years, have a history of prior exacerbations or pneumonia, a body mass index (BMI) < 25 kg/m², a poor MRC dyspnea grade and/or severe airflow obstruction.^(979,980) Independent of ICS use, there is evidence that a blood eosinophil count $< 2\%$ increases the risk of developing pneumonia.⁽⁹⁸¹⁾ In studies of patients with moderate COPD, ICS by itself or in combination with a LABA did not increase the risk of pneumonia.^(968,980)

Results from RCTs have yielded varied results regarding the risk of decreased bone density and fractures with ICS treatment, which may be due to differences in study designs and/or differences between ICS compounds.^(887,978,982-984) Results of observational studies suggest that ICS treatment could also be associated with increased risk of diabetes/poor control of diabetes,⁽⁹⁸⁵⁾ cataracts,⁽⁹⁸⁶⁾ and mycobacterial infection.⁽⁹⁸⁷⁾ An increased risk of tuberculosis has been found in both observational studies and a meta-analysis of RCTs.⁽⁹⁸⁸⁻⁹⁹⁰⁾ In the absence of RCT data on these issues, it is not possible to draw firm conclusions.⁽⁹⁹¹⁾ ICS and lung cancer incidence is discussed in **Chapter 5**.

Management of patients currently on LABA+ICS

In general, if there is an indication for ICS use then LABA+LAMA+ICS has been shown to be superior to LABA+ICS (**Figure 3.22**). For patients currently on LABA+ICS, it is important to review whether there was a relevant prior exacerbation history and whether there was a previous positive response to ICS treatment. Using this information, the following should be considered:

- ▶ If there was no relevant exacerbation history, then consider changing to LABA+LAMA (**Figure 3.22**).
- ▶ If there was a previous exacerbation history but currently there are no exacerbations this suggests a positive response to treatment.⁽⁹⁹²⁻⁹⁹⁷⁾ If dyspnea persists despite treatment with LABA+ICS, escalation to LABA+LAMA+ICS should be considered.⁽⁹⁹⁸⁻¹⁰⁰¹⁾
- ▶ If the patient is currently suffering with exacerbations, then blood eosinophil counts can be used to guide treatment; if < 100 cells/ μ l then consider changing to LABA+LAMA, while ≥ 100 cells/ μ l suggests that LABA+LAMA+ICS should be used (**Figure 3.22**).
- ▶ The benefits and risks of ICS withdrawal should be carefully considered, with a blood eosinophil count > 300 cells/ μ l being an indicator of increased risk of exacerbations with ICS withdrawal.



*Patient previously had exacerbations and responded to LABA+ICS treatment

Triple therapy (LABA+LAMA+ICS)

The step up in inhaled treatment to LABA plus LAMA plus ICS (triple therapy) can occur by various approaches⁽¹⁰⁰²⁾ and has been shown to improve lung function, patient reported outcomes and reduce exacerbations when compared to LAMA alone, LABA+LAMA and LABA+ICS.^(493,495,496,1003-1010) A *post-hoc* analysis of one of the RCTs that evaluated the effects of LABA+LAMA+ICS showed that triple therapy improved clinical outcomes versus dual therapy regardless of smoking status.⁽¹⁰¹¹⁾

A *post-hoc* pooled analysis of three triple therapy clinical trials in COPD patients with severe airflow obstruction and a history of exacerbations showed a non-significant trend for lower mortality (assessed as a safety outcome) with triple inhaled therapy compared to non-ICS based treatments.⁽¹⁰¹²⁾ Two large one-year randomized controlled trials (named IMPACT and ETHOS) were reviewed earlier in Chapter 3 (see 'Therapeutic interventions that reduce COPD mortality') and provide new evidence on mortality reduction with fixed-dose inhaled triple combinations compared to dual bronchodilation.^(699,1013)

Oral glucocorticoids

Oral glucocorticoids have numerous side effects, including steroid myopathy⁽¹⁰¹⁴⁾ which can contribute to muscle weakness, decreased functionality, and respiratory failure in people with very severe COPD. Systemic glucocorticoids for treating acute exacerbations in hospitalized patients, or during emergency department visits, have been shown to reduce the rate of treatment failure, the rate of relapse and to improve lung function and breathlessness.⁽¹⁰¹⁵⁾ Conversely, prospective studies on the long-term effects of oral glucocorticoids in stable COPD are limited.^(1016,1017) Therefore, while oral glucocorticoids play a role in the acute management of exacerbations, they have no role in the chronic daily treatment in COPD because of a lack of benefit balanced against a high rate of systemic complications.

Phosphodiesterase-4 (PDE4) inhibitor

The principal action of PDE4 inhibitors is to reduce inflammation by inhibiting the breakdown of intracellular cyclic AMP.⁽¹⁰¹⁸⁾ Roflumilast is a once daily oral medication with no direct bronchodilator activity. Roflumilast reduces moderate and severe exacerbations treated with systemic corticosteroids in patients with chronic bronchitis, severe to very severe COPD, and a history of exacerbations.⁽¹⁰¹⁹⁾ The effects on lung function are also seen when roflumilast is added to long-acting bronchodilators,⁽¹⁰²⁰⁾ and in patients who are not controlled on fixed-dose LABA+ICS combinations.⁽⁷⁰⁶⁾ The beneficial effects of roflumilast have been reported to be greater in patients with a prior history of hospitalization for an acute exacerbation.^(705,708) There has been no study directly comparing roflumilast with an inhaled corticosteroid.

Adverse effects

Roflumilast has more adverse effects than inhaled medications for COPD.⁽¹⁰²¹⁾ The most frequent are diarrhea, nausea, reduced appetite, weight loss, abdominal pain, sleep disturbance, and headache. Adverse effects have led to increased withdrawal rates from clinical trials. Adverse effects seem to occur early during treatment, are reversible, and diminish over time with continued treatment. In controlled studies an average unexplained weight loss of 2 kg has been seen and weight monitoring during treatment is advised, in addition to avoiding roflumilast treatment in underweight patients. Roflumilast should also be used with caution in patients with depression.

Antibiotics

In older studies prophylactic, *continuous* use of antibiotics had no effect on the frequency of exacerbations in COPD^(1022,1023) and a study that examined the efficacy of chemoprophylaxis undertaken in winter months over a period of 5 years concluded that there was no benefit.⁽¹⁰²⁴⁾ Later studies have shown that regular use of some antibiotics may reduce exacerbation rate.^(1025,1026)

Azithromycin (250 mg/day or 500 mg three times per week) or erythromycin (250 mg two times per day) for one year in patients prone to exacerbations reduced the risk of exacerbations compared to usual care.^(704,1027,1028) Azithromycin use was associated with an increased incidence of bacterial resistance, prolongation of QTc interval, and impaired hearing tests.⁽⁷⁰⁴⁾ A *post-hoc* analysis suggests lesser benefit in active smokers.⁽⁷⁰⁵⁾ There are no data showing the efficacy or safety of chronic azithromycin treatment to prevent COPD exacerbations beyond one-year of treatment.

Pulse therapy with moxifloxacin (400 mg/day for 5 days every 8 weeks) in patients with chronic bronchitis and frequent exacerbations had no beneficial effect on the exacerbation rate overall.⁽¹⁰²⁹⁾ Long-term doxycycline did not reduce exacerbations, although there may be responder subgroups.⁽¹⁰³⁰⁾

Mucolytic (mucokinetics, mucoregulators) and antioxidant agents (N-acetylcysteine, carbocysteine, erdoSteine)

In COPD patients not receiving ICS, regular treatment with mucolytics such as carbocysteine and N-acetylcysteine

(NAC) may reduce exacerbations and modestly improve health status.⁽¹⁰³¹⁻¹⁰³⁴⁾ In contrast, it has been shown that erdosteine may have a significant effect on (mild) exacerbations irrespective of concurrent treatment with ICS. Due to the heterogeneity of studied populations, treatment dosing and concomitant treatments, currently available data do not allow precise identification of the potential target population for antioxidant agents in COPD.⁽¹⁰³⁵⁾

Phosphodiesterase 3 and 4 (PDE 3 & PDE4) inhibitors

Ensifentrine is a novel, first-in-class, inhaled dual inhibitor of PDE3 and PDE4 with both anti-inflammatory activity and bronchodilator effects. PDE3 inhibition, through modulation of cyclic GMP levels, causes smooth muscle relaxation.⁽¹⁰³⁶⁾ In parallel phase III studies, ensifentrine, delivered via standard jet nebulizer, significantly improved lung function⁽¹⁰³⁶⁾ and dyspnea but had inconsistent effects on quality of life. A reduction in exacerbation rate was suggested but the patient populations were not enriched for exacerbation risk. In addition, the studies were not designed to assess the impact of ensifentrine on top of LABA+LAMA or LABA+LAMA+ICS making it difficult to fully position this agent in our treatment algorithm (**Figure 3.9**).^(501.700-702) Studies did not find safety or tolerability issues.⁽¹⁰³⁷⁾ Ensifentrine is currently only available in the United States.

Other drugs with potential to reduce exacerbations

Four large phase 3 studies have investigated the efficacy of the anti-IL-5 monoclonal antibody mepolizumab⁽¹⁰³⁸⁾ and the anti-IL-5 receptor- α antibody benralizumab⁽¹⁰³⁹⁾ in patients with COPD, who had a history of two or more exacerbations in the last year and increased blood eosinophil count. The studies showed inconsistent effects on exacerbation reduction, and none have received regulatory approval for treatment of COPD. Currently, large randomized trials are being conducted to investigate whether these and other biologic treatments are effective in a population who have more compelling evidence of eosinophilic or type II airway inflammation.⁽⁷⁰¹⁾

Dupilumab is a fully human monoclonal antibody that blocks the shared receptor component for interleukin-4 and interleukin-13. In two large, phase 3, double-blind, randomized trials, patients with COPD, chronic bronchitis, a history of two or more moderate exacerbations or one or more severe exacerbation(s) in the last year despite treatment with LABA+LAMA+ICS, and blood eosinophil count of ≥ 300 cells/ μ L who received dupilumab had fewer exacerbations, better lung function and improved health status over 52 weeks.^(700,701)

Nedocromil and leukotriene modifiers have not been tested adequately in COPD patients and the available evidence does not support their use.^(1040,1041)

There was no evidence of benefit, and some evidence of harm, including malignancy and pneumonia, following treatment with an anti-TNF-alpha antibody (infliximab) in moderate to severe COPD.⁽¹⁰⁴²⁾

A recent Cochrane meta-analysis did not show sufficient evidence to support the use of immunostimulants.⁽¹⁰⁴³⁾

An RCT of the selective β 1 receptor blocker metoprolol in patients with moderate or severe COPD, who did not have an established indication for beta-blocker use, showed it did not delay the time until the first COPD exacerbation compared to the placebo group and hospitalization for exacerbation was more common among the patients treated with metoprolol.^(1044,1045) There is no evidence that beta-blockers should be used in people with COPD who do not have a cardiovascular indication for their use.

Simvastatin did not prevent exacerbations in people with COPD who had no metabolic or cardiovascular indication for statin treatment.⁽¹⁰⁴⁶⁾ An association between statin use and improved outcomes (including decreased exacerbations and mortality) has been reported in observational studies of people with COPD who received them for cardiovascular and metabolic indications.⁽¹⁰⁴⁷⁾

There is no evidence that supplementation with vitamin D has a positive impact on exacerbations in unselected patients.⁽¹⁰⁴⁸⁾ In a meta-analysis vitamin D supplementation reduced exacerbation rates in patients with low baseline vitamin D levels,⁽¹⁰⁴⁹⁾ but a more recent study has shown no effect.⁽¹⁰⁵⁰⁾

Adherence to inhaled COPD medications

Adherence is defined as the process by which a person takes their medication as prescribed by a healthcare provider.⁽¹⁰⁵¹⁾ Adherence to therapy is a challenging issue in any chronic condition including COPD.

Non-adherence to COPD medication has been associated with poor symptom control, increased risk of exacerbation, increased healthcare utilization and costs, decreased health-related quality of life and higher mortality risk.⁽¹⁰⁵²⁻¹⁰⁶²⁾

Although inhaled therapy is a key component in the management of COPD, the adherence to inhaled medication is generally low, even in very severe disease. One systematic review⁽¹⁰⁶³⁾ reported non-adherence rates to COPD medication of 22% to 93%, with over half of the included studies reporting non-adherence in > 50% of subjects.⁽¹⁰⁶³⁾ Most studies included were conducted in high-income countries and many used pharmacy claims data to assess adherence.⁽¹⁰⁶³⁾ Self-reported non-adherence to COPD medication varies between 28% and 74% (mean 50.9%) in high income countries^(1054,1063,1064) and between 46% and 93% (mean 61.7%) in low- and middle-income countries (LMICs).⁽¹⁰⁶⁵⁻¹⁰⁶⁸⁾ However, when compared with data obtained through electronic monitoring, studies have consistently demonstrated that self-reports are inaccurate as people generally over-report medication use.^(1069,1070)

Adherence is a complex concept, influenced by multiple factors including social/environmental, person-related and treatment-related factors.⁽¹⁰⁷¹⁾ Several studies have explored the variables associated with medication adherence in people with COPD.^(1063,1065) Factors such as the presence of co-morbidities, in particular depression, smoking status, schooling level, disease severity, and drug regimen factors such as dosage complexity, polypharmacy and side effects of therapy, are the main factors associated with low adherence.^(1062,1063,1065,1066,1072,1073) In addition, socioeconomic factors, including unemployment, low-income status, immigration status, living alone and poor medication availability⁽⁶¹⁾ have been shown to negatively influence inhaled medication adherence and to be related to the non-use of medication.^(1072,1074,1075)

Although patient preferences may vary, prescribing strategies that could help improve adherence often include selecting devices with a similar inhalation technique (in the case of multiple inhalers) and combination therapy.^(725,1076)

Healthcare provider and caregiver factors can also contribute to perception of disease, healthcare, medication and ultimately adherence. A better understanding of the disease and drug therapy, as well as greater trust in healthcare professionals and pharmacist-led interventions have been shown to improve COPD medication adherence.^(747,1063) Self-management education can help a person understand their disease and the benefits of proper use of medication. Prescribing behavioral components that are tailored to the individual barriers of each person (e.g., keeping medications in one place, self-monitoring of symptoms, medication reminders, etc) is more effective in changing behavior than offering general suggestions. A study assessing interventions intended to improve adherence to pharmacological therapy showed that multi-component interventions with education, motivational or behavioral components delivered by health professionals may improve adherence.⁽⁸⁰²⁾ Involving a person in establishing an individually tailored treatment plan has been shown to improve adherence.⁽¹⁰⁷⁷⁾ Further research on medication adherence in COPD is needed to gain insight into the effectiveness of different self-management education and health behavior change strategies.

Other pharmacological treatments

Other pharmacological treatments for COPD are summarized in **Figure 3.23**.

Other Pharmacological Treatments	
Alpha-1 Antitrypsin Augmentation Therapy	<ul style="list-style-type: none">Intravenous augmentation therapy may slow down the progression of emphysema (Evidence B)
Antitussives	<ul style="list-style-type: none">There is no conclusive evidence of a beneficial role of antitussives in people with COPD (Evidence C)
Vasodilators	<ul style="list-style-type: none">Vasodilators do not improve outcomes and may worsen oxygenation (Evidence B)
Opioids	<ul style="list-style-type: none">Low-dose long acting oral and parenteral opioids may be considered for treating dyspnea in COPD patients with severe disease (Evidence B)
Pulmonary Hypertension Therapy	<ul style="list-style-type: none">Drugs approved for primary pulmonary hypertension are not recommended for patients with a pulmonary hypertension secondary to COPD (Evidence B)

Alpha-1 antitrypsin augmentation therapy

The logical approach to minimize the development and progression of lung disease in alpha-1 antitrypsin deficiency (AATD) patients is alpha-1-antitrypsin augmentation. Such therapy has been available in many, though not all, countries since the 1980s. Because AATD is rare, few clinical trials to assess efficacy with conventional spirometric outcome have been undertaken. However, a wealth of observational studies suggest a reduction in spirometric progression in treated versus non-treated patients⁽¹⁰⁷⁸⁾ and that this reduction is most effective for patients with FEV1 35% to 49% predicted.⁽¹⁰⁷⁹⁾ Never or ex-smokers with an FEV1 of 35% to 60% predicted have been suggested as those most suitable for AATD augmentation therapy (**Evidence B**).

The available clinical trial and registry data have almost exclusively been focussed on patients with the ZZ (ZZ-AATD/PiZZ) genotype. Risks to other genotypes have not been explored in clinical trials although people with the Z/null or null/null genotypes have even lower levels of plasma AAT and are usually assessed for augmentation therapy. Other genotypes are not considered at risk or likely to benefit from augmentation therapy. Recent studies have suggested an increased risk of developing mild COPD in heterozygotes for the Z gene^(111,112) although unlike ZZ neither develop COPD in the absence of smoking, so smoking cessation is thought to prevent progression and hence augmentation is not necessary or appropriate.

Studies using sensitive parameters of emphysema progression determined by CT scans have provided evidence for an effect on preserving lung tissue compared to placebo.⁽¹⁰⁸⁰⁻¹⁰⁸²⁾ Based on the last trial the indications for therapy have

been extended to include "those patients with evidence of progressive lung disease despite other optimal therapy." However, not all patients with AATD develop or persist with rapid spirometric progression especially following smoking cessation.⁽¹⁰⁸³⁾ Since the purpose of augmentation therapy is to preserve lung function and structure it seems logical to reserve such expensive therapy for those with evidence of continued and rapid progression following smoking cessation.⁽¹⁰⁸³⁾

The indication for AAT augmentation is emphysema although there are no fixed criteria for diagnosis or confirmation. The evidence for augmentation therapy efficacy varies according to the outcome studied.⁽¹⁰⁸⁴⁾ Intravenous augmentation therapy has been recommended for individuals with AATD and an FEV1 \leq 65% predicted based on previous observational studies. However, one study powered on CT scan as an outcome recommended that all patients with evidence of progressive lung disease related to AATD, and an FEV1 $>$ 65% should be considered for augmentation. Individual discussion is recommended with consideration of the cost of therapy and lack of evidence for much benefit,⁽¹⁰⁸⁵⁾ although recent studies comparing mortality in severe COPD associated with AATD have observed a survival advantage of augmentation.⁽¹⁰⁸⁶⁾ The main limitation for this therapy is the very high cost and lack of availability in many countries.

Antitussives

The role of antitussives in people with COPD is inconclusive.⁽¹⁰⁸⁷⁾

Vasodilators

Vasodilators have not been properly assessed in COPD patients with severe/disproportionate pulmonary hypertension. Inhaled nitric oxide can worsen gas exchange because of altered hypoxic regulation of ventilation-perfusion balance and is contraindicated in stable COPD.⁽¹⁰⁸⁸⁾ Studies have shown that sildenafil does not improve the results of rehabilitation in people with COPD and moderately increases pulmonary artery pressure.⁽¹⁰⁸⁹⁾ Tadalafil does not appear improve exercise capacity or health status in COPD patients with mild pulmonary hypertension.⁽¹⁰⁹⁰⁾

Management of mucus hypersecretion

Treatment goals for patient with chronic bronchitis (CB) include: 1) reducing the overproduction of mucus; 2) decreasing mucus hypersecretion by reducing inflammation; 3) facilitating elimination of mucus by increasing ciliary transport; 4) decreasing mucus viscosity; and 5) facilitating cough mechanisms. Smoking cessation can improve cough by improving mucociliary function and decreasing goblet cell hyperplasia.⁽¹⁰⁹¹⁾ Smoking cessation may decrease airway injury by limiting immune mechanisms that cause persistent inflammation and abnormal epithelial cell gene expression.⁽¹⁰⁹²⁾

Mucus clearance treatments that promote mechanical movement through the airway such as oscillating positive expiratory pressure (OPEP) therapy may improve mucus mobilization, symptoms and quality of life in people with COPD who produce sputum daily or most days.^(1093,1094) The use of nebulized hypertonic saline for copious mucus has been used in obstructive lung disease and cystic fibrosis with beneficial effects. However, in patients with COPD, current studies are limited, and results are inconsistent ⁽¹⁰⁹⁵⁻¹⁰⁹⁹⁾

Long-acting muscarinic antagonists, predominantly tiotropium and aclidinium, can improve sputum production and decrease cough in patients with moderate to severe COPD.⁽¹¹⁰⁰⁻¹¹⁰³⁾ Triple therapy with dual long-acting bronchodilators combined with inhaled steroids may be effective in reducing exacerbations and improving lung function and quality of life regardless of the presence of mucus hypersecretion.

Use of mucolytics was associated with a reduction of 0.03 exacerbations per participant per month compared with placebo, that is, about 0.36 per year, or one exacerbation every three years. Very high heterogeneity was noted for this outcome, so results need to be interpreted with caution.⁽¹⁰³²⁾ Nevertheless, in participants with chronic bronchitis

or COPD, we are moderately confident that treatment with mucolytics may produce a small reduction in acute exacerbations and a small effect on overall quality of life.⁽¹⁰³²⁾ Recombinant human DNase has similarly shown lack of benefit in mucopurulent patients with COPD.^(1104,1105) New classes of mucolytics agents are being developed.⁽¹¹⁰⁶⁾ In a small double-blind placebo-controlled study, patients randomized to receive a CFTR potentiator icenticaftor had improvements in FEV1 and sputum bacterial colonization compared to placebo.⁽¹¹⁰⁷⁾ New bronchoscopic interventions have been proposed to reduce mucus hypersecretion by eliminating airway goblet cell hyperplasia and submucosal glands. Liquid nitrogen metered cryospray, rheoplasty, and targeted lung denervation are currently under evaluation.⁽¹¹⁰⁸⁻¹¹¹¹⁾

Overview of the evidence: Non-pharmacological therapy

Self-management

A Delphi process has resulted in a conceptual definition for COPD self-management interventions: “A COPD self-management intervention is structured but personalized and often multi-component, with goals of motivating, engaging and supporting the patients to positively adapt their health behavior(s) and develop skills to better manage their disease.”⁽⁷⁶²⁾ The process requires iterative interactions between patients and healthcare professionals who are competent in delivering self-management interventions. Behavior change techniques are used to elicit patient motivation, confidence and competence. Literacy sensitive approaches are used to enhance comprehensibility.⁽⁷⁶²⁾

Systematic reviews have provided evidence that self-management interventions improve outcomes in COPD. A 2022 Cochrane review reported that interventions for people with COPD are associated with improvements in HRQoL, a lower probability of respiratory-related hospital admissions, and no excess respiratory-related and all-cause mortality risks.⁽⁷⁶⁶⁾ This strengthens the view that self-management interventions are unlikely to cause harm. There had previously been concerns that health benefits from self-management programs in COPD could be counterbalanced by increased mortality.^(1112,1113) However, a previous Cochrane review and another meta-analysis reported no impact of self-management interventions on overall mortality, and while the Cochrane review did find a small, but statistically significant, higher respiratory-related mortality rate in the self-management intervention group as compared to usual care, the authors of the review stated the results should be interpreted with caution as misclassification in cause of death is common, the overall effect was dominated by two studies, and no effect on all-cause mortality was seen in the overall analysis. Furthermore, two independent, well-designed studies, the COMET⁽¹¹¹⁴⁾ and the PIC-COPD,⁽¹¹¹⁵⁾ have shown the potential for reduction in mortality from integrated case management with self-management interventions. The program in these two studies may have promoted earlier appropriate treatment for exacerbations, which could have prevented some fatal complications. These data, in conjunction with the most recently published Cochrane review, once again strengthens the view that self-management interventions are unlikely to cause harm.⁽⁷⁶⁶⁾

An RCT has shown that implementation of a comprehensive 3-month program to improve long-term self-management of *patients recently discharged from hospital* with COPD exacerbation resulted in nearly two-fold higher rates of COPD-related hospitalizations and emergency visits over 6 months. These data suggest that self-management strategies in recently hospitalized patients may lead to increased health care service utilization compared with usual care.⁽¹¹¹⁶⁾

There remain problems with heterogeneity among interventions, consistency of their application, specifics of the intervention, patient populations, follow-up times and outcome measures that make generalization difficult in real life. It is also challenging to formulate clear recommendations regarding the most effective form and content of a self-management intervention in COPD given the range of heterogeneity across studies, and lack of precise definitions of self-management components (e.g., skills taught) and fidelity measures. The recent conceptual definition should help redress these deficiencies. For example, in the definition it is mentioned that: “The process requires iterative

interactions between patients and healthcare professionals who are competent in delivering self-management interventions.” Having proper health coaching is important to improve self-management abilities. In people with COPD admitted for an exacerbation, a study has reported the positive effect of health coaching, commencing at the time of hospital discharge, on reducing risk of re-hospitalization and emergency department visits.⁽¹¹¹⁷⁾ Furthermore, this randomized study indicated that health coaching delivered by a respiratory therapist or nurse may improve self-management abilities as demonstrated by meaningful improvements in Chronic Respiratory Disease Questionnaire mastery scores.⁽¹¹¹⁸⁾

Integrated care programs

COPD is a complex disease that requires the input of multiple care providers who need to work together closely. In principle, use of a formal structured program that determines how each component is delivered should make care more efficient and effective, but the evidence for this is divided. Currently available evidence is conflicting regarding the benefits of integrated care/disease management programs in terms of quality of life, exercise capacity, and use of healthcare resources.⁽¹¹¹⁹⁻¹¹²¹⁾ Besides, delivering integrated interventions by telemedicine did not show a significant effect.^(1122,1123) The pragmatic conclusion is that well organized care is important, but there may be no advantage in structuring it tightly into a formalized program. Furthermore, integrated care needs to be individualized to the stage of the person’s illness and health literacy.

Physical activity

Pulmonary rehabilitation, including community and home-based, is an approach with clear evidence of benefits. However, the challenge is promoting physical activity and maintaining it. There is evidence that physical activity is decreased in COPD patients.⁽¹¹²⁴⁾ This leads to a downward spiral of inactivity which predisposes patients to reduced quality of life, increased rates of hospitalization and mortality.⁽¹¹²⁵⁻¹¹²⁷⁾ As such, there has been tremendous interest in implementing behavior-targeted interventions with the aim of improving physical activity⁽¹¹²⁸⁾ and these should be encouraged.⁽¹¹²⁹⁾ Technology-based interventions have the potential to provide convenient and accessible means to enhance exercise self-efficacy, and to educate and motivate people in their efforts to make healthy lifestyle changes.⁽¹¹²⁹⁾ The use of an internet-mediated intervention may benefit people with COPD with low baseline self-efficacy to increase physical activity.⁽¹¹³⁰⁾ However, most published studies to date provide little guidance, being inconsistent in the techniques, and lacking the necessary details (e.g., type, quantity, timing and method of delivery; tools used; quality-assurance methods) to replicate the study or adapt the interventions for clinical care. One RCT that evaluated the long-term effectiveness of a community-based physical activity coaching intervention in people with COPD exacerbation history showed no benefits in acute care use or survival.⁽¹¹³¹⁾ Another pedometer-based physical activity interventional study (pedometer alone or pedometer plus a website with feedback) showed an association between the intervention and reduced risk for acute exacerbations over 12-15 months of follow-up.⁽¹¹³²⁾ Non-pharmacological interventions such as pursed lip breathing and diaphragmatic breathing have also been shown to improve pulmonary function and increased exercise capacity in patients with COPD.⁽¹¹³³⁾

Exercise training

A meta-analysis of RCTs found that exercise training alone, or with the addition of activity counseling, significantly improved physical activity levels in COPD patients.⁽¹¹³⁴⁾ A combination of constant load or interval training with strength training provides better outcomes than either method alone.⁽¹¹³⁵⁾

Where possible, endurance exercise training to 60-80% of the symptom-limited maximum work or heart rate is preferred,⁽¹¹³⁶⁾ or to a Borg-rated dyspnea or fatigue score of 4 to 6 (moderate to severe).⁽¹¹³⁷⁾ Endurance training can be accomplished through either continuous or interval exercise programs. The latter involves the patient doing the same total work but divided into briefer periods of high-intensity exercise, a useful strategy when performance is limited by other comorbidities.^(1138,1139)

In some cultures, other alternatives such as Tai Chi practice, emphasizing the use of 'mind' or concentration for control of breathing and circular body movement, has been shown to improve exercise capacity in comparison to usual care in COPD patients.⁽¹¹⁴⁰⁾ However, from this meta-analysis, the effects of Tai Chi in reducing dyspnea level and improving quality of life remain inconclusive. Future studies addressing these topics and the most beneficial protocols for Tai Chi practice are warranted.

Exercise training can be enhanced by optimizing bronchodilators,⁽⁹²³⁾ since both LAMA and LABA have shown reduced resting and dynamic hyperinflation. These changes contribute to better training effects.^(306,1141) Adding strength training to aerobic training is effective in improving strength, but does not improve health status or exercise tolerance.⁽¹¹⁴²⁾ Upper extremities exercise training improves arm strength and endurance, and results in improved functional capacity for upper extremity activities.⁽¹¹⁴³⁾ Exercise capacity may also be improved by whole-body vibration training.⁽¹¹⁴⁴⁾

Inspiratory muscle training increases strength of inspiratory muscles,⁽¹¹⁴⁵⁾ but this not consistently translate to better performance, reduced dyspnea or improved health related quality of life when added to a comprehensive pulmonary rehabilitation program.⁽¹¹⁴⁶⁻¹¹⁴⁸⁾

Pulmonary rehabilitation

The benefits to COPD patients from pulmonary rehabilitation are considerable (**Figure 3.24**), and rehabilitation has been shown to be the most effective therapeutic strategy to improve shortness of breath, health status and exercise tolerance.⁽¹¹⁴⁹⁾ Pulmonary rehabilitation is appropriate for most people with COPD; improved functional exercise capacity and health related quality of life have been demonstrated across all grades of COPD severity, although the evidence is especially strong in patients with moderate to severe disease. Even patients with chronic hypercapnic failure show benefit.^(1150,1151)

Exercise-induced oxygen desaturation can be seen in a significant minority of COPD patients and has been associated with impaired quality of life, exacerbation risk, and mortality.⁽¹¹⁵²⁾ A large RCT did not suggest clinical improvement with long term oxygen therapy for patients without resting hypoxemia but exertional desaturation.⁽¹¹⁵³⁾ During pulmonary rehabilitation it is common practice to supplement oxygen during exercise training with the aim of facilitating higher exercise intensity. There was little support for oxygen supplementation during exercise training for individuals with COPD from a 2007 systematic review,⁽¹¹⁵⁴⁾ but most evidence was limited by low study quality. A large RCT,⁽⁷⁷³⁾ with blinding of participants, trainers and assessors, demonstrated that COPD patients training with either supplemental oxygen or medical air had significantly improved exercise capacity and health-related quality of life; no greater benefit with oxygen was observed. The incidence and severity of adverse events were similar in both groups. In patients with severe COPD on long-term oxygen therapy (LTOT) in whom exercise training is done with oxygenation systems, there has been increased interest in using an alternative tool, namely nasally administered mixtures of humidified air-oxygen blends at flow rates of 20-60 L/min (HFNT). HFNT may reduce respiratory muscle load and respiratory rate, while increasing expiratory time.⁽¹¹⁵⁵⁾ In an RCT, the delivery of HFNT during training sessions, as compared with usual oxygen, was not associated with a greater improvement in endurance time, the primary outcome, or in health status.⁽¹¹⁵⁶⁾ However, a greater improvement in 6-minute walking distance (6MWD) test was observed with HFNT. A similar small trial suggested an improved walking distance.⁽¹¹⁵⁷⁾ The proportion of patients reaching the minimal clinically important difference (MCID) in endurance time and 6MWD was also significantly higher with HFNT. Finally, there was no significant difference between the two therapies in patients' satisfaction. Further studies are needed to evaluate the efficacy of this treatment.

Pulmonary Rehabilitation, Self-Management and Integrative Care in COPD

Figure 3.24

Pulmonary Rehabilitation	<ul style="list-style-type: none">• Rehabilitation is indicated in all patients with relevant symptoms and/or a high risk for exacerbation (Evidence A)• Pulmonary rehabilitation improves dyspnea, health status and exercise tolerance in stable patients (Evidence A)• Pulmonary rehabilitation reduces hospitalization among patients who have had a recent exacerbation (≤ 4 weeks from prior hospitalization) (Evidence B)• Pulmonary rehabilitation leads to a reduction in symptoms of anxiety and depression (Evidence A)
Education and Self-Management	<ul style="list-style-type: none">• Education is needed to change patient's knowledge but there is no evidence that used alone it will change patient behavior (Evidence C)• Self-management intervention with communication with a health care professional improves health status and decreases hospitalizations and emergency department visits (Evidence B)
Integrated Care Programs	<ul style="list-style-type: none">• Integrative care and telehealth have no demonstrated benefit at this time (Evidence B)
Physical Activity	<ul style="list-style-type: none">• Physical activity is a strong predictor of mortality (Evidence A). People with COPD should be encouraged to increase their level of physical activity although we still do not know how to best ensure the likelihood of success

There are data from large RCTs regarding the effectiveness of pulmonary rehabilitation after hospitalization for an acute exacerbation of COPD. A systematic review that included 13 RCTs reported reduced mortality, and number of readmissions among patients who had pulmonary rehabilitation initiated during hospitalization or within 4 weeks of discharge.⁽⁸⁴⁸⁾ Long-term effects on mortality were not statistically significant, but improvements in health-related quality of life and exercise capacity appeared to be maintained for at least 12 months. These results have been corroborated by real world evidence, from a large population-based cohort of more than 190,000 patients hospitalized for COPD in the US, in whom initiation of pulmonary rehabilitation within 90 days of discharge, while rare, was significantly associated with lower risk of mortality⁽⁸⁵¹⁾ and fewer rehospitalizations at one year.⁽¹¹⁵⁸⁾ One study has reported that initiating pulmonary rehabilitation before the patient's discharge may compromise survival through unknown mechanisms.⁽¹¹⁵⁹⁾ Pulmonary rehabilitation ranks as one of the most cost-effective treatment strategies.⁽⁷⁵²⁾

There are many challenges with pulmonary rehabilitation. Referral of patients who might benefit, uptake and completion of pulmonary rehabilitation is frequently limited, partly through provider ignorance as well as patients' lack of awareness of availability or benefits. The recommended length of pulmonary rehabilitation (minimum of 6 weeks) could also be a limitation in many countries due to funding constraints of insurance companies and/or national health funds. Virtual reality pulmonary rehabilitation could be an alternative combined or not with traditional exercise training; this may be of particular interest in countries where the length of pulmonary rehabilitation programs is limited to less than 4 weeks.⁽¹¹⁶⁰⁾ Another challenge is encouraging sustained long-term physical activity. Although the approach may need to be personalized, behavioral lifestyle physical activity intervention has shown promising results

i.e., the potential to decrease sedentarity and increase physical activity in patients with moderate to severe COPD.⁽¹¹⁶¹⁾ A major barrier to full participation is access, which is particularly limited by geography, culture, finances, transport and other logistics.^(750,800,807,1162)

Pulmonary rehabilitation can be conducted at a range of sites.⁽⁷⁵⁰⁾ Community-based and home-based programs have been shown to be as effective as hospital-based programs in randomized controlled trials,^(1163,1164) as long as the frequency and intensity are equivalent.⁽¹¹⁶⁵⁾ In countries where there is economic limitation or those with challenges because patients live in rural or remote regions, home-based programs that deliver exercise training using a stationary bicycle⁽¹¹⁶³⁾ or a walking program⁽¹¹⁶⁴⁾ could be considered as alternative to traditional hospital rehabilitation training programs. There is also evidence that standardized home-based pulmonary rehabilitation programs improve dyspnea in COPD patients.⁽¹¹⁶⁶⁾ However, in real life, traditional pulmonary rehabilitation with supervision remains the standard of care and first-line option, with home-based exercise likely to be a less effective alternative for people with COPD who are unable to attend pulmonary rehabilitation.⁽¹¹⁶⁷⁾ Another challenge is that the benefits of rehabilitation tend to wane over time. There is insufficient evidence, with conflicting research findings in the 11 available RCTs, to recommend continuation of lower intensity or lower frequency exercise programs with the aim of maintaining benefit long-term. However, if such programs are available, they should target health behavior taking into account the patient's own preferences, needs and personal goals.^(755,1168) Pulmonary rehabilitation may help reduce anxiety and depression symptoms.⁽¹¹⁶⁹⁾

Tele-rehabilitation

In- or out-patient pulmonary rehabilitation (PR) in COPD is effective in improving several clinically relevant outcomes.^(1149,1170) There is clear evidence that core components of PR including exercise training combined with disease-specific education and self-management interventions^(750,1149) can benefit almost every COPD patient.⁽¹¹⁷¹⁻¹¹⁷³⁾

However, there are many challenges encountered in the delivery of PR, which include systemic barriers integral to some health care systems leading to a scarcity of in-person PR programs and facilities. In many regions, the programs that do exist tend to be located in urban areas. Hence attending PR is challenging for many COPD patients. Even for those patients residing in urban areas, availability of frequent transportation that is required for out-patient PR may still be a challenge.

Tele-rehabilitation has been proposed as an alternative to the traditional approaches. This has become even more relevant in the COVID-19 pandemic era where in-person PR has not been feasible, and models of delivery had to be adapted. However, it is important to distinguish between evidence-based tele-rehabilitation models and pandemic-adapted models. Most of the available evidence regarding tele-rehabilitation has been analyzed in a recent Cochrane review.⁽⁷⁶⁵⁾

Across multiple trials performed in groups and individuals with a large variety of tele-rehabilitation delivery platforms (videoconferencing, telephone only, website with telephone support, mobile application with feedback, centralized "hub" for people to come together), the reported results suggest that tele-rehabilitation is safe and has similar benefits to those of center-based PR across a range of outcomes. The evidence-based models from the Cochrane review were published before the COVID-19 pandemic, and have all included an in-person exercise test at the center prior to commencement, for the purposes of assessing the full extent of desaturation during exercise training⁽¹¹⁷⁴⁾ and accurately prescribing exercise capacity.⁽¹¹⁷⁵⁾

Promoting physical activity is also central to the recommendations that should be given to every COPD patient regardless of disease severity. Promoting physical activity using smartphone apps is gaining popularity although at present data on effectiveness are lacking.⁽¹¹⁷⁶⁾

In the field of tele-rehabilitation, the evidence base is still evolving and best practices are not yet established at this time due to a lack of: i) standardization of delivery platform, e.g., no one single best mode of tele-rehabilitation delivery; ii) tests performed remotely allowing for accurate exercise prescription; iii) information on suitable variations in components and timing of interventions (e.g., no data are available regarding post-exacerbation rehabilitation); and iv) evidence about duration of benefit (beyond immediate post PR). Furthermore, it is unclear what types of patients were recruited to these studies or their level of familiarity with the technology used. In order to ensure that PR is accessible to all, we must understand the barriers that might be unique to tele-rehabilitation.

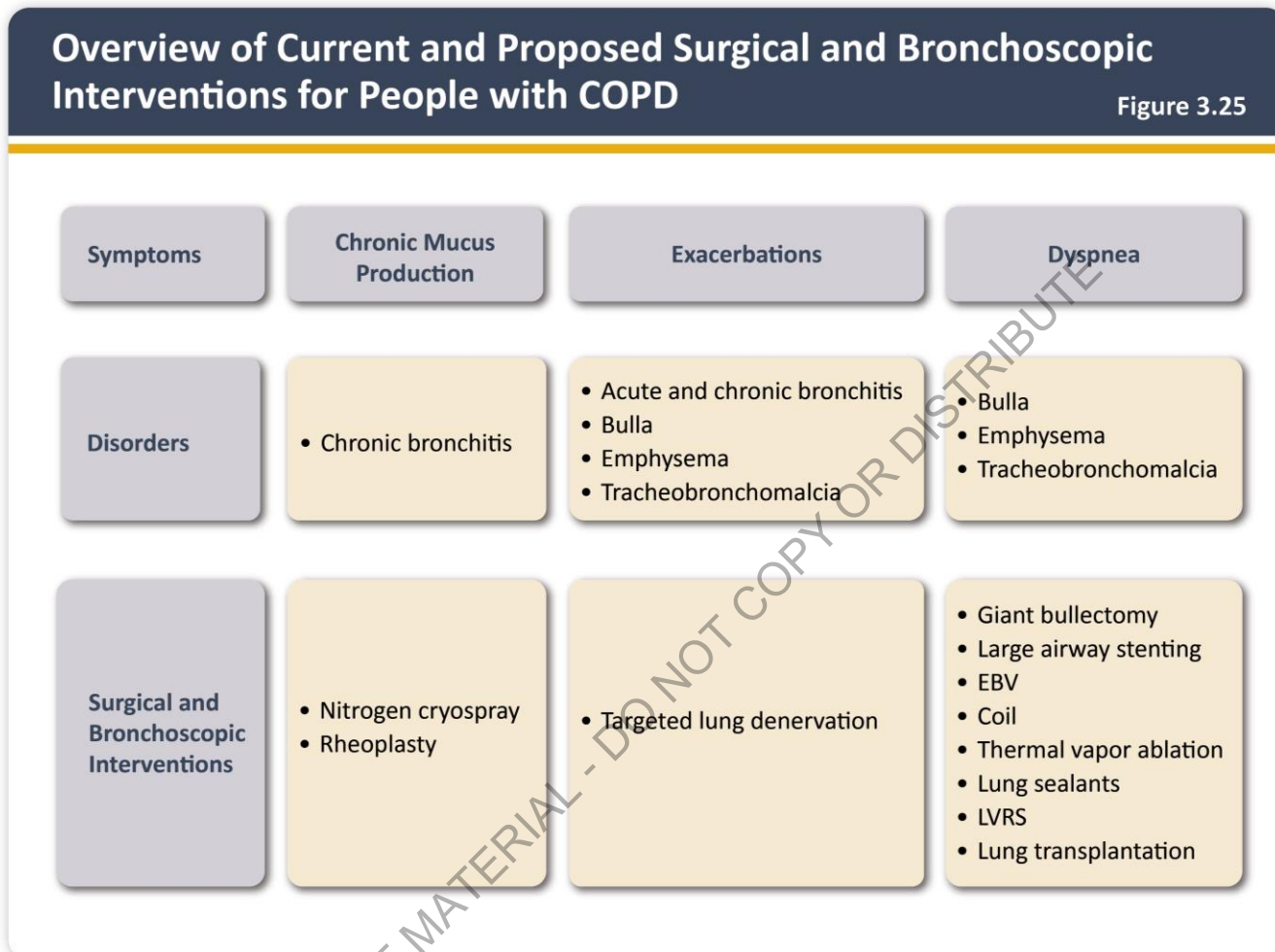
Nutritional support

In people with COPD, weight loss and malnutrition develop as disease severity progresses and indicates a poor prognosis. Malnutrition in COPD is associated with impaired lung function, increased hospitalizations, poor exercise tolerance, worsened quality of life and increased mortality.^(360,1177-1181) Malnutrition has been reported in 30-60% of patients hospitalized with COPD;⁽¹¹⁸²⁾ up to 50% of people with COPD weigh less than 90% of ideal body weight.⁽¹¹⁸³⁾ Weight loss occurs when energy expenditure exceeds energy supply; in people with COPD decreases in appetite and oral intake often coincide with elevated systemic levels of pro-inflammatory cytokines and the appetite suppressant hormone, leptin.^(1184,1185) The severity of airflow obstruction correlates with the presence of malnutrition⁽¹¹⁸⁶⁾ since ventilator inefficiency increases daily energy requirements.⁽¹¹⁸⁷⁾ The imbalance of decreased oral intake and increased energy expenditure can lead to a negative nitrogen balance and decreases in skeletal muscle mass and function.⁽¹¹⁸⁸⁻¹¹⁹⁰⁾

Nutritional repletion in people with COPD should be coupled with optimization of lung function, regular exercise, and improvement of tissue oxygenation. Dietary advice and oral supplementation have been reported to improve body weight, quality of life, respiratory muscle strength and 6-minute walk distance.^(826,1182) However, nutritional support has not been consistently shown to improve lung function.^(826,1191-1193) Multimodality treatment that incorporates rehabilitation with nutritional support and protein supplementation may improve fat free mass, BMI and exercise performance.⁽¹¹⁹⁴⁾ Among malnourished, hospitalized people with COPD, a protein enriched supplementation decreased mortality and improved handgrip strength, body weight and nutritional biomarkers 90 days post hospital discharge.⁽¹¹⁹⁵⁾

INTERVENTIONAL & SURGICAL THERAPIES FOR COPD

COPD is associated with airway and lung parenchyma structural changes that provide potential targets for interventional and surgical treatments to alleviate dyspnea, reduce cough and mucus production, and improve quality of life (Figure 3.25).



Lung structural related therapies for COPD include airway and emphysematous predominant treatments. Phenotyping patients with clinical, physiological, and imaging tests is critical to select appropriate candidates and in assessing the benefits, timing, and type of intervention to be performed. Multidisciplinary collaboration of pulmonology, thoracic surgery and imaging disciplines are necessary to ensure quality outcomes.

Airway predominant treatments are currently the subject of Phase III clinical trials; emphysematous based treatments include bullectomy, lung volume reduction surgery, bronchoscopic lung reduction and in select cases, lung transplantation. Each of these therapies are reviewed below.

Surgical and interventional treatments for patients with emphysema depends upon the severity of patient symptoms despite optimized medical treatment, the specific structural abnormalities and features of the lung seen on CT imaging, the presence of pulmonary and non-pulmonary comorbid conditions, physiological assessment, and the balance of benefits and risks for the individual patient.

Lung surgical treatments for patients with emphysema

Bullectomy

Giant bullectomy is a rare, but effective procedure for surgical resection of bulla that occupies > one-third of a hemithorax and compresses adjacent viable lung tissue. Reductions in dyspnea, and improvements in lung, respiratory muscle, and cardiac performance, as well as exercise tolerance have been reported.⁽¹¹⁹⁶⁻¹¹⁹⁸⁾ Blood or thrombin instillation may be effective in those unfit for resection.⁽¹¹⁹⁹⁻¹²⁰¹⁾

Lung volume reduction surgery (LVRS)

Lung hyperinflation is a major contributor to impaired respiratory function and is associated with increased hospitalization and mortality. Hyperinflation increases the sensation of breathlessness and causes a reduction in exercise due to increased chest wall elastance and reduced respiratory muscle and cardiac mechanics. Hyperinflation is most pronounced in those patients with COPD that have an emphysematous predominant phenotype.

With LVRS, the most emphysematous portions of the lungs are resected to reduce hyperinflation,⁽¹²⁰²⁾ and increase lung elastic recoil pressure and density.⁽¹²⁰³⁾ The structural changes that result from LVRS can significantly improve expiratory flow and chest wall, respiratory muscle and cardiac mechanics.^(1204,1205) that results in improvements in FEV1, walking distance and quality of life.⁽¹²⁰⁶⁻¹²⁰⁹⁾ LVRS can be performed unilaterally or bilaterally. In the National Emphysema Treatment Trial (NETT), a RCT that included severe emphysema patients, bilateral LVRS improved survival in patients with upper-lobe emphysema and low post-rehabilitation exercise capacity.⁽³¹³⁾ In similar patients with high post-pulmonary rehabilitation exercise capacity, no difference in survival was noted after LVRS, although health status and exercise capacity improved. A reinterpretation of the NETT data at 5 years post treatment showed sustained improvements in lung function, exercise, shortness of breath and quality of life.⁽¹²¹⁰⁾

LVRS has been demonstrated to result in higher mortality than medical management in severe emphysema patients with FEV1 \leq 20% predicted and either homogeneous emphysema on high resolution computed tomography or a DLco \leq 20% of predicted.⁽¹²¹¹⁾ In addition to a lower DLco, a lower FEV1 and BMI have also been reported to increase mortality.⁽¹²¹²⁾ Postoperative BODE (body mass index, degree of airflow obstruction, level of dyspnea and exercise capacity) is a predictor of survival following LVRS.⁽¹²¹³⁾ Successful outcomes with LVRS have been reported in select patients with severely impaired DLco when hyperinflation is severe, and associated with approachable emphysematous targets for resection.⁽¹²¹⁴⁾ Identification of target zones using three-dimensional computed tomographic imaging is beneficial in selecting resectable target zones.⁽¹²¹⁵⁾ A prospective economic analysis in NETT indicated that LVRS is costly relative to healthcare programs that do not include surgery.⁽¹²¹⁶⁾

Post NETT, experienced centers have reported substantial physiological and functional improvements with LVRS with reduced morbidity and mortality.^(1217,1218) However, the numbers of patients undergoing LVRS remain low worldwide.^(1218,1219) Several patient factors such as difficulty in obtaining referrals, the perception of increased surgical complications, and limited continuity of care are reasons why the numbers of patients undergoing LVRS remain low despite its reported benefits.⁽¹²²⁰⁾ Additionally, respiratory physicians are reluctant to refer patients for LVRS because of the uncertainty about the associated complications, or lack of access to a multidisciplinary team to discuss patient candidates.⁽¹²²¹⁾ To achieve successful outcomes, a multidisciplinary team is key to select potential LVRS patients and coordinate postoperative care.⁽¹²²²⁾

Lung transplantation

Over 1,000 patients with COPD undergo lung transplantation on an annual basis, about 30.6% of all patients that undergo transplantation.⁽¹²²³⁾ Since implementation of the lung allocation severity (LAS) scoring system, the numbers of patients undergoing lung transplantation for COPD is exceeded by the numbers of patients receiving transplantation for interstitial lung diseases. Patients with COPD should be referred for consideration of lung transplantation when

they have progressive disease despite maximal medical treatment, are not candidates for lung volume reduction surgery, have a BODE index of 5 to 6, a PaCO₂ > 50 mmHg (6.6 kPa) and/or PaO₂ < 60 mmHg (8 kPa) and FEV₁ < 25%.⁽¹²²⁴⁾ They should be considered for listing for lung transplantation when the BODE index is > 7, FEV₁ is < 15% to 20%, and they have had three or more severe exacerbations during the previous year, one severe exacerbation with hypercapnic respiratory failure, or have moderate to severe pulmonary hypertension.⁽¹²²⁴⁾ In the last decade, lung transplant has been increasingly performed in patients of older age, higher BMI, prior chest surgery, poor nutritional status, prior evidence of chronic infection, cardiovascular disease, or extrapulmonary comorbid conditions.⁽¹²²⁵⁾

Lung transplantation in patients with COPD has been predominately associated with an improvement in quality of life, not an increase in survival except for COPD patients with severe AATD or those severely impaired with high BODE scores.^(1196,1226-1232) The median survival post lung transplantation for COPD is 5.9 years.⁽¹²²³⁾ Over 70% of lung transplants conducted in COPD patients are double lung transplants; the remainder are single lung transplants.⁽¹²³³⁾ Bilateral lung transplantation leads to longer survival in patients with COPD especially in those < 60 years of age.^(1234,1235)

Two unique native lung complications have been proposed to account for the superiority of double lung transplantation in patients with COPD, native lung hyperinflation and lung cancer occurrence in the native lung.^(1236,1237) Lung cancer has been reported to occur in the native lung following single lung transplantation with an incidence of 5.2-6.1%.^(1237,1238) Native lung hyperinflation following single lung transplantation for COPD has been reported to occur 15-30% of the time.^(1239,1240) Positive pressure ventilation in a patient with COPD with an overly compliant native lung coupled with reduced compliance in an edematous allograft may result in native lung hyperinflation. However, some studies have shown no impact of single lung transplant on post-transplant morbidity, and even improved survival following single lung transplantation in patients with COPD.^(1239,1241,1242) Limitations in these studies include the retrospective nature of design, the potential for selection bias, missing covariates, and center-specific practice patterns.

In general, lung transplantation has limited availability due to the shortage of donor organs and cost, thus single vs. double lung transplantation is balanced between individual patient factors vs. societal demands to increase the donor pool for eligible recipients.⁽¹²⁴³⁾ The complications most seen in COPD patients after lung transplantation are acute rejection, bronchiolitis obliterans, opportunistic infections and lymphoproliferative disease.⁽¹²⁴⁴⁾

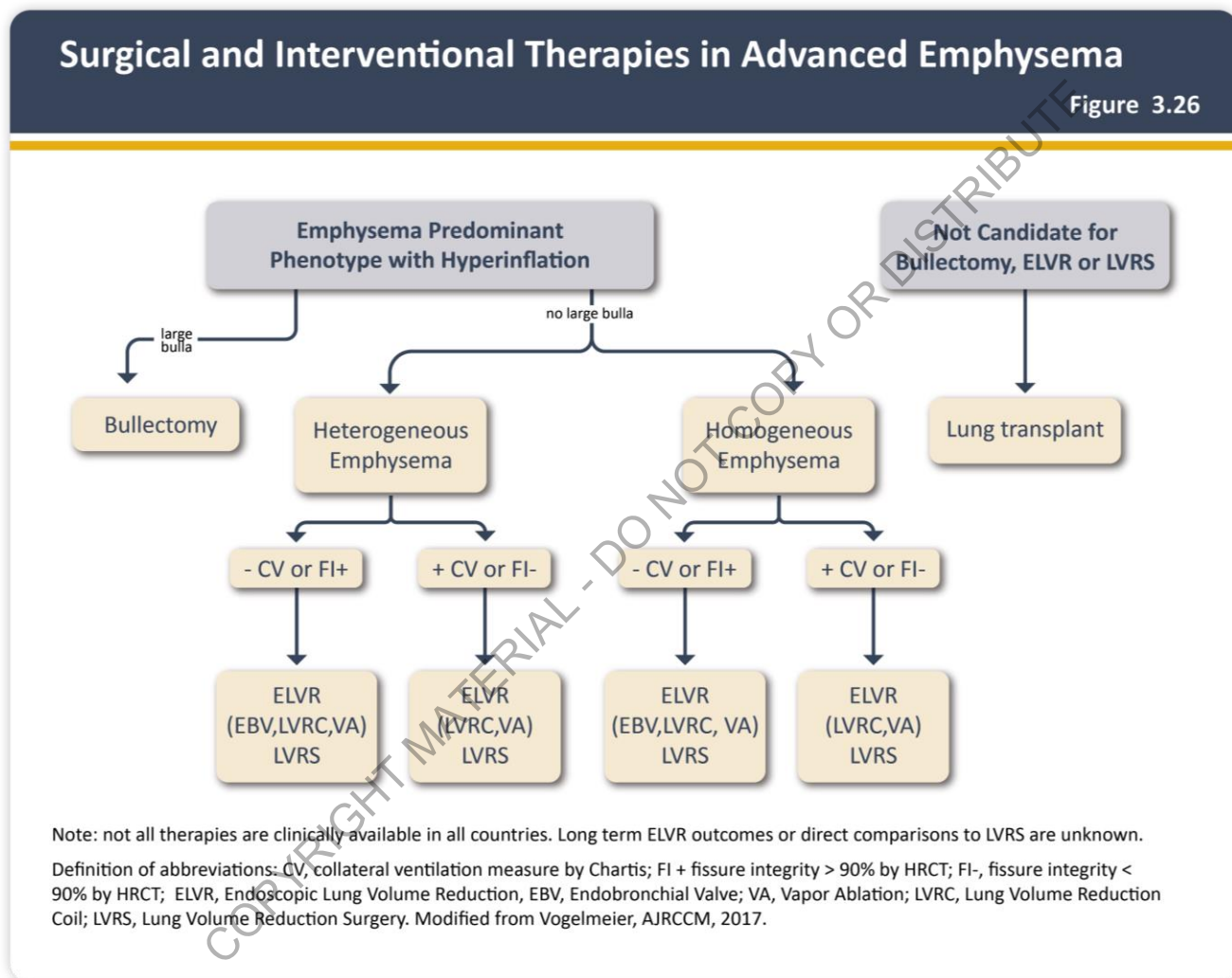
Bronchoscopic interventions in COPD

- ▶ In selected patients with heterogeneous or homogenous emphysema and significant hyperinflation refractory to optimized medical care, surgical or bronchoscopic modes of lung volume reduction (e.g., endobronchial one-way valves, lung coils or thermal ablation) may be considered.⁽¹²⁴⁵⁾ Some of these therapies (vapor ablation and lung coils) are not widely available for clinical care in many countries.
- ▶ In selected patients with a large bulla, surgical bullectomy may be considered.
- ▶ In selected patients with very severe COPD and without relevant contraindications, lung transplantation may be considered.

Bronchoscopic Interventions to reduce hyperinflation in severe emphysema

Due to the morbidity and mortality associated with LVRS, less invasive bronchoscopic approaches to lung reduction have been examined.⁽¹²⁴⁶⁾ These include a variety of different bronchoscopic procedures to perform lung volume reduction (i.e., endoscopic lung volume reduction, ELVR) including airway bypass stents, endobronchial one-way valves (EBV), self-activating coils, sealants and thermal ablative techniques.⁽¹²⁴⁶⁾ Although these techniques differ markedly from one another they are similar in their objective to decrease thoracic volume to improve lung, chest wall and respiratory muscle mechanics.

Choosing bronchoscopic lung reduction (endobronchial valve, coil placement or thermal ablation) or surgical resection (lung volume reduction surgery, LVRS) to treat hyperinflation in an emphysematous patient depends on a number of factors. These include: the extent and pattern of emphysema identified on HRCT; the presence of interlobar collateral ventilation measured by fissure integrity on HRCT or physiological assessment (endoscopic balloon occlusion and flow assessment); regional availability of the various therapies for clinical care, local proficiency in the performance of the procedures; and patient and provider preferences. Bronchoscopic techniques depend upon the presence of an intact fissure between the treated and non-treated lobe for EBV to be successful, but not for the other techniques. Vapor ablation therapy is the only lung reduction therapy that has been reported to be successfully performed at the segmental rather than lobar level.⁽¹²⁴⁷⁾ **Figure 3.26** provides an overview of the various interventional and surgical options for patients with emphysema.



Endobronchial one-way valves (EBV)

EBV are the most well studied therapy of all the ELVR techniques. RCTs showed significant increases in FEV1 and 6-minute walk distance as well as health status in subjects selected for the absence of interlobar collateral ventilation compared to the control group at 6 and 12 months.^(315,560) Adverse effects in the endobronchial valve treatment group in both studies included pneumothorax, valve removal or valve replacement.⁽⁵⁶⁰⁾ Pneumothorax was seen in 26.6% of subjects treated with the endobronchial valve usually within the first 72 hours of the procedure (76%).^(315,1248,1249) But benefits have also been shown in patients with heterogeneous compared to those with homogenous emphysema in one study.⁽⁵⁶⁰⁾

Early-onset pneumothorax in the EBV treated group likely results from lung structural changes due to acute volume

reduction in the emphysematous targeted lobe by valve therapy that triggers rapid ipsilateral non-targeted lobe expansion, a recognized indicator of successful target lobe occlusion in patients with intact fissures or absence of collateral ventilation.⁽³¹⁴⁾ Pleural adhesions may also be a contributing factor to the development of a pneumothorax.⁽¹²⁵⁰⁾ The occurrence of pneumothorax highlights the need for physicians performing this procedure to have expertise in the management of procedural complications.⁽³¹⁴⁾

After the post-procedural period however, patients treated with EBV compared to usual care tend to have a lower number of exacerbations and episodes of respiratory failure. A comparison of treatment benefits and complications associated with EBV compared to LVRS show comparable benefits with endobronchial valve treatment but with fewer complications.⁽³¹⁵⁾ Additionally, ELVR has similar beneficial effects whether it is performed in the upper or lower lobes.^(314,315)

Improved survival has been associated with post procedural atelectasis of the treated lobe post EBV.⁽¹²⁵¹⁻¹²⁵³⁾ Improved survival has also been reported in patients with severe hyperinflation undergoing EBV compared to a matched population not undergoing ELVR.⁽¹²⁵⁴⁾

When preferences for medical treatment for patients with severe emphysema are elicited, the majority chose treatments with EBV over LVRS or continued medical therapy.⁽¹²⁵⁵⁾ ELVR with EBV is clinically available and approved for treatment in many countries in the treatment of patients who have intact fissures or lack collateral ventilation.^(315,1256,1257)

The following bronchoscopic lung volume reduction techniques do not depend upon the presence of intact fissures or absence of collateral ventilation.

Airway bypass stents

Airway bypass stents are transbronchial passages that are created through the walls of the central airways into the emphysematous parenchyma to facilitate the emptying of trapped gas. In a prospective randomized controlled clinical trial, patients had short term improvements, but no durable improvements were found in lung function, 6 MWD or quality of life.⁽¹²⁵⁸⁾

Sealants

A multicenter study examining the effects of a lung sealant to create lung reduction was discontinued prematurely; while the study reported significant benefits in some physiologic parameters, the intervention was associated with significant morbidity and mortality.⁽¹²⁵⁹⁾

Vapor ablation

In a prospective RCT, targeted thermal vapour ablation of more diseased emphysematous segments to produce fibrosis and atelectasis resulted in clinically meaningful and statistically significant improvements in lung function and health status at 6 months. COPD exacerbation was the most common serious adverse event. Durability of these changes was subsequently reported at 12 months follow-up.^(1247,1260) This therapy has limited clinical availability.

Self-activating coils

Multicenter trials have examined nitinol coils implanted into the lung compared to usual care on changes in 6-minute walk distance, lung function and health status in patients with advanced homogenous and heterogeneous emphysema. Studies reported an increase in 6-minute walk distance with coil treatment compared to control and smaller improvements in FEV1, and quality of life measured by St George's Respiratory Questionnaire.⁽¹²⁶¹⁻¹²⁶³⁾ Patients with baseline residual volume > 200% predicted, emphysema score > 20% low attenuation area, and absence of airway disease are more likely to have clinically meaningful improvements in lung function and quality of life.⁽¹²⁶⁴⁾

Major complications included pneumonia, pneumothorax, hemoptysis and COPD exacerbations occurring more frequently in the coil group.⁽¹²⁶²⁾ This therapy has limited clinical availability.

Additional data are needed to define the optimal bronchoscopic lung volume technique to produce bronchoscopic lung volume reduction in patients who lack fissure integrity, or exhibit collateral ventilation, and to refine the procedure to reduce complications and improve longer term clinical outcomes.⁽¹²⁶²⁾

Sequential performance of LVRS or ELVR prior to or following lung transplantation

Because COPD is a progressive disease, LVRS or ELVR may be followed by lung transplantation. Conversely, patients who undergo single lung transplantation may subsequently undergo LVRS or ELVR to treat the hyperinflated native lung. In hyperinflated patients with advanced emphysema, LVRS or ELVR might be effective treatments to either delay the need for lung transplantation or optimize the condition of patients who may eventually require lung transplantation.⁽¹²⁶⁵⁻¹²⁶⁷⁾ In some patients following single lung transplantation, the performance of LVRS or ELVR to decrease native lung hyperinflation may improve lung function and performance status.⁽¹²⁶⁸⁻¹²⁷³⁾ The incidence of postoperative bleeding requiring re-exploration and renal dysfunction requiring dialysis or the use of extracorporeal membrane oxygenation (ECMO) may be higher in patients undergoing lung transplantation following LVRS.^(1274,1275) Previous ELVR has been reported to have no impact on morbidity or survival post subsequent lung transplantation but may affect microbial colonization.^(1275,1276)

Airway predominant treatments

Abnormalities that predominantly involve the airways, such as excessive dynamic collapse of the large airways (tracheobronchomalacia) chronic bronchitis and frequent and severe exacerbations not responsive to optimal medical treatment pose significant clinical challenges.

Excessive dynamic airway collapse (EDAC)

EDAC or tracheobronchomalacia (TBM) is a disorder of the large airways where abnormal collapsibility occurs with expiration. Common symptoms are dyspnea, cough and wheezing with inability to expectorate phlegm. In a cross-sectional analysis of smokers, the presence of excessive dynamic airway collapse observed on CT imaging was 5% and associated with worsened quality of life and more frequent and severe exacerbations.⁽¹²⁷⁷⁾ Airway stenting and tracheoplasty may be beneficial in select patients.^(1278,1279)

Chronic bronchitis is a common and significant contributor to a worsening of patient's symptoms of cough and sputum production and cause worsened quality of life and increased mortality. No specific medical intervention significantly and consistently alleviates chronic bronchitis. Newer interventions have been proposed to reduce mucus hypersecretion by eliminating airway goblet cell hyperplasia and submucosal glands.

Nitrogen cryospray

Liquid nitrogen metered cryospray is delivered to the central airways and ablates the epithelium to a depth of 0.1 to 0.5 mm.⁽¹¹⁰⁸⁾ After treatment, rapid regeneration of normal epithelium occurs without scarring and may potentially treat chronic bronchitis.⁽¹²⁸⁰⁾

Another novel treatment for chronic bronchitis is rheoplasty.⁽¹²⁸¹⁾ Rheoplasty delivers short bursts of high frequency electrical energy to the airway epithelium targeting submucosal tissues and goblet cells to facilitate their replacement with healthier tissue. Ongoing phase III randomized clinical trials are evaluating the efficacy of these therapies.^(1282,1283)

Lung denervation

Targeted lung denervation is another therapy currently undergoing phase III clinical trial study to determine its impact

of frequent moderate or severe exacerbations in patients with COPD already on maximal inhaled respiratory treatment.^(1284,1285) The therapy intends to disrupt the parasympathetic nerve transmission to and from the lungs. In patients with COPD, basal parasympathetic tone is elevated and increases acetylcholine levels and mucus production and airway contraction. The treatment uses a water-cooled catheter with radiofrequency energy to disrupt parasympathetic nerve transmission while protecting the airway surface.^(1110,1111,1285,1286)

Key points for interventional therapy in stable COPD are summarized in **Figure 3.27**.

Interventional Therapy in Stable COPD	
Lung Volume Reduction Surgery	<ul style="list-style-type: none"> Lung volume reduction surgery improves survival in severe emphysema patients with an upper-lobe emphysema and low post-rehabilitation exercise capacity (Evidence A)
Bulectomy	<ul style="list-style-type: none"> In selected patients, bullectomy is associated with decreased dyspnea, improved lung function and exercise tolerance (Evidence C)
Transplantation	<ul style="list-style-type: none"> In appropriately selected patients with very severe COPD, lung transplantation has been shown to improve quality of life and functional capacity (Evidence C) In patients with very severe COPD (progressive disease, BODE score of 7 to 10, and not candidates for lung volume reduction) lung transplantation may be considered for referral with at least one of the following: (1) history of hospitalization for exacerbation associated with acute hypercapnia ($P_{CO_2} > 50$ mmHg); (2) pulmonary hypertension and/or cor pulmonale, despite oxygen therapy; or (3) $FEV_1 < 20\%$ and either $DL_{CO} < 20\%$ or homogenous distribution of emphysema (Evidence C)
Bronchoscopic Interventions	<ul style="list-style-type: none"> In select patients with advanced emphysema, bronchoscopic interventions reduce end-expiratory lung volume and improve exercise tolerance, health status and lung function at 6-12 months following treatment. Endobronchial valves (Evidence A); Lung coils (Evidence B); Vapor ablation (Evidence B)
Bronchoscopic Interventions Under Study	<ul style="list-style-type: none"> Phase III trials are currently being conducted to determine the efficacy of treatments for patients with refractory exacerbations and chronic bronchitis using cryospray, rheoplasty and targeted lung denervation technology

Surgery in the COPD patient

General surgery

Postoperative pulmonary complications are as important and common as postoperative cardiac complications and, consequently, are a key component of the increased risk posed by general surgery in COPD patients.⁽¹²⁸⁷⁾ The key factors that can contribute to the risk include smoking, poor general health status, age, obesity, and COPD severity. A comprehensive definition of postoperative pulmonary complications should include only major pulmonary respiratory complications, namely lung infections, atelectasis and/or increased airflow obstruction, which all potentially result in

acute respiratory failure and aggravation of COPD.⁽¹²⁸⁸⁻¹²⁹⁰⁾

Increased risk of postoperative pulmonary complications in COPD patients may vary with the severity of COPD, although the surgical site is the most important predictor and risk increases as the incision approaches the diaphragm.⁽¹²⁹⁰⁾ Most reports conclude that epidural or spinal anesthesia have a lower risk than general anesthesia, although the results are not totally uniform. Some studies conducted in patients undergoing sham bronchoscopic procedures have reported acute exacerbation rates as high as 8.4%.⁽¹²⁵⁸⁾ These data suggest that intubation and/or simple airway manipulation may increase the risk of exacerbation in select COPD patients.

To prevent postoperative pulmonary complications, stable COPD patients clinically symptomatic and/or with limited exercise capacity should be treated medically intensively before surgery, with all the measures already well established for stable COPD patients who are not about to have surgery. The presence of comorbid conditions, especially cardiac abnormalities, should be systemically assessed and treated before any major surgical intervention.

Lung resection

For lung resection, the individual patient's risk factors should be identified by careful history taking including physical examination, chest radiography, and pulmonary function tests. Although the value of pulmonary function tests remains contentious, there is consensus that all COPD candidates for lung resection should undergo a complete battery of tests, including spirometry with bronchodilator response, static lung volumes, diffusing capacity, and arterial blood gases at rest.^(1291,1292) COPD patients at high risk for surgical complications due to poor lung function should undergo further assessment, for example, tests of regional distribution of perfusion and exercise capacity.^(1291,1292)

The risk of postoperative complications from lung resection appears to be increased in patients with decreased predicted postoperative pulmonary function (FEV1 or DLco < 30-40% predicted) or exercise capacity (peak VO₂ < 10 ml/kg/min or 35% predicted). The final decision to pursue surgery should be made after discussion with the surgeon, pulmonary specialist, primary clinician, and the patient. Surgery should be postponed if an exacerbation is present.

CHAPTER 4: MANAGEMENT OF EXACERBATIONS

KEY POINTS:

- An exacerbation of COPD is defined as an event characterized by dyspnea and/or cough and sputum that worsen over < 14 days. Exacerbations of COPD are often associated with increased local and systemic inflammation caused by airway infection, pollution, or other insults to the lungs.
- As the symptoms are not specific to COPD relevant differential diagnoses should be considered, particularly pneumonia, congestive heart failure and pulmonary embolism.
- The goals for treatment of COPD exacerbations are to minimize the negative impact of the current exacerbation and to prevent subsequent events.
- Short-acting inhaled beta₂-agonists, with or without short-acting anticholinergics, are recommended as the initial bronchodilators to treat an exacerbation.
- Maintenance therapy with long-acting bronchodilators should be initiated as soon as possible. In patients with frequent exacerbations and elevated blood eosinophil levels addition of inhaled corticosteroids to the double bronchodilator regimen should be considered.
- In patients with severe exacerbations, systemic corticosteroids can improve lung function (FEV1), oxygenation and shorten recovery time including hospitalization duration. Duration of therapy should not normally be more than 5 days.
- Antibiotics, when indicated, can shorten recovery time, reduce the risk of early relapse, treatment failure, and hospitalization duration. Duration of therapy should be 5 days.
- Methylxanthines are not recommended due to increased side effect profiles.
- Non-invasive mechanical ventilation should be the first mode of ventilation used in COPD patients with acute respiratory failure who have no absolute contraindication because it improves gas exchange, reduces work of breathing and the need for intubation, decreases hospitalization duration and improves survival.
- Exacerbation recovery time varies, taking up to 4-6 weeks to recover, with some patients failing to return to the pre-exacerbation functional state. Following an exacerbation, appropriate measures for exacerbation prevention should be initiated (see **Chapter 3**).

DEFINITION

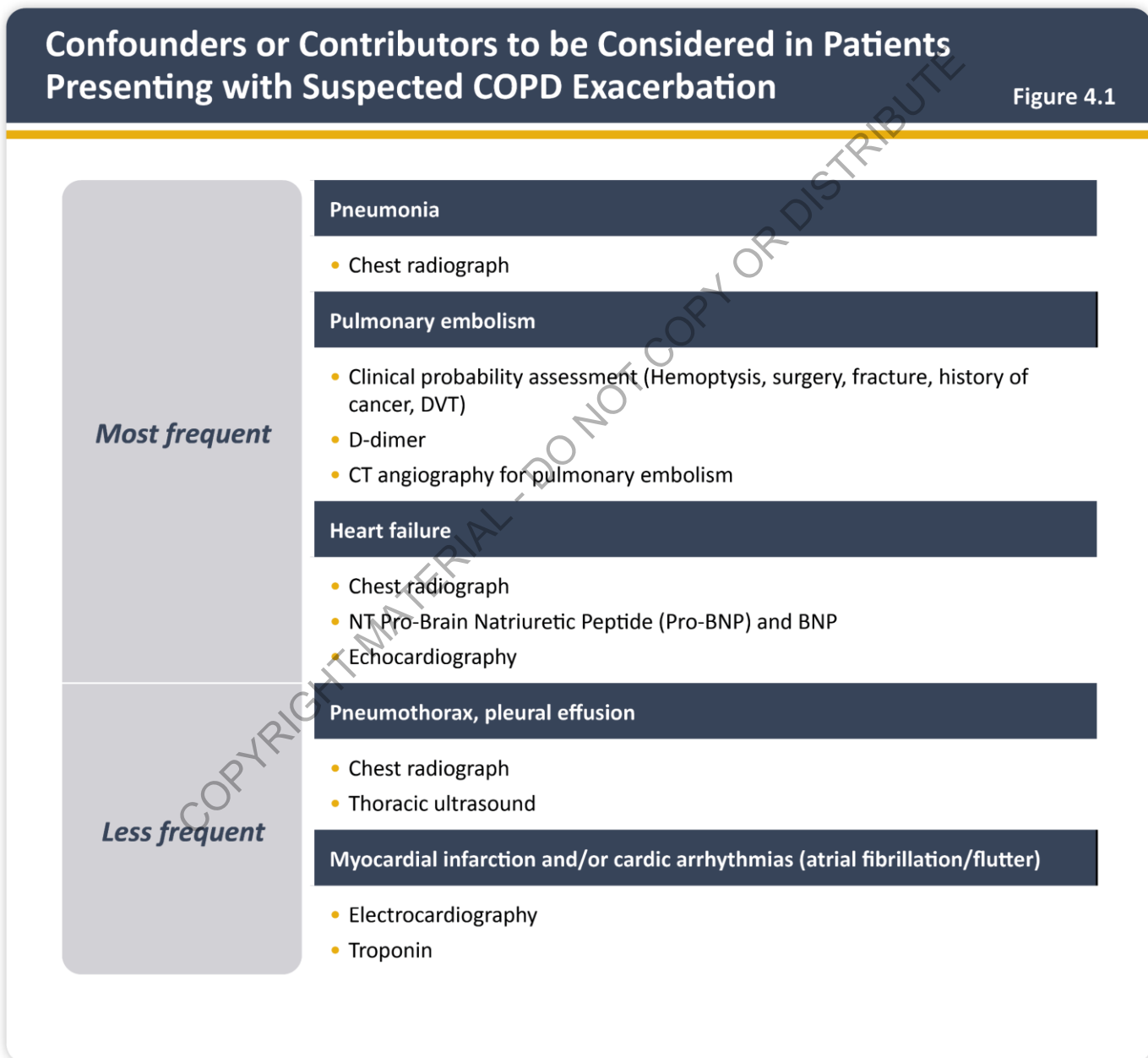
An exacerbation of chronic obstructive pulmonary disease (ECOPD) is defined as an event characterized by increased dyspnea and/or cough and sputum that worsens in < 14 days which may be accompanied by tachypnea and/or tachycardia and is often associated with increased local and systemic inflammation caused by infection, pollution, or other insult to the airways.⁽³²⁸⁾

Considerations

Exacerbations of COPD are important events in the management of COPD because they negatively impact health

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status, rates of hospitalization and readmission, and disease progression.^(483,484) COPD exacerbations are usually associated with increased airway inflammation, increased mucus production and marked gas trapping. These changes contribute to increased dyspnea that is the key symptom of an exacerbation. Other symptoms include increased sputum purulence and volume, together with increased cough and wheeze.^(1293,1294) Patients with COPD are at increased risk of other acute events, particularly decompensated heart failure,^(1295,1296) pneumonia,^(1297,1298) pulmonary embolism^(1299,1300) that may also mimic or aggravate an ECOPD. Thus, while worsening of dyspnea, particularly if associated with cough and, purulent sputum, and no other symptoms or signs in a patient with COPD may be diagnosed as an ECOPD, other patients may have worsening of respiratory symptoms, particularly dyspnea without the classic characteristics of ECOPD, that should prompt careful consideration and/or search of those potential confounders, or contributors. In some patients one or more of these diagnoses may contribute to the clinical presentations and should be addressed appropriately (**Figure 4.1**).



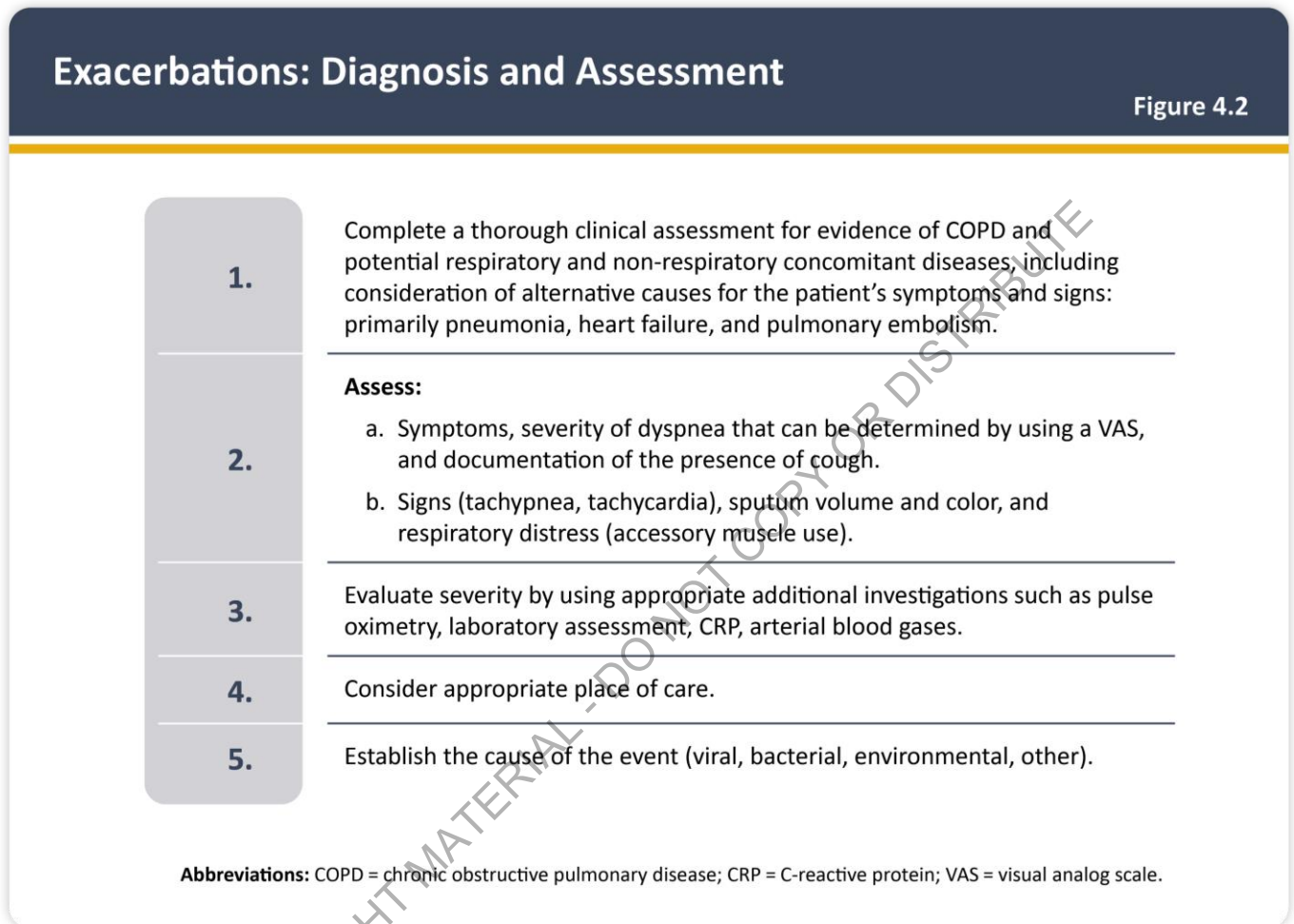
Currently, exacerbations are classified after the event has occurred as:

- ▶ Mild (treated with short acting bronchodilators only, SABDs)
- ▶ Moderate (treated with SABDs and oral corticosteroids ± antibiotics) or

- ▶ Severe (patient requires hospitalization or visits the emergency room). Severe exacerbations may also be associated with acute respiratory failure.

The current grading of the severity of an ECOPD, based on *post facto* use of healthcare resources, is a major limitation of the current definition. Because of global variability in the available resources to treat patients and local customs affecting the criteria for hospital visits and admissions, there is substantial variability in reported ECOPD outcomes. ⁽¹³⁰¹⁾

Figure 4.2 shows a proposed clinical approach based on the current best available evidence. ⁽³²⁸⁾



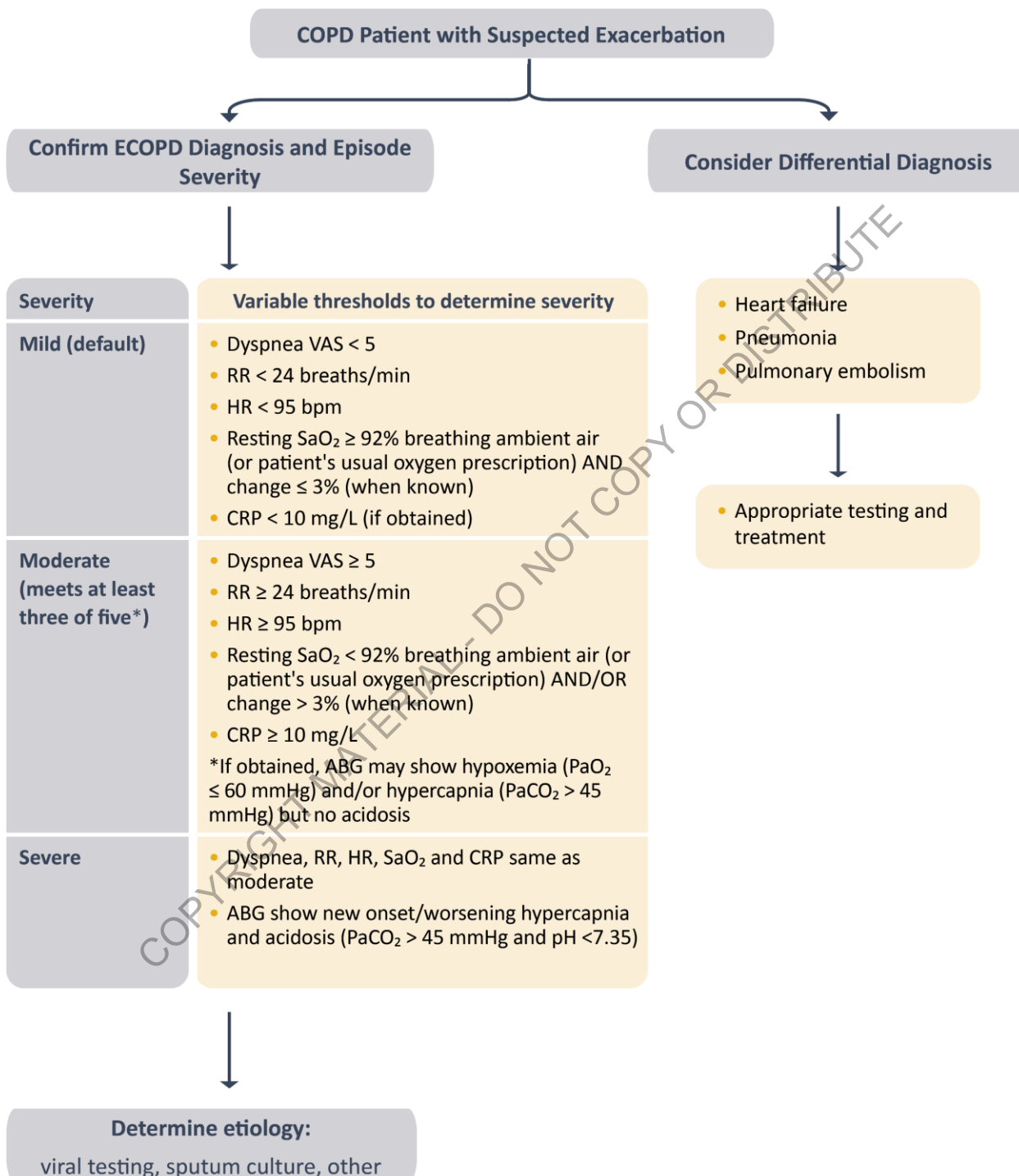
It has been proposed that these easy to obtain clinical variables can help define the severity of exacerbations on point of contact (Rome classification). ⁽³²⁸⁾ Using the Rome classification for exacerbations, hospitalized patients with acute exacerbations can be further subclassified into mild, moderate and severe events with differences in mortality. ^(1302,1303) Based on a thorough review of the available literature and using a Delphi approach to agree on the variable thresholds, the severity classification is summarized in **Figure 4.3**. The severity of exacerbations assessed using this grading scheme correlates with prognosis.

In the primary care setting, where laboratories may not be available, severity can be determined with the easily obtainable dyspnea intensity (using a VAS 0 to 10 dyspnea scale with zero being not short of breath at all and 10 the worst shortness of breath you have ever experienced), respiratory rate, heart rate and oxygen saturation level. Where available, blood C-reactive protein (CRP) level is recommended. To determine the need for ventilator support (usually in the emergency room or hospital setting) arterial blood gases or equivalent should be measured. To move from a mild to a moderate level, three of the variables need to exceed the established thresholds. It is hoped that prospective validation will help better define exacerbations and their severity at point of contact, and that documented validation

may confirm or help modify the proposed thresholds of the variables now included. It is proposed that prospective research can help determine a more specific marker of lung injury than the more generic CRP, as has been true for other organs acute events.

Classification of the Severity of COPD Exacerbations

Figure 4.3



Adapted from: The ROME Proposal, Celli et al. (2021) Am J Respir Crit Care Med. 204(11): 1251-8.

Abbreviations: VAS visual analog dyspnea scale; RR respiratory rate; HR heart rate; SaO₂ oxygen saturation; CRP C-reactive protein; ABG arterial blood gases; PaO₂ Arterial pressure of oxygen.

It is now recognized that many exacerbations are not reported to healthcare professionals for therapy and yet these events, although often shorter in duration, also have a significant impact on health status.^(1304,1305) Thus, COPD patients need to receive education about the importance of understanding exacerbation symptoms and when to seek professional healthcare. The WHO has defined a minimum set of interventions for the management of exacerbations.⁽⁸⁹¹⁾

Exacerbations are mainly triggered by respiratory viral infections although bacterial infections and environmental factors such as ambient air pollution and excess heat may also initiate and/or amplify these events.^(1306,1307) Short-term exposure to fine (PM_{2.5}) and coarse (PM₁₀) particulate matter is associated with increased hospitalizations, ER visits, and outpatient visits,⁽¹³⁰⁷⁾ as well as increased mortality of COPD exacerbations.^(1306,1308,1309) Another study also showed that short-term exposure to ambient nitrogen dioxide and PM_{2.5} was associated with exacerbations in mild to moderate COPD patients.⁽¹⁰⁵⁾ The most common viruses isolated are human rhinovirus (the cause of the common cold), influenza, para-influenza and metapneumovirus which can be detected for up to a week after an exacerbation onset.^(1310,1311) When associated with viral infections, exacerbations are often more severe, last longer and precipitate more hospitalizations, as seen during winter. Filamentous fungi, particularly *Aspergillus* species, may be identified in sputum samples of patients during moderate or severe exacerbations⁽¹³¹²⁻¹³¹⁴⁾ although their clinical relevance remains unclear. Invasive pulmonary aspergillosis is rare (1.3%-3.9%)⁽¹³¹⁵⁾ and more frequent in patients with more severe baseline airflow obstruction, recent use of broad-spectrum antibiotics or parenteral steroids, and hypoalbuminemia.⁽¹³¹⁶⁾ *Aspergillus* sensitization is also a marker of increased risk of exacerbations.⁽¹³¹⁷⁾ The diagnostic approach to invasive aspergillosis in this setting remains challenging.⁽¹³¹⁸⁾

Exacerbations can be associated with increased sputum production and, if purulent, they are most likely due to bacterial infection^(1294,1310,1319) There is reasonable evidence to support the concept that eosinophils are increased in the airways, lung, and blood in a significant proportion of people with COPD.⁽¹³²⁰⁻¹³²²⁾ The presence of sputum eosinophilia has been related to susceptibility to viral infection.⁽¹³¹⁹⁾ It has been suggested that exacerbations associated with an increase in sputum or blood eosinophils may be more responsive to systemic steroids⁽¹³²³⁾ although more prospective trials are needed to test this hypothesis.⁽¹³²³⁾

During a COPD exacerbation, increased symptoms are usually present for 7 to 10 days, but some events may last longer. At 8 weeks up to 20% of patients will not have recovered to their pre-exacerbation state.⁽¹³²⁴⁾ COPD exacerbations contribute to disease progression,⁽¹³²⁵⁾ which is more likely if recovery from exacerbations is slow.⁽¹³²⁶⁾ Exacerbations can also cluster in time and once they occur there is increased likelihood of another event^(487,1327) (see **Chapter 2**).

Some patients are susceptible to frequent exacerbations (defined as two or more exacerbations per year), and these patients have worse health status and morbidity than patients with less frequent exacerbations.⁽⁴⁸⁴⁾ The exact reason for an individual's increased susceptibility to exacerbation symptoms remains largely unknown. However, the perception of breathlessness is greater in frequent exacerbators than infrequent exacerbators,⁽⁵⁴⁹⁾ suggesting that a perception of breathing difficulty may contribute to precipitating the respiratory symptoms rather than solely physiological, or causative factors. The strongest predictor of a patient's future exacerbation frequency remains the number of exacerbations they have had in the prior year.⁽⁴⁸⁷⁾ It is recognized that these patients form a moderately stable phenotype, although some studies have shown that a significant proportion of patients change their exacerbation frequency especially with worsening FEV₁.⁽¹³²⁸⁾

Other factors that have been associated with an increased risk of acute exacerbations and/or severity of exacerbations include an increase in the ratio of the pulmonary artery to aorta cross sectional dimension (i.e., ratio > 1),⁽³²⁵⁾ a greater percentage of emphysema or airway wall thickness⁽⁵⁶³⁾ measured by chest CT imaging and the presence of chronic bronchitis.^(183,1329)

Vitamin D has an immune-modulating role and has been implicated in the pathophysiology of exacerbations. As with many chronic diseases vitamin D levels are lower in people with COPD than in healthy individuals. Some, but not all studies have shown that supplementation in people with severe deficiency results in a 50% reduction in episodes and hospital admission.^(1049,1330) Therefore, it is recommended that all patients hospitalized for exacerbations should be assessed and investigated for severe deficiency (< 10 ng/ml or < 25 nM) followed by supplementation if required.

TREATMENT OPTIONS

Treatment setting

The goals of treatment for COPD exacerbations are to minimize the negative impact of the current exacerbation and prevent the development of subsequent events.⁽¹³³¹⁾ Depending on the severity of an exacerbation and/or the severity of the underlying disease, an exacerbation can be managed in either the outpatient or inpatient setting. More than 80% of exacerbations are managed on an outpatient basis with pharmacological therapies including bronchodilators, corticosteroids, and antibiotics.^(487,889,1332)

Potential Indications for Hospitalization Assessment*

Figure 4.4

- Severe symptoms such as sudden worsening of resting dyspnea, high respiratory rate, decreased oxygen saturation, confusion, drowsiness
- Acute respiratory failure
- Onset of new physical signs (e.g., cyanosis, peripheral edema)
- Failure of an exacerbation to respond to initial medical management
- Presence of serious comorbidities (e.g., heart failure, newly occurring arrhythmias, etc.)
- Insufficient home support

*Local resources need to be considered

The indications for assessing the need for hospitalization during a COPD exacerbation are shown in **Figure 4.4**. When patients with a COPD exacerbation come to the emergency department, if hypoxemic they should be provided with supplemental oxygen and undergo assessment to determine whether the exacerbation is life-threatening and if increased work of breathing or impaired gas exchange requires consideration for non-invasive ventilation. If so, healthcare providers should consider admission to an area where proper monitoring and care can be provided. In less severe cases, the patient may be managed in the emergency department or hospital ward unit. In addition to pharmacological therapy, hospital management of exacerbations includes respiratory support (oxygen therapy, ventilation). The management of severe, but not life threatening, exacerbations is outlined in **Figure 4.5**.

The clinical presentation of COPD exacerbation is heterogeneous; thus, we recommend that in **hospitalized patients** the severity of the exacerbation should be based on the patient's clinical signs and recommend the following classification:⁽¹³³³⁾

No respiratory failure: Respiratory rate: ≤ 24 breaths per minute; heart rate < 95 beats per minute, no use of accessory respiratory muscles; no changes in mental status; hypoxemia improved with supplemental oxygen given via Venturi mask 24-35% inspired oxygen (FiO_2); no increase in PaCO_2 .

Acute respiratory failure – non-life-threatening: Respiratory rate: > 24 breaths per minute; using accessory respiratory muscles; no change in mental status; hypoxemia improved with supplemental oxygen via Venturi mask $> 35\%$ FiO_2 ; hypercarbia i.e., PaCO_2 increased compared with baseline or elevated 50-60 mmHg.

Acute respiratory failure – life-threatening: Respiratory rate: > 24 breaths per minute; using accessory respiratory muscles; acute changes in mental status; hypoxemia not improved with supplemental oxygen via Venturi mask or requiring $\text{FiO}_2 > 40\%$; hypercarbia i.e., PaCO_2 increased compared with baseline or elevated > 60 mmHg or the presence of acidosis ($\text{pH} \leq 7.25$).

Management of Severe but not Life-threatening Exacerbations*

Figure 4.5

Assess severity of symptoms, blood gases, chest radiograph

Administer supplemental oxygen therapy, obtain serial arterial blood gas, venous blood gas and pulse oximetry measurements

Bronchodilators:

- Increase doses and/or frequency of short-acting bronchodilators
- Combine short-acting beta 2-agonists and anticholinergics
- Consider use of long-acting bronchodilators when patient becomes stable
- Use spacers or air-driven nebulizers when appropriate

Consider oral corticosteroids

Consider antibiotics (oral) when signs of bacterial infection are present

Consider noninvasive mechanical ventilation (NIV)

At all times:

- Monitor fluid balance
- Consider subcutaneous heparin or low molecular weight heparin for thromboembolism prophylaxis
- Identify and treat associated conditions (e.g., heart failure, arrhythmias, pulmonary embolism etc.)

*Local resources need to be considered

Long-term prognosis following hospitalization for COPD exacerbation is poor, with a five-year mortality rate of about 50%.⁽¹³³⁴⁾ Factors independently associated with poor outcome include older age, lower BMI, comorbidities (e.g., cardiovascular disease or lung cancer), previous hospitalizations for COPD exacerbations, clinical severity of the index exacerbation and need for long-term oxygen therapy at discharge.⁽¹³³⁵⁻¹³³⁷⁾ Patients characterized by a higher prevalence and severity of respiratory symptoms, poorer quality of life, worse lung function, lower exercise capacity, lower lung density and thickened bronchial walls on CT-scan are also at increased risk for a higher mortality following

an acute COPD exacerbation.⁽¹³³⁸⁾ COPD exacerbations increase the risk of adverse cardiovascular events, with heightened risk in the first 30 days persisting for up to 1-2 years.⁽¹³³⁹⁾ Mortality risk may be heightened during spells of cold weather.⁽¹³⁴⁰⁾

An updated Cochrane review concluded that the use of COPD exacerbation action plans with a single short educational component, in conjunction with ongoing support, reduced in-hospital healthcare utilization. Such educational interventions were also found to increase the treatment of COPD exacerbations with corticosteroids and antibiotics.⁽¹³⁴¹⁾

Key points for the management of all exacerbations are given in **Figure 4.6**.

Key Points for the Management of Exacerbations

Figure 4.6

- Short-acting inhaled beta₂-agonists, with or without short-acting anticholinergics, are recommended as the initial bronchodilators to treat an acute exacerbation **(Evidence C)**
- Systemic corticosteroids can improve lung function (FEV1), oxygenation and shorten recovery time and hospitalization duration. Duration of therapy should not normally be more than 5 days **(Evidence A)**
- Antibiotics, when indicated, can shorten recovery time, reduce the risk of early relapse, treatment failure, and hospitalization duration. Duration of therapy should normally be 5 days **(Evidence B)**
- Methylxanthines are not recommended due to increased side effect profiles **(Evidence B)**
- Non-invasive mechanical ventilation should be the first mode of ventilation used in COPD patients with acute respiratory failure who have no absolute contraindication because it improves gas exchange, reduces work of breathing and the need for intubation, decreases hospitalization duration and improves survival **(Evidence A)**

Pharmacological treatment

The three classes of medications most commonly used for COPD exacerbations are bronchodilators, corticosteroids, and antibiotics.

Bronchodilators

Although there is no high-quality evidence from RCTs, it is recommended that short-acting inhaled beta₂-agonists, with or without short-acting anticholinergics, are the initial bronchodilators for acute treatment of a COPD exacerbation.^(1288,1342) A systematic review of the route of delivery of short-acting bronchodilators found no significant differences in FEV1 between using metered dose inhalers (MDI) (with or without a spacer device) or nebulizers to deliver the agent,^(592,1343) although the latter may be an easier delivery method for sicker patients. It is recommended that patients do not receive continuous nebulization but use the MDI inhaler one or two puffs every one hour for two or three doses and then every 2-4 hours based on the patient's response. Although, there are no clinical studies that have evaluated the use of inhaled long-acting bronchodilators (either beta₂-agonists or anticholinergics or combinations) with or without ICS during an exacerbation, we recommend continuing these treatments during the exacerbation or to start these medications as soon as possible before hospital discharge. Intravenous methylxanthines (theophylline or aminophylline) are not recommended to use in these patients due to significant side effects.^(1344,1345) If a nebulizer is chosen to deliver the bronchodilator agent, air-driven bronchodilator nebulization is preferable to oxygen-driven in acute exacerbations of COPD in order to avoid the potential risk of increasing the PaCO₂ associated

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with oxygen-driven bronchodilator administration.⁽¹³⁴⁶⁾

Glucocorticoids

Data from studies (mostly hospital based) indicate that systemic glucocorticoids in COPD exacerbations shorten recovery time and improve lung function (FEV1). They also improve oxygenation,⁽¹³⁴⁷⁻¹³⁵⁰⁾ the risk of early relapse, treatment failure,⁽¹³⁵¹⁾ and the length of hospitalization.^(1347,1349,1352) A dose of 40 mg prednisone-equivalent per day for 5 days is recommended.⁽¹³⁵³⁾ One observational study suggests that longer courses of oral corticosteroids for COPD exacerbations are associated with an increased risk of pneumonia and mortality.⁽¹³⁵⁴⁾ Therapy with oral prednisolone is equally effective to intravenous administration.⁽¹³⁵⁵⁾ Nebulized budesonide alone may be a suitable alternative for treatment of exacerbations in some patients,^(1348,1356,1357) and provides similar benefits to intravenous methylprednisolone, although the choice between these options may depend on local cost issues.^(1358,1359) Even short bursts of corticosteroids are associated with subsequent increased risk of pneumonia, sepsis and death⁽¹³⁶⁰⁾ and use should be confined to patients with significant exacerbations. Recent studies suggest that glucocorticoids may be less efficacious to treat acute COPD exacerbations in patients with lower levels of blood eosinophils^(487,1320,1323,1361) and more trials of steroid-sparing treatment regimens are required. A double-blind, placebo-controlled RCT (STARR2) of prednisolone therapy guided by blood eosinophil count during acute COPD exacerbation found that this strategy was non-inferior to standard care including systematic prednisolone treatment (30 mg per day for 14 days) and allowed a 33% reduction in the proportion of patients receiving prednisolone.⁽¹³⁶²⁾ The study authors concluded that blood eosinophil-directed prednisolone can be used to safely reduce systemic glucocorticoid use in clinical practice.⁽¹³⁶²⁾

Antibiotics

Although the infectious agents in COPD exacerbations can be viral or bacterial,^(1311,1363) the use of antibiotics in exacerbations remains controversial.^(352,1364,1365) The uncertainties originate from studies that did not differentiate between bronchitis (acute or chronic) and COPD exacerbations, studies without placebo-control, and/or studies without chest X-rays that do not exclude that patients may have had underlying pneumonia. There is evidence supporting the use of antibiotics in exacerbations when patients have clinical signs of a bacterial infection e.g., increased sputum purulence.^(352,1365) Indeed, the use of observed sputum color can safely modulate antibiotic therapy with no adverse effects if sputum is white or clear in color. On the other hand, observed sputum purulence has 94.4% sensitivity and 52% specificity for high bacterial load, indicative of a causative relationship.⁽³⁵²⁾

A systematic review of placebo-controlled studies has shown that antibiotics reduce the risk of short-term mortality by 77%, treatment failure by 53% and sputum purulence by 44%.⁽¹³⁶⁶⁾ The review provides evidence to treat moderately or severely ill patients with COPD exacerbations and increased cough and sputum purulence with antibiotics.^(1366,1367) These data are supported by more RCTs in patients with diagnoses of moderate COPD.⁽¹³⁶⁸⁾ In an RCT, the addition of doxycycline to oral corticosteroid in an outpatient setting did not prolong time to next exacerbation.⁽¹³⁶⁹⁾ In the outpatient setting, sputum cultures are not feasible as they take at least two days and frequently do not give reliable results for technical reasons. Several biomarkers of airway infection are being studied in exacerbations of COPD that have a better diagnostic profile. Earlier studies of C-reactive protein (CRP) have reported contradictory findings.^(1370,1371) A randomized trial found a marked reduction in antibiotic prescriptions without impaired outcomes in UK primary care outpatients with ECOPD in whom antibiotics prescriptions were guided by point-of-care CRP testing.⁽¹³⁷²⁾ Another trial in patients hospitalized for exacerbations of COPD in The Netherlands found similar results (reduced antibiotic use with no increase in treatment failure). These findings need confirmation in other settings before a recommendation to generalize this approach. However, data has indicated that antibiotic usage can be safely reduced from 77.4% to 47.7% when CRP is low.⁽¹³⁷³⁾

Procalcitonin is an acute phase reactant that increases in response to inflammation and infection and has been studied to determine the use of antibiotics in COPD exacerbations.⁽¹³⁷⁴⁾ The efficacy of this biomarker is controversial. Several studies, mainly done in the outpatient setting, suggested that procalcitonin-guided antibiotic treatment reduces

antibiotic exposure and side effects with the same clinical efficacy.⁽¹³⁷⁵⁻¹³⁷⁷⁾ A systematic review and meta-analysis on the use of procalcitonin in hospitalized patients with a COPD exacerbation found no significant reduction in overall antibiotic exposure.⁽¹³⁷⁸⁾ In patients with COPD exacerbations treated in an ICU setting, the use of a procalcitonin-based algorithm for initiating or stopping antibiotics was associated with a higher mortality rate when compared to those receiving standard antibiotic regimens.⁽¹³⁷⁹⁾ Based on these conflicting results we cannot recommend at this time the use of procalcitonin-based protocols to make the decision on using antibiotics in patient with COPD exacerbations; however, confirmatory trials with rigorous methodology are required.

In summary, antibiotics should be given to patients with exacerbations of COPD who have three cardinal symptoms: increase in dyspnea, sputum volume, and sputum purulence; have two of the cardinal symptoms, if increased purulence of sputum is one of the two symptoms; or require mechanical ventilation (invasive or noninvasive).^(1294,1311) A metanalysis demonstrated that ≤ 5 days of antibiotic treatment had the same clinical and bacteriological efficacy to longer conventional treatment in outpatients with COPD exacerbations. Furthermore, shorter exposure to antibiotics may decrease the risk developing antimicrobial resistance and complications associated with this therapy. The recommended length of antibiotic therapy is 5-7 days.⁽¹³⁸⁰⁾ We recommend a duration of ≤ 5 days of antibiotic treatment for outpatient treatment of COPD exacerbations.^(1379,1381)

The choice of the antibiotic should be based on the local bacterial resistance pattern. Usually, initial empirical treatment is an aminopenicillin with clavulanic acid, macrolide, tetracycline or, in selected patients, quinolone. In patients with frequent exacerbations, severe airflow obstruction,^(1382,1383) and/or exacerbations requiring mechanical ventilation,⁽¹³⁸⁴⁾ cultures from sputum or other materials from the lung should be performed, as gram-negative bacteria (e.g., *Pseudomonas* species) or resistant pathogens that are not sensitive to the above-mentioned antibiotics may be present. The route of administration (oral or intravenous) depends on the patient's ability to eat and the pharmacokinetics of the antibiotic, although it is preferable that antibiotics be given orally. Improvements in dyspnea and sputum purulence suggest clinical success.

Adjunct therapies

Depending on the clinical condition of the patient, an appropriate fluid balance, use of diuretics when clinically indicated, anticoagulants, treatment of comorbidities and nutritional aspects should be considered. Among COPD patients hospitalized with a suspected exacerbation, up to 5.9% were found to have pulmonary embolism.⁽¹²⁹⁹⁾ Hospitalized patients with COPD are at an increased risk of deep vein thrombosis and pulmonary embolism^(1385,1386) and prophylactic measures for thromboembolism should be instituted.^(1387,1388) At all times, healthcare providers should strongly enforce the need for smoking cessation.

Respiratory support

Oxygen therapy

This is a key component of hospital treatment of an exacerbation. Supplemental oxygen should be titrated to improve the patient's hypoxemia with a target saturation of 88-92%.⁽¹³⁸⁹⁾ Once oxygen is started, blood gases should be checked frequently, or as clinically indicated, to ensure satisfactory oxygenation without carbon dioxide retention and/or worsening acidosis. Pulse oximetry is not as accurate as arterial blood gas⁽⁵⁴⁸⁾ and in particular, may overestimate blood oxygen content among individuals with darker skin tones.⁽¹³⁹⁰⁾ A study demonstrated that venous blood gas to assess bicarbonate levels and pH is accurate when compared with arterial blood gas assessment.⁽¹³⁹¹⁾ Additional data are needed to clarify the utility of venous blood gas sampling to make clinical decisions in scenarios of acute respiratory failure; most patients included had a pH > 7.30 on presentation, PCO₂ levels were dissimilar when measured by venous compared to arterial blood samples and the severity of airflow obstruction was not reported.⁽¹³⁹¹⁾ Venturi masks offer more accurate and controlled delivery of oxygen than do nasal prongs.⁽¹²⁸⁸⁾

High-flow nasal therapy

High-flow nasal therapy (HFNT) delivers heated and humidified air-oxygen blends via special devices (e.g., Vapotherm®, Comfort Flo®, or Optiflow®) at rates up to 8 L/min in infants and up to 60 L/min in adults.⁽¹³⁹²⁾ HFNT has been associated with decreased respiratory rate and effort, decreased work of breathing, improved gas exchange, improved lung volume and dynamic compliance, transpulmonary pressures and homogeneity.^(1393,1394) These physiologic benefits positively improve oxygenation and clinical outcomes in patients with acute hypoxemic respiratory failure.⁽¹³⁹³⁻¹³⁹⁶⁾ HFNT has been reported to improve oxygenation and ventilation, decrease hypercarbia and improve health-related quality of life in patients with acute hypercapnia during an acute exacerbation, and also in select patients with stable hypercapnic COPD.^(1393,1397-1399) However, the small sample sizes, heterogeneity of the patient populations and short duration of follow-up are current limitations in the interpretation of the value of HFNT for the COPD patient population at large.⁽¹⁴⁰⁰⁾ HFNT has been reported to improve oxygenation and ventilation, decrease hypercarbia, prolong the time to next moderate exacerbation and improve health-related quality of life scores in patients with acute hypercapnia during an exacerbation or in select patients with stable hypercapnic COPD receiving long term oxygen therapy.⁽¹⁴⁰¹⁾ HFNT did not prevent intubation in a RCT conducted in patients hospitalized with an acute exacerbation.⁽¹⁴⁰²⁾ It should be noted that European Respiratory Society (ERS) Clinical Practice Guidelines recommend trialling NIV prior to use of HFNT in patients with COPD and hypercapnic ARF.⁽¹⁴⁰³⁾ There is a need for well-designed, prospective, randomized and controlled multicenter trials to study the effects of HFNT in people with COPD experiencing episodes of either acute or chronic hypercapnic respiratory failure.

Ventilatory support

Some patients need immediate admission to the respiratory care or intensive care unit (ICU) (**Figure 4.7**). Admission of patients with severe exacerbations to intermediate or special respiratory care units may be appropriate if adequate personnel skills and equipment exist to identify and manage acute respiratory failure. Ventilatory support in an exacerbation can be provided by either noninvasive (nasal or facial mask) or invasive (oro-tracheal tube or tracheostomy) ventilation. Respiratory stimulants are not recommended for acute respiratory failure.⁽¹³⁴²⁾

Indications for Respiratory or Medical Intensive Care Unit Admission*

Figure 4.7

- Severe dyspnea that responds inadequately to initial emergency therapy
- Changes in mental status (confusion, lethargy, coma)
- Persistent or worsening hypoxemia ($\text{PaO}_2 < 5.3 \text{ kPa}$ or $< 40 \text{ mmHg}$) and/or severe/worsening respiratory acidosis ($\text{pH} < 7.25$) despite supplemental oxygen and noninvasive ventilation
- Need for invasive mechanical ventilation
- Hemodynamic instability - need for vasopressors

*Local resources need to be considered.

Indications for Noninvasive Mechanical Ventilation (NIV)

Figure 4.8

At least one of the following:

- Respiratory acidosis ($\text{PaCO}_2 \geq 6.0$ kPa or 45 mmHg and arterial $\text{pH} \leq 7.35$)
- Severe dyspnea with clinical signs suggestive of respiratory muscle fatigue, increased work of breathing, or both, such as use of respiratory accessory muscles, paradoxical motion of the abdomen, or retraction of the intercostal spaces
- Persistent hypoxemia despite supplemental oxygen therapy

Indications for Invasive Mechanical Ventilation

Figure 4.9

- Unable to tolerate NIV or NIV failure
- Status post-respiratory or cardiac arrest
- Diminished consciousness, psychomotor agitation inadequately controlled by sedation
- Massive aspiration or persistent vomiting
- Persistent inability to remove respiratory secretions
- Severe hemodynamic instability without response to fluids and vasoactive drugs
- Severe ventricular or supraventricular arrhythmias
- Life-threatening hypoxemia in patients unable to tolerate NIV

Noninvasive mechanical ventilation

The use of noninvasive mechanical ventilation (NIV) is preferred over invasive ventilation (intubation and positive pressure ventilation) as the initial mode of ventilation to treat acute respiratory failure in patients hospitalized for acute exacerbations of COPD. NIV has been studied in RCTs showing a success rate of 80-85%.^(783,1404-1407) NIV has been shown to improve oxygenation and acute respiratory acidosis i.e., NIV increases pH and decreases PaCO_2 . NIV also decreases respiratory rate, work of breathing and the severity of breathlessness but also decreases complications such as ventilator associated pneumonia, and length of hospital stay. More importantly, mortality and intubation rates are reduced by this intervention.^(1405,1408-1410) Once patients improve and can tolerate at least 4 hours of unassisted breathing, NIV can be directly discontinued without any need for a “weaning” period.⁽¹⁴¹¹⁾ The indications for NIV⁽¹⁴⁰⁷⁾ are summarized in **Figure 4.8**.

Invasive mechanical ventilation

The indications for initiating invasive mechanical ventilation during an exacerbation are shown in **Figure 4.9**, and include failure of an initial trial of NIV.⁽¹⁴¹²⁾ As experience is gained with the generalized clinical use of NIV in COPD, a number of indications for invasive mechanical ventilation are being successfully treated with NIV, thus eliminating invasive mechanical ventilation as first line treatment of acute respiratory failure during hospitalization for COPD exacerbation.⁽¹⁴¹²⁾ In patients who fail non-invasive ventilation as initial therapy and receive invasive ventilation as

subsequent rescue therapy, morbidity, hospital length of stay and mortality are greater.⁽⁷⁸³⁾ The use of invasive ventilation in patients with very severe COPD is influenced by the likely reversibility of the precipitating event, the patient's wishes, and the availability of intensive care facilities.⁽⁷⁸³⁾ When possible, a clear statement of the patient's own treatment wishes, such as an advance directive or "living will", makes these difficult decisions easier to resolve. Major hazards include the risk of ventilator-acquired pneumonia (especially when multi-resistant organisms are prevalent), barotrauma and volutrauma, and the risk of tracheostomy and consequential prolonged ventilation.

Acute mortality among COPD patients with respiratory failure is lower than mortality among patients ventilated for non-COPD causes.⁽¹⁴¹³⁾ Despite this, there is evidence that patients who might otherwise survive are frequently denied admission to intensive care for intubation because of unwarranted prognostic pessimism.⁽¹⁴¹⁴⁾ A large study of COPD patients with acute respiratory failure reported in-hospital mortality of 17-49%.⁽¹⁴¹⁵⁾ Further deaths were reported over the next 12 months, particularly among those patients who had poor lung function before invasive ventilation (FEV1 < 30% predicted), had a non-respiratory comorbidity, or were housebound. Patients who did not have a previously diagnosed comorbidity, had respiratory failure due to a potentially reversible cause (such as an infection), or were relatively mobile and not using long-term oxygen, did well after ventilator support.

Hospital discharge and follow-up

The cause, severity, impact, treatment and time course of exacerbations varies from patient to patient and facilities in the community, and healthcare systems, differ from country to country. Accordingly, there are no standards that can be applied to the timing and nature of discharge. However, it is recognized that recurrent exacerbations leading to short-term readmission and increased all-cause mortality are associated with the initial hospitalization for an acute episode of deterioration.⁽¹⁴¹⁶⁾

When features related to re-hospitalization and mortality have been studied, defects in perceived optimal management have been identified including spirometric assessment and arterial blood gas analysis.⁽¹⁴¹⁷⁾ A systematic review has shown that comorbidities, previous exacerbations and hospitalization, and increased length of stay were significant risk factors for 30- and 90-day all-cause readmission after an index hospitalization with an exacerbation of COPD.⁽¹⁴¹⁸⁾ Mortality relates to patient age, the presence of acidotic respiratory failure, the need for ventilatory support and comorbidities including anxiety and depression.⁽¹⁴¹⁹⁾

The introduction of care bundles at hospital discharge to include education, optimization of medication, supervision and correction of inhaler technique, assessment and optimal management of comorbidities, early rehabilitation, telemonitoring and continued patient contact have all been investigated to address these issues (**Figure 4.10**).⁽¹⁴²⁰⁾ While these measures all seem sensible there is insufficient data that they influence either readmission rates or short-term mortality^(1417,1419,1421,1422) and there is little evidence of cost-effectiveness.⁽¹⁴¹⁹⁾ One RCT showed that telemonitoring did not change hospitalization or exacerbation rates in people with COPD.⁽¹⁴²³⁾ Nevertheless, it remains good clinical practice to cover these issues before discharge and their effectiveness on health status and readmission rates may be increased if they are delivered with an approach that includes motivational interview-based health coaching.⁽¹¹¹⁷⁾

Discharge Criteria and Recommendations for Follow-up

Figure 4.10

1. Full review of all clinical and laboratory data
2. Check maintenance therapy and understanding
3. Reassess inhaler technique
4. Ensure understanding of withdrawal of acute medications (steroids and/or antibiotics)
5. Assess need for continuing any oxygen therapy
6. Provide management plan for comorbidities and follow-up
7. Ensure follow-up arrangements: early follow-up < 4 weeks, and late follow-up < 12 weeks as indicated
8. All clinical or investigational abnormalities have been identified

1 – 4 Weeks Follow-up

- Evaluate ability to cope in his/her usual environment
- Review understanding of treatment regimen
- Reassessment of inhaler techniques
- Reassess need for long-term oxygen
- Document the capacity to do physical activity and consider patient eligibility to be enrolled in pulmonary rehabilitation
- Document symptoms: CAT or mMRC
- Determine status of comorbidities

12 – 16 Weeks Follow-up

- Evaluate ability to cope in his/her usual environment
- Review understanding of treatment regimen
- Reassessment of inhaler techniques
- Reassess need for long-term oxygen
- Document the capacity to do physical activity and activities of daily living
- Measure spirometry: FEV1
- Document symptoms: CAT or mMRC
- Determine status of comorbidities

The only possible exception is early rehabilitation as there is some evidence that this factor is associated with increased mortality, although the reasons remain unknown.⁽¹⁴²²⁾ However, other data suggest that early rehabilitation post hospital discharge (i.e., < 4 weeks) may be associated with improved survival.⁽⁸⁴⁹⁾

Early follow-up (within one month) following discharge should be undertaken when possible and has been related to less exacerbation-related readmissions.⁽¹⁴²⁴⁾ There are many patient issues that prevent early follow-up; those not attending early follow-up have increased 90-day mortality. This may reflect both patient compliance, limited access to medical care, poor social support, and/or the presence of more severe disease. Nevertheless, early follow-up permits a careful review of discharge therapy and an opportunity to make any needed changes in therapy.

Additional follow-up at three months is recommended to ensure return to a stable clinical state and permit a review of the patient's symptoms, lung function (by spirometry), and where possible the assessment of prognosis using multiple scoring systems such as BODE.⁽¹⁴²⁵⁾ In addition, arterial oxygen saturation and blood gas assessment will determine the need for long-term oxygen therapy more accurately at prolonged follow-up compared to shortly after discharge.⁽¹⁴²⁶⁾

CT assessment to determine the presence of bronchiectasis and emphysema should be done in patients with recurrent exacerbations and/or hospitalizations.^(542,1427) A further detailed assessment of the presence and management of comorbidities should also be undertaken (**Figure 4.10**).⁽¹⁴²⁷⁾

Prevention of exacerbations

After an acute exacerbation, appropriate measures for prevention of further exacerbations should be initiated (**Figure 4.6** and **Figure 4.11**). For the following treatment modalities significant effects on exacerbation risk/frequency could be shown in clinical trials. For details refer to **Chapter 3**.

Based on findings from observational studies in various countries⁽¹⁴²⁸⁻¹⁴³¹⁾ there was a major decrease in hospital admissions for COPD exacerbations during the COVID-19 epidemic. It was hypothesized that this phenomenon may be a consequence of shielding measures (e.g., wearing masks, avoiding social contact, regular hand washing etc). Accordingly, shielding measures could be considered during the winter months (on top of established pharmacological and non-pharmacological measures) in patients at risk of exacerbation.

Interventions that Reduce the Frequency of COPD Exacerbations

Figure 4.11

Intervention Class	Intervention
Bronchodilators	LABAs LAMAs LABA + LAMA
Corticosteroid-containing regimens	LABA + ICS LABA + LAMA + ICS
Anti-inflammatory (non-steroid)	Roflumilast Dupilumab
Anti-infectives	Vaccines Long Term Macrolides
Mucoregulators	N-acetylcysteine Carbocysteine Erdosteine
Various others	Smoking Cessation Rehabilitation Lung Volume Reduction Vitamin D Shielding measures (e.g., mask wearing, minimizing social contact, frequent hand washing)

CHAPTER 5: COPD AND COMORBIDITIES

KEY POINTS:

- COPD often coexists with other diseases (comorbidities) that may have a significant impact on disease course.
- In general, the presence of comorbidities should not alter COPD treatment and comorbidities should be treated per usual standards regardless of the presence of COPD.
- Cardiovascular diseases are common and important comorbidities in COPD.
- Lung cancer is frequently seen in people with COPD and is a major cause of death.
 - Annual low-dose CT scan (LDCT) is recommended for lung cancer screening in people with COPD due to smoking according to recommendations for the general population
 - Annual LDCT is not recommended for lung cancer screening in people with COPD not due to smoking due to insufficient data to establish benefit over harm
- Osteoporosis and depression/anxiety are frequent, important comorbidities in COPD, are often under-diagnosed, and are associated with poor health status and prognosis.
- Gastroesophageal reflux (GERD) is associated with an increased risk of exacerbations and poorer health status.
- People with COPD presenting with new or worsening respiratory symptoms, fever, and/or any other symptoms that could be COVID-19 related, even if these are mild, should be tested for possible infection with SARS-CoV-2 or influenza.
- When COPD is part of a multimorbidity care plan, attention should be directed to ensure simplicity of treatment and to minimize polypharmacy.

INTRODUCTION

COPD often coexists with other diseases (comorbidities) that may have a significant impact on prognosis. [\(329,510,511,520,1432-1435\)](#) Some of these arise independently of COPD whereas others may be causally related, either with shared risk factors or by one disease increasing the risk or compounding the severity of the other. It is possible that features of COPD, are shared with other diseases and as such this mechanism represents a link between COPD and some of its comorbidities. [\(1436,1437\)](#) The risk of comorbid disease can be increased by the sequelae of COPD e.g., reduced physical activity or continued smoking. Whether or not COPD and comorbid diseases are related, management of the COPD patient must include identification and treatment of its comorbidities. Importantly, comorbidities with symptoms also associated with COPD may be overlooked e.g., heart failure and lung cancer (breathlessness) or depression (fatigue and reduced physical activity).

Comorbidities are common at any severity of COPD [\(182\)](#) and the differential diagnosis can often be difficult. For

example, in a patient with both COPD and heart failure, an exacerbation of COPD may be accompanied by worsening of heart failure or *vice versa*. Although COPD is negatively impacted by multiple comorbid diseases, COPD itself is one of the most important comorbid conditions that adversely affects the outcomes of other disorders. For example, patients with congestive heart failure or those undergoing cardiac procedures such as coronary artery bypass grafting have greater morbidity and mortality when COPD is present compared to when it is absent.^(1438,1439)

Below is a brief guide to the management of some common comorbidities occurring in people with COPD with stable disease. The recommendations may be insufficient for the management of all COPD patients and are not a substitute for the use of guidelines for the management of each individual comorbid condition.

Cardiovascular diseases (CVD)

▶ A large primary care population study in COPD patients with no history of cardiovascular disease found a 25% increase in the adjusted risk of major adverse cardiac events including acute myocardial infarction, stroke, or cardiovascular death.⁽¹⁴⁴⁰⁾

Heart failure

▶ The prevalence of systolic or diastolic heart failure in COPD patients ranges from 20% to 70%,⁽¹⁴⁴¹⁾ and its annual incidence is between 3-4%. Incident heart failure is a significant and independent predictor of all-cause mortality.

▶ Unrecognized heart failure may mimic or accompany acute COPD; 40% of COPD patients that are mechanically ventilated because of hypercapnic respiratory failure have evidence of left ventricular dysfunction.^(1442,1443)

▶ Treatment with β_1 -blockers improves survival in heart failure and is recommended in patients with heart failure who also have COPD. Selective β_1 -blockers should be used, and only used, to treat people with COPD for approved cardiovascular indications; not solely for the purpose of preventing exacerbations of COPD.⁽¹⁰⁴⁴⁾

▶ Acute heart failure should be treated according to usual heart failure guidelines since there is no evidence to support an alternative management strategy. Noninvasive ventilation added to conventional therapy improves outcomes for patients with either hypercapnic respiratory failure due to an exacerbation of COPD as well as heart failure with acute pulmonary edema.⁽¹⁴⁴⁴⁾

Ischaemic heart disease (IHD)

▶ Ischaemic heart disease should be considered in all COPD patients depending on their risk factor profile. Cardiovascular risk may be assessed by the global risk calculator, which can be found on the US National Heart Blood Lung Institute website⁽¹⁴⁴⁵⁾ and treatment initiated based on the current recommendations.

▶ During, and for at least 90 days after, acute COPD exacerbations there is an increased risk of cardiovascular events (death, myocardial infarction, stroke, unstable angina, and transient ischemic attack) in patients at high risk of concomitant IHD.⁽¹⁴⁴⁶⁾ Hospitalization for an acute COPD exacerbation has been associated with 90-day mortality of acute myocardial infarction, ischemic stroke, and intracranial hemorrhage.⁽¹⁴⁴⁷⁾ Patients who demonstrate abnormal cardiac troponins in isolation are at increased risk of adverse outcomes including short-term (30-day) and long-term mortality.^(1448,1449)

▶ The treatment of ischaemic heart disease should be according to guidelines irrespective of the presence of COPD and *vice versa*.

Arrhythmias

▶ Cardiac arrhythmias are common in COPD and *vice versa*.⁽¹⁴⁵⁰⁾ Atrial fibrillation is frequent and associated with a lower FEV1.⁽¹⁴⁵¹⁾ The risk of hospitalization for atrial fibrillation in the first 30 days after an exacerbation of COPD is increased when the exacerbation is severe (hospitalized).⁽¹⁴⁵²⁾

▶ In COPD patients presenting with severe worsening dyspnea, associated atrial fibrillation is frequently documented, and it may be either a trigger or a consequence of an acute exacerbation episode.⁽¹⁴⁵³⁾

▶ The presence of atrial fibrillation does not alter the treatment of COPD. Bronchodilators have been previously described as potentially pro-arrhythmic agents;^(1454,1455) however, available evidence suggests an overall acceptable safety profile for long-acting beta₂-agonists,⁽¹⁴⁵⁶⁾ anticholinergic drugs (and ICS).^(889,932,968,1457-1461) Nevertheless, caution is advised when using short-acting beta₂-agonists^(1456,1462) and theophylline, which may precipitate atrial fibrillation and make control of the ventricular response rate difficult.⁽¹⁴⁶³⁻¹⁴⁶⁵⁾

Pulmonary hypertension

▶ Pulmonary hypertension (PH) is defined by an elevated mean pulmonary arterial pressure (mPAP) >20 mmHg, as assessed by right heart catheterization.^(1466,1467) PH is classified in five distinct groups, based on their different pathophysiological mechanisms, clinical presentation and therapeutic management: pulmonary arterial hypertension (PAH, group 1), PH associated with left heart disease (group 2), PH associated with lung diseases and/or hypoxia (group 3), chronic thromboembolic PH (CTEPH, group 4) and PH associated with unclear and/or multifactorial mechanisms (group 5). All groups of PH can be diagnosed in patients with COPD.⁽³²²⁾ Indeed, COPD is a common disease occurring in patients with multiple comorbidities and exposures, which may contribute to pulmonary vascular disease.

▶ Therefore, a diagnosis of PH in a COPD patient requires a careful analysis of the possible mechanisms leading to elevated mPAP. This is critical in order to identify treatable traits of PH-COPD. For example, CTEPH, a treatable cause of PH occurring more frequently in patients above the age of 40 years, can be detected in patients with COPD.⁽¹⁴⁶⁸⁾

▶ Mild PH is frequent in patients with COPD, based on epidemiological estimations 25-30% of all COPD patients present with elevated mPAP.^(1466,1467,1469) Most of these patients are classified as “group 3 PH” or “group 2 PH”, if significant left heart disease is present. The presence of PH in COPD is clinically relevant, as it is associated with increased health-care resource utilization, more hospitalizations and a poor prognosis.⁽³²⁴⁾

▶ A subgroup of PH-COPD patients has severe PH, which is of special clinical importance because PH may represent a major limiting factor in these patients. The 2022 ESC/ERS PH guidelines define severe PH-COPD by an increased PVR > 5 WU.^(1466,1467,1470) Severe PH-COPD is rare, affecting around 5 % of COPD patients.^(1466,1467,1471) The severity of PH is an independent predictor of prognosis⁽³²⁴⁾ and patients with severe PH-COPD frequently present with mild-to-moderate airflow limitation, no or very mild hypercapnia, a low DLco <45% predicted and a circulatory exercise limitation. For this phenotype of COPD patients the term “pulmonary vascular phenotype” has been suggested.⁽³²²⁾

▶ Echocardiography is the best non-invasive tool to estimate the probability and severity of PH.^(324,1466,1467) In addition, elevated NT-proBNP and increased ratio of the diameter of the pulmonary artery and the aorta (PA:Ao ratio) on HR-CT are associated with the presence of PH-COPD. Of note, the diameter of the pulmonary artery has also been associated with the risk of COPD exacerbations.⁽³²⁵⁾

▶ Patients with PH-COPD should be referred to a PH center with experience in respiratory diseases where they will undergo right heart catheterization and multidisciplinary assessment to guide treatment decision (**Figure 5.1**). Long-term oxygen therapy is recommended in hypoxemic patients.

Treatable Traits in Pulmonary Hypertension-COPD (PH-COPD) & Suggested Management

Figure 5.1

COPD and PAH
(Group 1 PH)

- Treat as PAH with comorbidity according to 2022 ESC/ERS PH guidelines

COPD and CTEPH
(Group 4 PH)

- Treat as CTEPH according to 2022 ESC/ERS PH guidelines

COPD and severe PH associated with lung diseases and/or hypoxia
(Group 3 PH)

- Individualized treatment approach in PH center with experience in respiratory diseases

▶ When PAH is diagnosed in a patient with COPD, management should follow the 2022 ESC/ERS Guidelines. In such patients, the preferred option is initial monotherapy followed by careful sequential combination therapy if the treatment goals are not reached.

▶ When CTEPH is diagnosed in a patient with COPD, multidisciplinary CTEPH team assessment will consider whether pulmonary endarterectomy, angioplasty and/or PH medications are indicated.

▶ In patients with non-severe PH-COPD the use of PAH medications is not recommended.

▶ In patients with severe PH-COPD an individualized approach is suggested.^(1466,1467) In clinical practice, off-label use of phosphodiesterase type 5 inhibitors has been most frequently proposed to treat these patients.^(1472,1473) However, the results of the PERFECT trial highlight the challenges of the management of PH-COPD. In this study, treatment with inhaled treprostinil showed no clinical efficacy, but was associated with potential adverse events. Further well-designed randomized-controlled trials should be encouraged to firmly advise for or against the use of PAH medications in PH-COPD.⁽¹⁴⁷⁴⁾

Peripheral vascular disease

▶ Peripheral artery disease (PAD) is commonly associated with atherosclerotic heart disease and may have significant implications for functional activity as well as quality of life in people with COPD.⁽¹⁴⁷⁵⁾

▶ In a large cohort of people with COPD of all degrees of severity, 8.8% were diagnosed with PAD that was higher than the prevalence in non-COPD controls (1.8%).⁽¹⁴⁷⁵⁾

▶ COPD patients with PAD reported a worse functional capacity and worse health status compared to those without PAD. Clinicians should consider PAD in people with COPD to those at risk for vascular events and to fully understand their functional impairments.

Hypertension

► Hypertension is likely to be the most frequently occurring comorbidity in COPD and may have implications for prognosis.^(1436,1437) Diastolic dysfunction as a result of sub-optimally treated hypertension may be associated with exercise intolerance and mimic symptoms associated with an acute exacerbation thereby provoking hospitalization in COPD.⁽¹⁴⁴¹⁾ These data stress the importance of optimal blood pressure control in COPD patients with underlying hypertension.^(1476,1477)

► Hypertension should be treated according to usual guidelines. There is no evidence that hypertension should be treated differently in the presence of COPD. The role of treatment with selective beta-blockers is less prominent in recent hypertension guidelines and there is no evidence that in people with COPD and increased cardiovascular risk cardio-selective beta-blockers either reduce the benefits of treatment with LABA or increase cardiovascular risk.⁽¹⁴⁷⁸⁾

► COPD should be treated as usual as there is no direct evidence that COPD should be treated differently in the presence of hypertension.

Lung cancer

Lung cancer is the leading cause of death from malignant disease worldwide, with more deaths from lung cancer than from colon, breast and prostate cancer together and it causes an estimated 1.6 million deaths worldwide each year.⁽¹⁴⁷⁹⁾ Unfortunately, the great majority of lung cancers are diagnosed at an advanced stage, resulting in poor overall survival.⁽¹⁴⁸⁰⁾ Therefore, primary, and secondary prevention and early detection are important to improve survival. There is evidence for an association between COPD and lung cancer that has been systematically confirmed in several epidemiological and observational cohort studies.^(1437,1481-1483) These two diseases appear to share more than tobacco exposure as their common origin. Genetic susceptibility, epigenetic changes in DNA methylation, local pulmonary chronic inflammation and abnormal lung repair mechanisms present in COPD are also thought to be the most important potential contributors to lung cancer development.⁽¹⁴⁸⁴⁻¹⁴⁸⁶⁾ Whether the spirometric severity of airflow obstruction is directly or inversely associated with a greater risk for lung cancer development remains controversial.^(416,1483) The association between lung cancer and degree of emphysema is stronger than that existing between lung cancer and degree of airflow obstruction and the greatest risk is observed in people with the combination of emphysema diagnosed by CT and airflow obstruction determined by spirometry.^(1487,1488) The best preventive measure for lung cancer (as it is for COPD) is smoking prevention and in smokers, smoking cessation.⁽¹⁴⁸⁹⁾

Several studies involving the use of low-dose chest computed tomography (LDCT) screening have shown improved survival.^(442,443,1490) The United States Preventive Services Task Force (USPSTF) updated its recommendation for lung cancer screening in 2021.⁽¹⁴⁹¹⁾ Their recommendation was based on a systematic review that examined the accuracy of screening for lung cancer considering the benefits and harms associated with lung cancer screening. USPSTF also commissioned collaborative modeling studies from the National Cancer Institute (NCI) Cancer Intervention and surveillance modeling Network (CISNET) to provide the optimal age to begin and end lung cancer screening, the optimal screening interval, and to assess the relative benefits and harms of different screening strategies. The USPSTF now recommends annual screening for lung cancer with LDCT in adults aged 50-80 years who have a 20-pack year smoking history and currently smoke or quit smoking within the past 15 years. They recommend stopping screening once a person has not smoked for 15 years or develops a health problem that substantially limits life expectancy or the ability or willingness to have curative lung surgery. Additionally, the CISNET modeling analysis supports screening at a younger age with a lower smoking burden to address current racial and gender disparities that exist with lung cancer screening.⁽¹⁴⁹¹⁻¹⁴⁹⁵⁾ In patients with smoking related COPD, annual screening for lung cancer with LDCT should be conducted in those 50-80 years of age with a 20-pack year smoking history who currently smoke, or who have quit smoking within the past 15 years. COPD has also been reported to be an independent risk factor for lung cancer incidence in never smokers.^(1496,1497) Risk factors include biomass fuel exposure, second-hand smoke, radon, air

pollution, a family history of lung cancer, and asbestos exposure. Routine annual screening with LDCT has not been conducted in people with COPD who are never smokers and annual LDCT screening is not currently recommended because the possible harms of screening seem to outweigh the possible benefit of finding early lung cancer. ⁽¹⁴⁹⁸⁾

Although this recommendation is supported by several major medical societies several important questions remain. Several studies have suggested that the yield of CT screening would improve if additional variables such as age, smoking history, BMI, presence of airflow obstruction and or emphysema and family history of lung cancer were added to the current screening criteria. ^(446,1499)

The implementation of a screening program, where available, could be useful, but has to be implemented in the appropriate environment to avoid over diagnosis, greater morbidity and mortality with needless diagnostic procedures for benign abnormalities, anxiety and incomplete follow-up, as has been suggested by studies in primary care. ⁽¹⁵⁰⁰⁾ On the other hand, one Danish study showed that being part of a lung cancer screening programme significantly promotes smoking abstinence ⁽¹⁵⁰¹⁾ and a review of different studies concluded that smoking cessation during LDCT screening results in improved spirometry as well as a decrease in micronodules seen on the baseline CT, thus beneficially affecting lung cancer and COPD. ⁽¹⁴⁸⁹⁾ Smoking cessation interventions as part of CT scan screening programs could be of use (Figure 5.2).

Common Risk Factors for the Development of Lung Cancer

Figure 5.2

- Age > 55 years
- Smoking history > 30 pack years
- Presence of emphysema by CT scan
- Presence of airflow limitation FEV1/FVC < 0.7
- BMI < 25 kg/m²
- Family history of lung cancer

Inhaled corticosteroids (ICS) and lung cancer incidence

ICS are recommended in selected people with COPD and their potential impact on development of lung cancer has been the subject of conflicting reports. Several retrospective analyses of large databases or observational cohorts ⁽¹⁵⁰²⁾ have suggested a reduction in lung cancer risk with the use of ICS but confounding factors have not been consistently controlled for in all studies. ⁽¹⁵⁰³⁻¹⁵⁰⁸⁾ A more pronounced protective effect of ICS was reported in former compared to current smokers, ⁽¹⁵⁰⁶⁾ those with a concurrent diagnosis of asthma ⁽¹⁵⁰⁸⁾ or, those prescribed a higher dose of ICS. ⁽¹⁵⁰⁷⁾ A systematic review that included two observational studies and 4 RCTs, reported a protective effect of ICS on lung cancer risk in the observational studies that used a higher dose of ICS, but no benefit in the RCTs. ⁽¹⁵⁰⁹⁾ An analysis designed to avoid immortal time bias ⁽⁹⁸⁵⁾ and an observational study (> 65,000 patients) reported no effect of ICS use on lung cancer incidence. ⁽¹⁵¹⁰⁾ In contrast, one database study reported an increased risk of lung cancer in patients prescribed ICS compared to those not prescribed ICS. ⁽¹⁵¹¹⁾ Reports from large prospective RCTs focused on lung function decline, exacerbation reduction or mortality, conducted in patients with moderate to severe COPD where cause of death was analyzed using clinical end-point committees reported no difference in cancer deaths in patients randomized to ICS versus non-ICS use. ^(496,699,844,889,968,1460)

The conflicting results between observational and RCTs are probably due to differences in the patient populations, characterization of lung cancer risk, follow-up time (shorter in interventional trials), impact of immortal time bias, and the rigorousness used to detect lung cancer. Based on the available data ICS do not appear to increase or decrease the risk of lung cancer pending studies adequately planned to clarify these important questions.

COVID-19 and COPD

- ▶ People with COPD presenting with new or worsening respiratory symptoms, fever, and/or any other symptoms that could be COVID-19 related, even if these are mild, should be tested for possible infection with SARS-CoV-2.
- ▶ Patients should keep taking their oral and inhaled respiratory medications for COPD as directed.
- ▶ Physical distancing and shielding, or sheltering-in-place, should not lead to social isolation and inactivity. Patients should stay in contact with their friends and families by telecommunication and continue to keep active. They should also ensure they have enough medication.
- ▶ Patients should be encouraged to use reputable resources for medical information regarding COVID-19 and its management.
- ▶ Guidance for remote (phone/virtual/online) COPD patient follow-up and a printable checklist are provided.
- ▶ Differentiating the symptoms of COVID-19 infection from the usual symptoms of COPD can be challenging. Cough and breathlessness are found in over 60% of patients with COVID-19 but are usually also accompanied by fever (> 60% of patients) as well as fatigue, confusion, diarrhea, nausea, vomiting, muscle aches and pains, anosmia, dysgeusia and headaches.⁽¹⁵¹²⁾
- ▶ In COVID-19 symptoms may be mild at first, but rapid deterioration in lung function may occur. The prodrome of milder symptoms is especially problematic in patients with underlying COPD who may already have diminished lung reserve. Lack of recognition of the prodromal symptoms may delay early diagnosis and preliminary data suggest that people with COPD reporting exacerbations and suspected of having COVID-19 infection were infrequently tested for its presence.⁽¹⁵¹³⁾ A high index of suspicion for COVID-19 needs to be maintained in people with COPD who present with symptoms of an exacerbation, especially if accompanied by fever, impaired taste or smell or GI complaints.
- ▶ Persistent symptoms in people with COPD may cause diagnostic difficulty. Approximately 10-20% of patients infected with SARS-CoV-2 may develop persistent symptoms with 25-45% experiencing dyspnea at 6-9 months after the acute infection and approximately 20% at 9-12 months.⁽¹⁵¹⁴⁻¹⁵¹⁷⁾ Delayed recovery was more common in people with multiple chronic medical conditions including COPD.⁽¹⁵¹⁸⁻¹⁵²⁰⁾

Bronchiectasis

- ▶ With increasing use of computed tomography in the assessment of people with COPD, the presence of previously unrecognized bronchiectasis is being identified.⁽¹⁵²¹⁾ The prevalence of bronchiectasis in COPD patients has been analyzed in several studies with conflicting results ranging from 20% to 69% (mean prevalence was 54.3%).^(349,1522)
- ▶ Whether this diagnosis based on radiological criteria has the same impact as a clinical diagnosis of bronchiectasis remains unknown at present. Two systematic reviews and meta-analyses have compared the characteristics of COPD patients with and without bronchiectasis. The results indicated that people with COPD and comorbid bronchiectasis are more often male with a longer smoking history, greater daily sputum production, more frequent exacerbations, poorer lung function, higher level of inflammatory biomarkers, more chronic colonization by potentially pathogenic

microorganisms, higher rate of *Pseudomonas aeruginosa* isolation and increased mortality.^(348,349)

- ▶ Bronchiectasis should be treated according to usual guidelines.
- ▶ Regarding COPD treatment, some patients may need more aggressive and prolonged antibiotic therapy. ICS may not be indicated in patients with bacterial colonization or recurrent lower respiratory tract infections.

Obstructive sleep apnea & insomnia

- ▶ COPD has an estimated prevalence in U.S. adults of 13.9%^(1523,1524) and obstructive sleep apnea (OSA), a sleep disorder hallmarked by repeated episodes of upper airway closure, affects 9% to 26% of the U.S. adult population.⁽¹⁵²⁵⁾
- ▶ Patients with both COPD and OSA have a worse prognosis compared with either condition alone.⁽¹⁵²⁶⁾ During sleep, patients with both COPD and OSA suffer more frequent episodes of oxygen desaturation and have more total sleep time with hypoxemia and hypercapnia than OSA patients without COPD.⁽¹⁵²⁷⁾
- ▶ The apneic events in patients with combined OSA and COPD have more profound hypoxemia and more cardiac arrhythmias.⁽¹⁵²⁸⁾ Additionally, patients with combined COPD and OSA are more likely to develop daytime pulmonary hypertension^(1529,1530) than patients with just OSA or COPD alone.
- ▶ The use of positive pressure ventilation in patients with COPD and OSA has been reported to reduce all-cause hospitalizations, emergency room visits, moderate and severe exacerbations and associated healthcare costs.^(781,1531)
- ▶ Insomnia in COPD is associated with higher rates of outpatients' visits and hospitalizations.⁽¹⁵³²⁾

Periodontitis & dental hygiene

The association between COPD and periodontitis has been noted mainly in the dental literature although whether this reflects common causative factors such as age, smoking and socioeconomic circumstances remains speculative. Although both conditions have a common (neutrophilic) relationship whether this reflects cause or effect is difficult to elucidate.⁽¹⁵³³⁾ In a more complete study the data supported shared pathophysiology between periodontitis and COPD with similar aberrant neutrophil function, especially when associated with alpha-1-antitrypsin deficiency.⁽¹⁵³⁴⁾

The risk of developing periodontitis increases with the number of emergency room visits for COPD.⁽¹⁵³⁵⁾ High antibody levels to common periodontal pathogens is associated with less exacerbations of COPD.⁽¹⁵³⁶⁾ In a recent systematic review low to moderate evidence suggests that periodontal treatment is associated with slower lung function decline, reduced frequency of exacerbations and less use of healthcare resources in patients with COPD and chronic periodontitis.⁽¹⁵³⁷⁾ In the absence of an effective curative treatment for COPD it is difficult to prove the reverse is also true.

Nevertheless, periodontitis is common in COPD and often requires treatment in its own right which may lead to a reduction in exacerbations.

Metabolic syndrome and diabetes

- ▶ Studies have shown that metabolic syndrome and manifest diabetes are more frequent in COPD and likely to affect prognosis.^(510,1538)
- ▶ Insulin resistance has been associated with increased risk of COPD in women but not in men.⁽¹⁵³⁹⁾

- ▶ The prevalence of metabolic syndrome has been estimated to be more than 30%.⁽¹⁵⁴⁰⁾
- ▶ Diabetes should be treated according to usual guidelines for diabetes. COPD should be treated as usual.

Gastroesophageal reflux (GERD)

- ▶ GERD is an independent risk factor for exacerbations and is associated with worse health status.^(487,1541,1542) The mechanisms responsible for increased risk of exacerbations are not yet fully established.
- ▶ Proton pump inhibitors are often used for treatment of GERD. One small, single-blind study suggested these agents decrease the risk of exacerbation,⁽¹⁵⁴³⁾ but their value in preventing these events remains controversial most effective treatment for this condition in COPD has yet to be established.^(1544,1545)

Osteoporosis

- ▶ Osteoporosis is an important and common comorbidity^(511,1436) which is often under-diagnosed⁽¹⁵⁴⁶⁾ and associated with poor health status and prognosis.
- ▶ Osteoporosis is often associated with emphysema,⁽¹⁵⁴⁷⁾ decreased body mass index⁽¹⁵⁴⁸⁾ and low fat-free mass.⁽¹⁵⁴⁹⁾ Low bone mineral density and fractures are commonly in COPD patients even after adjustment for steroid use, age, pack-years of smoking, current smoking, and exacerbations.^(1550,1551)
- ▶ Osteoporosis should be treated according to usual guidelines.
- ▶ COPD should be treated as usual despite the presence of osteoporosis. An association between ICS and fractures has been found in pharmaco- epidemiological studies; however, these studies have not fully taken severity of COPD or exacerbations and their treatment into account.
- ▶ Systemic corticosteroids significantly increase the risk of osteoporosis and repeated courses for COPD exacerbations should be avoided if possible

Anemia

Anemia is frequent in people with COPD, with a reported prevalence of 7.5% to 34%.⁽¹⁵⁵²⁾ People with COPD and anemia are generally older, have more frequent cardiometabolic comorbidities, greater dyspnea, worse quality of life and airflow obstruction, reduced exercise capacity, an increased risk of severe exacerbations and higher mortality.⁽¹⁵⁵²⁻¹⁵⁵⁸⁾

Anemia due to chronic disease is the most common type seen in COPD, followed by iron deficiency anemia,^(1559,1560) and is mainly related to chronic systemic inflammation and impaired iron utilization. However, other possible reversible factors should be investigated including use of long-term oxygen, theophylline, angiotensin-converting-enzyme inhibitors, angiotensin II receptor inhibitors, renal dysfunction, and androgens.⁽¹⁵⁶¹⁻¹⁵⁶⁹⁾

Although anemia has been established as an important comorbidity in COPD, optimal hemoglobin and hematocrit levels in these patients have not yet been defined, and it is also unclear whether its correction alters outcomes. However, hemoglobin assessment is advisable, particularly in more severely affected patients. If anemia is diagnosed, a systematic search for a treatable cause is recommended in accordance with appropriate clinical guidelines.

Polycythemia

Secondary polycythemia has long been recognized as a common comorbidity in COPD with a reported prevalence of

6% to 10.2% in COPD outpatients (when defined as hemoglobin \geq 17g/dL in males and \geq 15g/dL in females).^(1554,1556,1570) Interestingly, in the COPDGene cohorts 9.2% of men and 3.5% of women had secondary polycythemia.⁽¹⁵⁷¹⁾ Although the prevalence of polycythemia in COPD has decreased following the introduction of long-term oxygen therapy (LTOT),⁽¹⁵⁷²⁾ one study reported a prevalence of 8.4% in patients with severe COPD receiving LTOT.⁽¹⁵⁵⁵⁾

Data from a large cohort (COPDGene cohort) of individuals with moderate to very severe COPD, indicate that male sex, current smoking, living at high altitude (e.g., Denver, Colorado, USA), impaired DLco, and severe hypoxemia were associated with increased risk for secondary polycythemia, whereas, LTOT use was associated with a decreased risk of polycythemia.⁽¹⁵⁷¹⁾ The coexistence of obstructive sleep apnea has also been associated with increased risk of polycythemia in patients with COPD.⁽¹⁵⁷³⁾ Smoking causes an increase in carboxyhemoglobin, thereby increasing red blood cell mass and risk of secondary polycythemia in people with COPD.^(1574,1575)

Secondary polycythemia in COPD may be associated with pulmonary hypertension,^(1576,1577) venous thromboembolism,⁽¹⁵⁷⁷⁾ and mortality.^(1578,1579) However, these findings should be interpreted with caution, since secondary polycythemia may be related to the presence of severe uncorrected hypoxemia, which is a predictor of mortality in COPD, as well as to the presence of concomitant interstitial lung disease or pulmonary vascular disease.

In COPD, if secondary polycythemia is present, a careful evaluation should be performed to determine uncorrected hypoxemia or to rule out the presence of any comorbidities that require a specific intervention.

Anxiety and depression

► Anxiety and depression are important and underdiagnosed comorbidities in COPD^(361,1580-1582) and both are associated with a poor prognosis,^(1581,1583) younger age, female sex, smoking, lower FEV1, cough, higher SGRQ score, and a history of cardiovascular disease.^(43,361,1582)

► There is no evidence that anxiety and depression should be treated differently in the presence of COPD.

► COPD should be treated as usual in patients with psychological disorders. The potential impact of pulmonary rehabilitation should be stressed as studies have found that physical exercise has a beneficial effect on depression in general.^(1584,1585)

► COPD is very common in patients with other psychiatric illnesses, often under-diagnosed and treated.^(1586,1587)

► A systematic review has shown that COPD patients are 1.9 times more likely to commit suicide than people without COPD.⁽¹⁵⁸⁸⁾

► Following a diagnosis of COPD patients are more likely to develop depression and the risk is greater in patients with worse breathlessness.⁽¹⁵⁸⁹⁾

Cognitive impairment

► Cognitive impairment (CI) is common in people with COPD.⁽¹⁵⁹⁰⁾ An average prevalence of 32% has been suggested.⁽¹⁵⁹¹⁾ The prevalence and severity varies by the type of assessment.⁽¹⁵⁹²⁾ Extensive neuropsychological testing suggests that up to 56% of patients may suffer CI.^(1593,1594) Longitudinal studies suggest greater risk of developing CI in COPD diagnosed in midlife,^(1590,1595) and associate COPD with the development of dementia.⁽¹⁵⁹⁶⁾

► CI has been reported in patients across the entire range of spirometric severity.⁽¹⁵⁹⁴⁾

► CI has been associated with impairment in basic activities of daily living,^(1597,1598) and variably associated with

impaired health status.^(1599,1600)

▶ The coexistence of CI and COPD has been associated with an increased risk of hospitalization⁽¹⁶⁰¹⁾ and increased length of stay during acute exacerbation hospitalization.⁽¹⁶⁰²⁾

▶ The impact of CI on self-management skills in COPD patients remains unclear,⁽¹⁵⁹⁷⁾ although inhaler incompetency has been linked to CI.⁽¹⁵⁹⁷⁾

Frailty

▶ Frailty can be defined as the presence of five components: weakness, slowness, exhaustion, low physical activity, and unintentional weight loss.⁽¹⁶⁰³⁾

▶ In a cohort study, the prevalence of frailty among individuals with COPD was higher than in individuals without COPD and may help identify people with COPD at risk of poor outcomes.⁽¹⁶⁰⁴⁾

▶ In a meta-analysis it was reported that frailty and pre-frailty were associated with all-cause mortality, acute exacerbation, and hospitalization in patients with COPD.⁽¹⁶⁰⁵⁾

▶ The European Respiratory Society has published a review of current evidence on treating frailty in adults with chronic respiratory disease and includes clinical management options such as geriatric care, rehabilitation, nutrition, pharmacological and psychological therapies.⁽¹⁶⁰⁶⁾

COPD as part of multimorbidity

▶ An increasing number of people in any aging population will suffer from multi-morbidity, defined as the presence of two or more chronic conditions, and COPD is present in most multi-morbid patients.

▶ Multi-morbid patients have symptoms from multiple diseases and thus symptoms and signs are complex and most often attributable to several causes in the chronic state as well as during acute events.

▶ There is no evidence that COPD should be treated differently when part of multi-morbidity; however, it should be kept in mind that most evidence comes from trials in people with COPD as the only significant disease.⁽⁵¹²⁾

▶ Treatments should be kept simple in the light of the unbearable polypharmacy that these patients are often exposed to.

Other considerations

▶ Consider checking for vitamin D deficiency in COPD patients.

APPENDIX 1 - COPD FOLLOW-UP CHECKLIST

In-person follow-up **Phone follow-up** **Virtual/online follow-up**

Date: YYYY / MM / DD	Diagnosis:				
1. BASELINE SYMPTOMS – Breathlessness on a regular day: mMRC /4					
Daily sputum production: <input type="checkbox"/> no <input type="checkbox"/> yes, color:			Regular cough <input type="checkbox"/> no <input type="checkbox"/> yes		
Recent change in symptoms <input type="checkbox"/> no <input type="checkbox"/> yes			<u>Maintenance medication and adherence:</u>		
If yes, since when:			<input type="checkbox"/> SABA <input type="checkbox"/> LABA+LAMA <input type="checkbox"/> LABA <input type="checkbox"/> LABA+ICS <input type="checkbox"/> LAMA <input type="checkbox"/> LABA+LAMA+ICS <input type="checkbox"/> Other:		
<input type="checkbox"/> Sputum color:	<input type="checkbox"/> Sputum volume ↑ = ↓		<u>Non pharmacological Rx:</u>		
<input type="checkbox"/> Dyspnea ↑ = ↓	<input type="checkbox"/> Fatigue ↑ = ↓		O2:	CPAP:	BIPAP :
<input type="checkbox"/> Cough ↑ = ↓	<input type="checkbox"/> Other				
<input type="checkbox"/> Signs of hypercapnia	CAT: /40				
2. COVID-19 – If patient is feeling unwell, check other symptoms: <input type="checkbox"/> Fever ____ <input type="checkbox"/> Sore throat <input type="checkbox"/> Anosmia <input type="checkbox"/> Others _____					
Contact with someone COVID-19 positive? <input type="checkbox"/> no <input type="checkbox"/> yes Tested for COVID-19? <input type="checkbox"/> no <input type="checkbox"/> yes If yes <input type="checkbox"/> positive <input type="checkbox"/> negative					
3. WRITTEN ACTION PLAN – no <input type="checkbox"/> yes <input type="checkbox"/>					
Instruction and any additional treatment: _____					
Last time it has been used (date): _____					
4. RECENT ADMISSIONS AND EMERGENCY VISITS					<u>Comments:</u>
Hospital/ER	Where	Date	Length	Reason (Dx)	
5. COPD Self-management (healthy behaviors) – Integrated (patient has used it in their daily life)?					
Smoke-free environment	yes	no	cannot tell		
Medication adherence	yes	no	cannot tell		
Prevention/management of exacerbations	yes	no	cannot tell		
Breathing control	yes	no	cannot tell		
Stress management	yes	no	cannot tell		
Physical activity and exercise	yes	no	cannot tell		
Other _____	yes	no			
<u>Comments and what patient should prioritize based on his/her needs:</u>					
6. MAIN ISSUES					
1.		2.		3.	
7. SUMMARY, INTERVENTIONS & PLAN					

(healthcare professional name & signature)

Instructions for using the COPD follow-up checklist

1. Introduction

- a. Identify dates, Dx and whether this follow-up is being done in-person, by phone or remotely.

2. Section 1 – Baseline symptoms

- a. Go over the patient symptoms and whether there have been changes in dyspnea, cough, sputum volume and color (from least to most purulent: mucus; mucopurulent; purulent).
- b. Identify maintenance pharmacological and non-pharmacological treatment and whether the patient is observing treatment as prescribed.

3. Section 2 – COVID-19

- a. Assess whether the patient has any symptoms of COVID-19 and would need to be tested. Have at hand local numbers where the patient can be referred to for testing and treatment.
- b. If the patient has already been tested identify when the results will be obtained, or whether the result was positive or negative. If positive, is there a follow-up test planned, and dates.
- c. Verify patient is practicing COVID-19 precautions (face masks, hand washing, social distancing, or shielding if necessary).

4. Section 3 – Action Plan

- a. Describe if the patient already has a written action plan. See example of an action plan from the Living well with COPD program.⁽⁸⁰¹⁾ Describe if the education for this action plan has already been done. Describe if the written action plan includes a prescription to be self-administered at home or whether the patient need to call his contact person / physician to obtain the prescription. Describe when it was used the last time and if used appropriately.

5. Section 4 – Recent Admissions and ER visits

- a. Write down recent admissions and ER visits, dates and where they took place.

6. Section 5 – COPD Self-Management behaviors

- a. Go over each of the self-management behaviors described in the list. You should cover what is pertinent to the patient treatable traits (dyspnea and/or exacerbation). Describe whether the patient has integrated these strategies in their daily life (yes), not at all (e.g., it has not been discussed or not applicable), and whether the patient is unsure “cannot tell”.

7. Section 6 – Main issues

- a. Identify with the patient the main issues of the call. Up to a maximum of 3 items that can be covered for the duration of the call. Avoid covering too many issues in one visit.

8. Section 7 – Summary, Intervention and Plan

- a. Finalize by describing the interventions done during the remote visit, the ones to be put in place, and agreed by the patient, the plan, including whether the patient needs to be referred to other services, healthcare professionals, etc. and when the next follow-up will take place (describe whether will it be in-person or remote).

REFERENCES

1. Halpin DMG, Celli BR, Criner GJ, et al. The GOLD Summit on chronic obstructive pulmonary disease in low- and middle-income countries. *Int J Tuberc Lung Dis* 2019; **23**(11): 1131-41 <https://pubmed.ncbi.nlm.nih.gov/31718748>.
2. Meghji J, Mortimer K, Agusti A, et al. Improving lung health in low-income and middle-income countries: from challenges to solutions. *Lancet* 2021; **397**(10277): 928-40 <https://pubmed.ncbi.nlm.nih.gov/33631128>.
3. Mathers CD, Loncar D. Projections of global mortality and burden of disease from 2002 to 2030. *PLoS Med* 2006; **3**(11): e442 <https://pubmed.ncbi.nlm.nih.gov/17132052>.
4. Halpin DMG, Celli BR, Criner GJ, et al. It is time for the world to take COPD seriously: a statement from the GOLD board of directors. *Eur Respir J* 2019; **54**(1): 1900914 <https://pubmed.ncbi.nlm.nih.gov/31273036>.
5. United Nations. Sustainable Development Goals, online information available here: <https://www.un.org/sustainabledevelopment/sustainable-development-goals/> [accessed Oct 2024].
6. Celli B, Fabbri L, Criner G, et al. Definition and Nomenclature of Chronic Obstructive Pulmonary Disease: Time for Its Revision. *Am J Respir Crit Care Med* 2022; **206**(11): 1317-25 <https://pubmed.ncbi.nlm.nih.gov/35914087>.
7. Agusti A, Melen E, DeMeo DL, Breyer-Kohansal R, Faner R. Pathogenesis of chronic obstructive pulmonary disease: understanding the contributions of gene-environment interactions across the lifespan. *Lancet Respir Med* 2022; **10**(5): 512-24 <https://pubmed.ncbi.nlm.nih.gov/35427533>.
8. Sin DD, Doiron D, Agusti A, et al. Air pollution and COPD: GOLD 2023 committee report. *Eur Respir J* 2023; **61**(5): <https://pubmed.ncbi.nlm.nih.gov/36958741>.
9. Yang IA, Jenkins CR, Salvi SS. Chronic obstructive pulmonary disease in never-smokers: risk factors, pathogenesis, and implications for prevention and treatment. *Lancet Respir Med* 2022; **10**(5): 497-511 <https://pubmed.ncbi.nlm.nih.gov/35427530>.
10. Cho MH, Hobbs BD, Silverman EK. Genetics of chronic obstructive pulmonary disease: understanding the pathobiology and heterogeneity of a complex disorder. *Lancet Respir Med* 2022; **10**(5): 485-96 <https://pubmed.ncbi.nlm.nih.gov/35427534>.
11. Martinez FJ, Agusti A, Celli BR, et al. Treatment Trials in Young Patients with Chronic Obstructive Pulmonary Disease and Pre-Chronic Obstructive Pulmonary Disease Patients: Time to Move Forward. *Am J Respir Crit Care Med* 2022; **205**(3): 275-87 <https://pubmed.ncbi.nlm.nih.gov/34672872>.
12. Wan ES, Castaldi PJ, Cho MH, et al. Epidemiology, genetics, and subtyping of preserved ratio impaired spirometry (PRISm) in COPD Gene. *Respir Res* 2014; **15**(1): 89 <https://pubmed.ncbi.nlm.nih.gov/25096860>.
13. Agusti A, Faner R. COPD beyond smoking: new paradigm, novel opportunities. *Lancet Respir Med* 2018; **6**(5): 324-6 <https://pubmed.ncbi.nlm.nih.gov/29496484>.
14. Lozano R, Naghavi M, Foreman K, et al. Global and regional mortality from 235 causes of death for 20 age groups in 1990 and 2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet* 2012; **380**(9859): 2095-128 <https://pubmed.ncbi.nlm.nih.gov/23245604>.
15. Vos T, Flaxman AD, Naghavi M, et al. Years lived with disability (YLDs) for 1160 sequelae of 289 diseases and injuries 1990-2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet* 2012; **380**(9859): 2163-96 <https://pubmed.ncbi.nlm.nih.gov/23245607>.
16. Stern DA, Morgan WJ, Wright AL, Guerra S, Martinez FD. Poor airway function in early infancy and lung function by age 22 years: a non-selective longitudinal cohort study. *Lancet* 2007; **370**(9589): 758-64 <https://pubmed.ncbi.nlm.nih.gov/17765525>.
17. Tashkin DP, Altose MD, Bleecker ER, et al. The lung health study: airway responsiveness to inhaled methacholine in smokers with mild to moderate airflow limitation. The Lung Health Study Research Group. *Am Rev Respir Dis* 1992; **145**(2 Pt 1): 301-10 <https://pubmed.ncbi.nlm.nih.gov/1736734>.
18. Eisner MD, Anthonisen N, Coultas D, et al. An official American Thoracic Society public policy statement: Novel risk factors and the global burden of chronic obstructive pulmonary disease. *Am J Respir Crit Care Med* 2010; **182**(5): 693-718 <https://pubmed.ncbi.nlm.nih.gov/20802169>.
19. Salvi SS, Barnes PJ. Chronic obstructive pulmonary disease in non-smokers. *Lancet* 2009; **374**(9691): 733-43 <https://pubmed.ncbi.nlm.nih.gov/19716966>.
20. World Health Organization. World Health Organization (WHO) Website [accessed Oct 2024]. <http://www.who.int>.
21. Safiri S, Carson-Chahhoud K, Noori M, et al. Burden of chronic obstructive pulmonary disease and its attributable risk factors in 204 countries and territories, 1990-2019: results from the Global Burden of Disease Study 2019. *Bmj* 2022; **378**: e069679 <https://pubmed.ncbi.nlm.nih.gov/35896191>.
22. World Health Organization. The Global Health Observatory, Global Health Estimates: Life expectancy and leading causes of death and disability [accessed Oct 2024]. <https://www.who.int/data/gho/data/themes/mortality-and-global-health-estimates>.
23. Halbert RJ, Natoli JL, Gano A, Badamgarav E, Buist AS, Mannino DM. Global burden of COPD: systematic review and meta-analysis. *Eur Respir J* 2006; **28**(3): 523-32 <https://pubmed.ncbi.nlm.nih.gov/16611654>.

24. Quach A, Giovannelli J, Cherot-Kornobis N, et al. Prevalence and underdiagnosis of airway obstruction among middle-aged adults in northern France: The ELISABET study 2011-2013. *Respir Med* 2015; **109**(12): 1553-61 <https://pubmed.ncbi.nlm.nih.gov/26564001>.
25. Adeloje D, Chua S, Lee C, et al. Global and regional estimates of COPD prevalence: Systematic review and meta-analysis. *J Glob Health* 2015; **5**(2): 020415 <https://pubmed.ncbi.nlm.nih.gov/26755942>.
26. Ntritsos G, Franek J, Belbasis L, et al. Gender-specific estimates of COPD prevalence: a systematic review and meta-analysis. *Int J Chron Obstruct Pulmon Dis* 2018; **13**: 1507-14 <https://pubmed.ncbi.nlm.nih.gov/29785100>.
27. Varmaghani M, Dehghani M, Heidari E, Sharifi F, Moghaddam SS, Farzadfar F. Global prevalence of chronic obstructive pulmonary disease: systematic review and meta-analysis. *East Mediterr Health J* 2019; **25**(1): 47-57 <https://pubmed.ncbi.nlm.nih.gov/30919925>.
28. Menezes AM, Perez-Padilla R, Jardim JR, et al. Chronic obstructive pulmonary disease in five Latin American cities (the PLATINO study): a prevalence study. *Lancet* 2005; **366**(9500): 1875-81 <https://pubmed.ncbi.nlm.nih.gov/16310554>.
29. Schirnhofner L, Lamprecht B, Vollmer WM, et al. COPD prevalence in Salzburg, Austria: results from the Burden of Obstructive Lung Disease (BOLD) Study. *Chest* 2007; **131**(1): 29-36 <https://pubmed.ncbi.nlm.nih.gov/17218553>.
30. Marshall DC, Al Omari O, Goodall R, et al. Trends in prevalence, mortality, and disability-adjusted life-years relating to chronic obstructive pulmonary disease in Europe: an observational study of the global burden of disease database, 2001-2019. *BMC Pulm Med* 2022; **22**(1): 289 <https://pubmed.ncbi.nlm.nih.gov/35902833>.
31. BOLD. Burden of Obstructive Lung Disease Initiative Webpage, published by Imperial College London, available here: <https://www.imperial.ac.uk/nhli/bold/> [accessed Oct 2024].
32. Burney P, Patel J, Minelli C, et al. Prevalence and Population-Attributable Risk for Chronic Airflow Obstruction in a Large Multinational Study. *Am J Respir Crit Care Med* 2021; **203**(11): 1353-65 <https://pubmed.ncbi.nlm.nih.gov/33171069>.
33. Lamprecht B, McBurnie MA, Vollmer WM, et al. COPD in never smokers: results from the population-based burden of obstructive lung disease study. *Chest* 2011; **139**(4): 752-63 <https://pubmed.ncbi.nlm.nih.gov/20884729>.
34. Al Ghobain M, Alhamad EH, Alorainy HS, Al Kassimi F, Lababidi H, Al-Hajjaj MS. The prevalence of chronic obstructive pulmonary disease in Riyadh, Saudi Arabia: a BOLD study. *Int J Tuberc Lung Dis* 2015; **19**(10): 1252-7 <https://pubmed.ncbi.nlm.nih.gov/26459542>.
35. Denguezli M, Daldoul H, Harrabi I, et al. COPD in Nonsmokers: Reports from the Tunisian Population-Based Burden of Obstructive Lung Disease Study. *PLoS One* 2016; **11**(3): e0151981 <https://pubmed.ncbi.nlm.nih.gov/27010214>.
36. El Rhazi K, Nejari C, BenJelloun MC, El Biaze M, Attassi M, Garcia-Larsen V. Prevalence of chronic obstructive pulmonary disease in Fez, Morocco: results from the BOLD study. *Int J Tuberc Lung Dis* 2016; **20**(1): 136-41 <https://pubmed.ncbi.nlm.nih.gov/26688540>.
37. Obaseki DO, Erhabor GE, Gnatiuc L, Adewole OO, Buist SA, Burney PG. Chronic Airflow Obstruction in a Black African Population: Results of BOLD Study, Ile-Ife, Nigeria. *COPD* 2016; **13**(1): 42-9 <https://pubmed.ncbi.nlm.nih.gov/26451840>.
38. Adeloje D, Song P, Zhu Y, et al. Global, regional, and national prevalence of, and risk factors for, chronic obstructive pulmonary disease (COPD) in 2019: a systematic review and modelling analysis. *Lancet Respir Med* 2022; **10**(5): 447-58 <https://pubmed.ncbi.nlm.nih.gov/35279265>.
39. Fallahzadeh A, Sharifnejad Tehrani Y, Sheikhy A, et al. The burden of chronic respiratory disease and attributable risk factors in North Africa and Middle East: findings from global burden of disease study (GBD) 2019. *Respir Res* 2022; **23**(1): 268 <https://pubmed.ncbi.nlm.nih.gov/36175873>.
40. Boers E, Barrett M, Su JG, et al. Global Burden of Chronic Obstructive Pulmonary Disease Through 2050. *JAMA Netw Open* 2023; **6**(12): e2346598 <https://pubmed.ncbi.nlm.nih.gov/38060225>.
41. Divo MJ, Celli BR, Poblador-Plou B, et al. Chronic Obstructive Pulmonary Disease (COPD) as a disease of early aging: Evidence from the EpiChron Cohort. *PLoS One* 2018; **13**(2): e0193143 <https://pubmed.ncbi.nlm.nih.gov/29470502>.
42. Agusti A, Noell G, Brugada J, Faner R. Lung function in early adulthood and health in later life: a transgenerational cohort analysis. *Lancet Respir Med* 2017; **5**(12): 935-45 <https://pubmed.ncbi.nlm.nih.gov/29150410>.
43. Chen W, Thomas J, Sadatsafavi M, FitzGerald JM. Risk of cardiovascular comorbidity in patients with chronic obstructive pulmonary disease: a systematic review and meta-analysis. *Lancet Respir Med* 2015; **3**(8): 631-9 <https://pubmed.ncbi.nlm.nih.gov/26208998>.
44. Mannino DM, Higuchi K, Yu TC, et al. Economic Burden of COPD in the Presence of Comorbidities. *Chest* 2015; **148**(1): 138-50 <https://pubmed.ncbi.nlm.nih.gov/25675282>.
45. World Health Organization. Evidence-Informed Policy Network: EVIPnet in Action [accessed Oct 2024]. <https://www.who.int/initiatives/evidence-informed-policy-network>.
46. Buist AS, McBurnie MA, Vollmer WM, et al. International variation in the prevalence of COPD (the BOLD Study): a population-based prevalence study. *Lancet* 2007; **370**(9589): 741-50 <https://pubmed.ncbi.nlm.nih.gov/17765523>.
47. Duong M, Islam S, Rangarajan S, et al. Global differences in lung function by region (PURE): an international, community-based prospective study. *Lancet Respir Med* 2013; **1**(8): 599-609 <https://pubmed.ncbi.nlm.nih.gov/24461663>.
48. Schneider A, Gantner L, Maag I, Borst MM, Wensing M, Szecsenyi J. Are ICD-10 codes appropriate for performance assessment in asthma and COPD in general practice? Results of a cross sectional observational study. *BMC Health Serv Res* 2005; **5**(1): 11 <https://pubmed.ncbi.nlm.nih.gov/15683548>.

49. Cooke CR, Joo MJ, Anderson SM, et al. The validity of using ICD-9 codes and pharmacy records to identify patients with chronic obstructive pulmonary disease. *BMC Health Serv Res* 2011; **11**: 37 <https://pubmed.ncbi.nlm.nih.gov/21324188>.
50. Stein BD, Bautista A, Schumock GT, et al. The validity of International Classification of Diseases, Ninth Revision, Clinical Modification diagnosis codes for identifying patients hospitalized for COPD exacerbations. *Chest* 2012; **141**(1): 87-93 <https://pubmed.ncbi.nlm.nih.gov/21757568>.
51. Jensen HH, Godtfredsen NS, Lange P, Vestbo J. Potential misclassification of causes of death from COPD. *Eur Respir J* 2006; **28**(4): 781-5 <https://pubmed.ncbi.nlm.nih.gov/16807258>.
52. Hoyert DL, Xu JQ. Deaths: preliminary data for 2011. *Natl Vital Stat Rep* 2011; **61**(6): 1-65
53. GBD Chronic Respiratory Disease Collaborators. Prevalence and attributable health burden of chronic respiratory diseases, 1990-2017: a systematic analysis for the Global Burden of Disease Study 2017. *Lancet Respir Med* 2020; **8**(6): 585-96 <https://pubmed.ncbi.nlm.nih.gov/32526187>.
54. Mortality GBD, Causes of Death C. Global, regional, and national age-sex specific all-cause and cause-specific mortality for 240 causes of death, 1990-2013: a systematic analysis for the Global Burden of Disease Study 2013. *Lancet* 2015; **385**(9963): 117-71 <https://pubmed.ncbi.nlm.nih.gov/25530442>.
55. Lopez AD, Shibuya K, Rao C, et al. Chronic obstructive pulmonary disease: current burden and future projections. *Eur Respir J* 2006; **27**(2): 397-412 <https://pubmed.ncbi.nlm.nih.gov/16452599>.
56. World Health Organization. Projections of mortality and causes of death, 2016 and 2060, online information available here: <https://colinmathers.com/2022/05/10/projections-of-global-deaths-from-2016-to-2060/> [accessed Oct 2024].
57. Forum of International Respiratory Societies (FIRS). The global impact of respiratory disease. Third Edition. ERS, 2021 available at: https://www.firsnet.org/images/publications/FIRS_Master_09202021.pdf [accessed Oct 2024].
58. Guarascio AJ, Ray SM, Finch CK, Self TH. The clinical and economic burden of chronic obstructive pulmonary disease in the USA. *Clinicoecon Outcomes Res* 2013; **5**: 235-45 <https://pubmed.ncbi.nlm.nih.gov/23818799>.
59. Zafari Z, Li S, Eakin MN, Bellanger M, Reed RM. Projecting Long-term Health and Economic Burden of COPD in the United States. *Chest* 2021; **159**(4): 1400-10 <https://pubmed.ncbi.nlm.nih.gov/33011203>.
60. Gutierrez Villegas C, Paz-Zulueta M, Herrero-Montes M, Paras-Bravo P, Madrazo Perez M. Cost analysis of chronic obstructive pulmonary disease (COPD): a systematic review. *Health Econ Rev* 2021; **11**(1): 31 <https://pubmed.ncbi.nlm.nih.gov/34403023>.
61. Stolbrink M, Thomson H, Hadfield RM, et al. The availability, cost, and affordability of essential medicines for asthma and COPD in low-income and middle-income countries: a systematic review. *Lancet Glob Health* 2022; **10**(10): e1423-e42 <https://pubmed.ncbi.nlm.nih.gov/36113528>.
62. Sin DD, Stafinski T, Ng YC, Bell NR, Jacobs P. The impact of chronic obstructive pulmonary disease on work loss in the United States. *Am J Respir Crit Care Med* 2002; **165**(5): 704-7 <https://pubmed.ncbi.nlm.nih.gov/11874818>.
63. Murray CJ, Lopez AD. Alternative projections of mortality and disability by cause 1990-2020: Global Burden of Disease Study. *Lancet* 1997; **349**(9064): 1498-504 <https://pubmed.ncbi.nlm.nih.gov/9167458>.
64. Chen X, Zhou CW, Fu YY, et al. Global, regional, and national burden of chronic respiratory diseases and associated risk factors, 1990-2019: Results from the Global Burden of Disease Study 2019. *Front Med (Lausanne)* 2023; **10**: 1066804 <https://pubmed.ncbi.nlm.nih.gov/37056726>.
65. Li H, Liang H, Wei L, et al. Health Inequality in the Global Burden of Chronic Obstructive Pulmonary Disease: Findings from the Global Burden of Disease Study 2019. *Int J Chron Obstruct Pulmon Dis* 2022; **17**: 1695-702 <https://pubmed.ncbi.nlm.nih.gov/35923358>.
66. GBD Chronic Respiratory Disease Collaborators. Global, regional, and national deaths, prevalence, disability-adjusted life years, and years lived with disability for chronic obstructive pulmonary disease and asthma, 1990-2015: a systematic analysis for the Global Burden of Disease Study 2015. *Lancet Respir Med* 2017; **5**(9): 691-706 <https://pubmed.ncbi.nlm.nih.gov/28822787>.
67. Murray CJ, Atkinson C, Bhalla K, et al. The state of US health, 1990-2010: burden of diseases, injuries, and risk factors. *JAMA* 2013; **310**(6): 591-608 <https://pubmed.ncbi.nlm.nih.gov/23842577>.
68. Kohansal R, Martinez-Cambor P, Agusti A, Buist AS, Mannino DM, Soriano JB. The natural history of chronic airflow obstruction revisited: an analysis of the Framingham offspring cohort. *Am J Respir Crit Care Med* 2009; **180**(1): 3-10 <https://pubmed.ncbi.nlm.nih.gov/19342411>.
69. Çolak Y, Løkke A, Marott JL, et al. Low smoking exposure and development and prognosis of COPD over four decades: A population-based cohort study. *Eur Respir J* 2024: <https://pubmed.ncbi.nlm.nih.gov/38936967>.
70. Rennard SI, Vestbo J. COPD: the dangerous underestimate of 15%. *Lancet* 2006; **367**(9518): 1216-9 <https://pubmed.ncbi.nlm.nih.gov/16631861>.
71. Bardsen T, Roksund OD, Benestad MR, et al. Tracking of lung function from 10 to 35 years after being born extremely preterm or with extremely low birth weight. *Thorax* 2022; **77**(8): 790-8 <https://pubmed.ncbi.nlm.nih.gov/35410959>.
72. Raad D, Gaddam S, Schunemann HJ, et al. Effects of water-pipe smoking on lung function: a systematic review and meta-analysis. *Chest* 2011; **139**(4): 764-74 <https://pubmed.ncbi.nlm.nih.gov/20671057>.
73. She J, Yang P, Wang Y, et al. Chinese water-pipe smoking and the risk of COPD. *Chest* 2014; **146**(4): 924-31 <https://pubmed.ncbi.nlm.nih.gov/24557573>.
74. Gunen H, Tarraf H, Nemati A, Al Ghobain M, Al Mutairi S, Aoun Bacha Z. Waterpipe tobacco smoking. *Tuberk Toraks* 2016; **64**(1): 94-6 <https://pubmed.ncbi.nlm.nih.gov/27266294>.

75. Tan WC, Lo C, Jong A, et al. Marijuana and chronic obstructive lung disease: a population-based study. *CMAJ* 2009; **180**(8): 814-20 <https://pubmed.ncbi.nlm.nih.gov/19364790>.
76. Yin P, Jiang CQ, Cheng KK, et al. Passive smoking exposure and risk of COPD among adults in China: the Guangzhou Biobank Cohort Study. *Lancet* 2007; **370**(9589): 751-7 <https://pubmed.ncbi.nlm.nih.gov/17765524>.
77. Chen P, Li Y, Wu D, Liu F, Cao C. Secondhand Smoke Exposure and the Risk of Chronic Obstructive Pulmonary Disease: A Systematic Review and Meta-Analysis. *Int J Chron Obstruct Pulmon Dis* 2023; **18**: 1067-76 <https://pubmed.ncbi.nlm.nih.gov/37309392>.
78. Tager IB, Ngo L, Hanrahan JP. Maternal smoking during pregnancy. Effects on lung function during the first 18 months of life. *Am J Respir Crit Care Med* 1995; **152**(3): 977-83 <https://pubmed.ncbi.nlm.nih.gov/7663813>.
79. Orozco-Levi M, Garcia-Aymerich J, Villar J, Ramirez-Sarmiento A, Anto JM, Gea J. Wood smoke exposure and risk of chronic obstructive pulmonary disease. *Eur Respir J* 2006; **27**(3): 542-6 <https://pubmed.ncbi.nlm.nih.gov/16507854>.
80. Mortimer K, Montes de Oca M, Salvi S, et al. Household air pollution and COPD: cause and effect or confounding by other aspects of poverty? *Int J Tuberc Lung Dis* 2022; **26**(3): 206-16 <https://pubmed.ncbi.nlm.nih.gov/35197160>.
81. Gan WQ, FitzGerald JM, Carlsten C, Sadatsafavi M, Brauer M. Associations of ambient air pollution with chronic obstructive pulmonary disease hospitalization and mortality. *Am J Respir Crit Care Med* 2013; **187**(7): 721-7 <https://pubmed.ncbi.nlm.nih.gov/23392442>.
82. Ezzati M. Indoor air pollution and health in developing countries. *Lancet* 2005; **366**(9480): 104-6 <https://pubmed.ncbi.nlm.nih.gov/16005317>.
83. Zhou Y, Zou Y, Li X, et al. Lung function and incidence of chronic obstructive pulmonary disease after improved cooking fuels and kitchen ventilation: a 9-year prospective cohort study. *PLoS Med* 2014; **11**(3): e1001621 <https://pubmed.ncbi.nlm.nih.gov/24667834>.
84. Sana A, Somda SMA, Meda N, Boulard C. Chronic obstructive pulmonary disease associated with biomass fuel use in women: a systematic review and meta-analysis. *BMJ Open Respir Res* 2018; **5**(1): e000246 <https://pubmed.ncbi.nlm.nih.gov/29387422>.
85. Assad NA, Balmes J, Mehta S, Cheema U, Sood A. Chronic obstructive pulmonary disease secondary to household air pollution. *Semin Respir Crit Care Med* 2015; **36**(3): 408-21 <https://pubmed.ncbi.nlm.nih.gov/26024348>.
86. Sherrill DL, Lebowitz MD, Burrows B. Epidemiology of chronic obstructive pulmonary disease. *Clin Chest Med* 1990; **11**(3): 375-87 <https://pubmed.ncbi.nlm.nih.gov/2205437>.
87. Ramirez-Venegas A, Velazquez-Uncal M, Aranda-Chavez A, et al. Bronchodilators for hyperinflation in COPD associated with biomass smoke: clinical trial. *Int J Chron Obstruct Pulmon Dis* 2019; **14**: 1753-62 <https://pubmed.ncbi.nlm.nih.gov/31496674>.
88. Puzzolo E, Fleeman N, Lorenzetti F, et al. Estimated health effects from domestic use of gaseous fuels for cooking and heating in high-income, middle-income, and low-income countries: a systematic review and meta-analyses. *Lancet Respir Med* 2024: <https://pubmed.ncbi.nlm.nih.gov/38310914>.
89. Guldaval F, Polat G, Doruk S, et al. What are the Differences Between Smoker and Non-smoker COPD Cases? Is it a Different Phenotype? *Turk Thorac J* 2021; **22**(4): 284-8 <https://pubmed.ncbi.nlm.nih.gov/35110244>.
90. Ramirez-Venegas A, Montiel-Lopez F, Falfan-Valencia R, Perez-Rubio G, Sansores RH. The "Slow Horse Racing Effect" on Lung Function in Adult Life in Chronic Obstructive Pulmonary Disease Associated to Biomass Exposure. *Front Med (Lausanne)* 2021; **8**: 700836 <https://pubmed.ncbi.nlm.nih.gov/34307427>.
91. Salvi SS, Brashier BB, Londhe J, et al. Phenotypic comparison between smoking and non-smoking chronic obstructive pulmonary disease. *Respir Res* 2020; **21**(1): 50 <https://pubmed.ncbi.nlm.nih.gov/32050955>.
92. Hansel NN, Woo H, Koehler K, et al. Indoor Pollution and Lung Function Decline in Current and Former Smokers: SPIROMICS AIR. *Am J Respir Crit Care Med* 2023; **208**(10): 1042-51 <https://pubmed.ncbi.nlm.nih.gov/37523421>.
93. Hansel NN, Putcha N, Woo H, et al. Randomized Clinical Trial of Air Cleaners to Improve Indoor Air Quality and Chronic Obstructive Pulmonary Disease Health: Results of the CLEAN AIR Study. *Am J Respir Crit Care Med* 2022; **205**(4): 421-30 <https://pubmed.ncbi.nlm.nih.gov/34449285>.
94. Paulin LM, Diette GB, Blanc PD, et al. Occupational exposures are associated with worse morbidity in patients with chronic obstructive pulmonary disease. *Am J Respir Crit Care Med* 2015; **191**(5): 557-65 <https://pubmed.ncbi.nlm.nih.gov/25562375>.
95. Lytras T, Kogevinas M, Kromhout H, et al. Occupational exposures and 20-year incidence of COPD: the European Community Respiratory Health Survey. *Thorax* 2018; **73**(11): 1008-15 <https://pubmed.ncbi.nlm.nih.gov/29574416>.
96. Faruque MO, Boezen HM, Kromhout H, Vermeulen R, Bultmann U, Vonk JM. Airborne occupational exposures and the risk of developing respiratory symptoms and airway obstruction in the Lifelines Cohort Study. *Thorax* 2021; **76**(8): 790-7 <https://pubmed.ncbi.nlm.nih.gov/33653936>.
97. De Matteis S, Jarvis D, Darnton A, et al. The occupations at increased risk of COPD: analysis of lifetime job-histories in the population-based UK Biobank Cohort. *Eur Respir J* 2019; **54**(1): 1900186 <https://pubmed.ncbi.nlm.nih.gov/31248951>.
98. Marchetti N, Garshick E, Kinney GL, et al. Association between occupational exposure and lung function, respiratory symptoms, and high-resolution computed tomography imaging in COPD Gene. *Am J Respir Crit Care Med* 2014; **190**(7): 756-62 <https://pubmed.ncbi.nlm.nih.gov/25133327>.

99. Hnizdo E, Sullivan PA, Bang KM, Wagner G. Association between chronic obstructive pulmonary disease and employment by industry and occupation in the US population: a study of data from the Third National Health and Nutrition Examination Survey. *Am J Epidemiol* 2002; **156**(8): 738-46 <https://pubmed.ncbi.nlm.nih.gov/12370162>.
100. Balmes J, Becklake M, Blanc P, et al. American Thoracic Society Statement: Occupational contribution to the burden of airway disease. *Am J Respir Crit Care Med* 2003; **167**(5): 787-97 <https://pubmed.ncbi.nlm.nih.gov/12598220>.
101. Institute for Health Metrics and Evaluation. GBD Compare—Viz Hub. <https://vizhub.healthdata.org/gbd-compare/> [Accessed Oct 2024]. 2022:
102. GBD Risk Factors Collaborators. Global burden of 87 risk factors in 204 countries and territories, 1990-2019: a systematic analysis for the Global Burden of Disease Study 2019. *Lancet* 2020; **396**(10258): 1223-49 <https://pubmed.ncbi.nlm.nih.gov/33069327>.
103. Guo C, Zhang Z, Lau AKH, et al. Effect of long-term exposure to fine particulate matter on lung function decline and risk of chronic obstructive pulmonary disease in Taiwan: a longitudinal, cohort study. *Lancet Planet Health* 2018; **2**(3): e114-e25 <https://pubmed.ncbi.nlm.nih.gov/29615226>.
104. Bourbeau J, Doiron D, Biswas S, et al. Ambient Air Pollution and Dysanapsis: Associations with Lung Function and Chronic Obstructive Pulmonary Disease in the Canadian Cohort Obstructive Lung Disease Study. *Am J Respir Crit Care Med* 2022; **206**(1): 44-55 <https://pubmed.ncbi.nlm.nih.gov/35380941>.
105. Ross BA, Doiron D, Benedetti A, et al. Short-term air pollution exposure and exacerbation events in mild to moderate COPD: a case-crossover study within the CanCOLD cohort. *Thorax* 2023; **78**(10): 974-82 <https://pubmed.ncbi.nlm.nih.gov/37147124>.
106. Regan EA, Lowe ME, Make BJ, et al. Early Evidence of Chronic Obstructive Pulmonary Disease Obscured by Race-Specific Prediction Equations. *Am J Respir Crit Care Med* 2024; **209**(1): 59-69 <https://pubmed.ncbi.nlm.nih.gov/37611073>.
107. McCloskey SC, Patel BD, Hinchliffe SJ, Reid ED, Wareham NJ, Lomas DA. Siblings of patients with severe chronic obstructive pulmonary disease have a significant risk of airflow obstruction. *Am J Respir Crit Care Med* 2001; **164**(8 Pt 1): 1419-24 <https://pubmed.ncbi.nlm.nih.gov/11704589>.
108. Stoller JK, Aboussouan LS. Alpha1-antitrypsin deficiency. *Lancet* 2005; **365**(9478): 2225-36 <https://pubmed.ncbi.nlm.nih.gov/15978931>.
109. Blanco I, Diego I, Bueno P, Perez-Holanda S, Casas-Maldonado F, Miravittles M. Prevalence of alpha(1)-antitrypsin PiZZ genotypes in patients with COPD in Europe: a systematic review. *Eur Respir Rev* 2020; **29**(157): 200014 <https://pubmed.ncbi.nlm.nih.gov/32699024>.
110. Martinez-Gonzalez C, Blanco I, Diego I, Bueno P, Miravittles M. Estimated Prevalence and Number of PiMZ Genotypes of Alpha-1 Antitrypsin in Seventy-Four Countries Worldwide. *Int J Chron Obstruct Pulmon Dis* 2021; **16**: 2617-30 <https://pubmed.ncbi.nlm.nih.gov/34556982>.
111. Franciosi AN, Hobbs BD, McElvaney OJ, et al. Clarifying the Risk of Lung Disease in SZ Alpha-1 Antitrypsin Deficiency. *Am J Respir Crit Care Med* 2020; **202**(1): 73-82 <https://pubmed.ncbi.nlm.nih.gov/32197047>.
112. Molloy K, Hersh CP, Morris VB, et al. Clarification of the risk of chronic obstructive pulmonary disease in alpha1-antitrypsin deficiency PiMZ heterozygotes. *Am J Respir Crit Care Med* 2014; **189**(4): 419-27 <https://pubmed.ncbi.nlm.nih.gov/24428606>.
113. Stockley RA. Alpha-1 Antitrypsin Deficiency: The Learning Goes On. *Am J Respir Crit Care Med* 2020; **202**(1): 6-7 <https://pubmed.ncbi.nlm.nih.gov/32343597>.
114. Hunninghake GM, Cho MH, Tesfaigzi Y, et al. MMP12, lung function, and COPD in high-risk populations. *N Engl J Med* 2009; **361**(27): 2599-608 <https://pubmed.ncbi.nlm.nih.gov/20018959>.
115. Ding Z, Wang K, Li J, Tan Q, Tan W, Guo G. Association between glutathione S-transferase gene M1 and T1 polymorphisms and chronic obstructive pulmonary disease risk: A meta-analysis. *Clin Genet* 2019; **95**(1): 53-62 <https://pubmed.ncbi.nlm.nih.gov/29704242>.
116. Cho MH, Boutaoui N, Klanderma BJ, et al. Variants in FAM13A are associated with chronic obstructive pulmonary disease. *Nat Genet* 2010; **42**(3): 200-2 <https://pubmed.ncbi.nlm.nih.gov/20173748>.
117. Pillai SG, Ge D, Zhu G, et al. A genome-wide association study in chronic obstructive pulmonary disease (COPD): identification of two major susceptibility loci. *PLoS Genet* 2009; **5**(3): e1000421 <https://pubmed.ncbi.nlm.nih.gov/19300482>.
118. Soler Artigas M, Wain LV, Repapi E, et al. Effect of five genetic variants associated with lung function on the risk of chronic obstructive lung disease, and their joint effects on lung function. *Am J Respir Crit Care Med* 2011; **184**(7): 786-95 <https://pubmed.ncbi.nlm.nih.gov/21965014>.
119. Repapi E, Sayers I, Wain LV, et al. Genome-wide association study identifies five loci associated with lung function. *Nat Genet* 2010; **42**(1): 36-44 <https://pubmed.ncbi.nlm.nih.gov/20010834>.
120. Cho MH, McDonald ML, Zhou X, et al. Risk loci for chronic obstructive pulmonary disease: a genome-wide association study and meta-analysis. *Lancet Respir Med* 2014; **2**(3): 214-25 <https://pubmed.ncbi.nlm.nih.gov/24621683>.
121. Lange P, Celli B, Agusti A, et al. Lung-Function Trajectories Leading to Chronic Obstructive Pulmonary Disease. *N Engl J Med* 2015; **373**(2): 111-22 <https://pubmed.ncbi.nlm.nih.gov/26154786>.
122. Agusti A, Faner R. Lung function trajectories in health and disease. *Lancet Respir Med* 2019; **7**(4): 358-64 <https://pubmed.ncbi.nlm.nih.gov/30765254>.

123. Bertels X, Ross JC, Faner R, et al. Clinical relevance of lung function trajectory clusters in middle-aged and older adults. *ERJ Open Res* 2024; **10**(1): <https://pubmed.ncbi.nlm.nih.gov/38333649>.
124. Çolak Y, Nordestgaard BG, Vestbo J, Lange P, Afzal S. Relationship between supernormal lung function and long-term risk of hospitalisations and mortality: a population-based cohort study. *European Respiratory Journal* 2021: 2004055
125. Agusti A, Fabbri LM, Baraldi E, et al. Spirometry: A practical lifespan predictor of global health and chronic respiratory and non-respiratory diseases. *Eur J Intern Med* 2021; **89**: 3-9 <https://pubmed.ncbi.nlm.nih.gov/34016514>.
126. Melén E, Faner R, Allinson JP, et al. Lung-function trajectories: relevance and implementation in clinical practice. *Lancet* 2024; **403**(10435): 1494-503 <https://pubmed.ncbi.nlm.nih.gov/38490231>.
127. ERS CADSET collaboration. Lungtracker website: Lung Function Tracker. 2024. https://calculator.ersnet.org/lung_tracker/ [accessed Oct 2024].
128. Regan EA, Lynch DA, Curran-Everett D, et al. Clinical and Radiologic Disease in Smokers With Normal Spirometry. *JAMA Intern Med* 2015; **175**(9): 1539-49 <https://pubmed.ncbi.nlm.nih.gov/26098755>.
129. Lawlor DA, Ebrahim S, Davey Smith G. Association of birth weight with adult lung function: findings from the British Women's Heart and Health Study and a meta-analysis. *Thorax* 2005; **60**(10): 851-8 <https://pubmed.ncbi.nlm.nih.gov/16055617>.
130. Green M, Mead J, Turner JM. Variability of maximum expiratory flow-volume curves. *J Appl Physiol* 1974; **37**(1): 67-74 <https://pubmed.ncbi.nlm.nih.gov/4836570>.
131. Ito K, Barnes PJ. COPD as a disease of accelerated lung aging. *Chest* 2009; **135**(1): 173-80 <https://pubmed.ncbi.nlm.nih.gov/19136405>.
132. Martin TR, Feldman HA, Fredberg JJ, Castile RG, Mead J, Wohl ME. Relationship between maximal expiratory flows and lung volumes in growing humans. *J Appl Physiol (1985)* 1988; **65**(2): 822-8 <https://pubmed.ncbi.nlm.nih.gov/3170432>.
133. Rawlins EL, Okubo T, Xue Y, et al. The role of Scgb1a1+ Clara cells in the long-term maintenance and repair of lung airway, but not alveolar, epithelium. *Cell Stem Cell* 2009; **4**(6): 525-34 <https://pubmed.ncbi.nlm.nih.gov/19497281>.
134. Smith BM, Kirby M, Hoffman EA, et al. Association of Dysanapsis With Chronic Obstructive Pulmonary Disease Among Older Adults. *JAMA* 2020; **323**(22): 2268-80 <https://pubmed.ncbi.nlm.nih.gov/32515814>.
135. Dharmage SC, Bui DS, Walters EH, et al. Lifetime spirometry patterns of obstruction and restriction, and their risk factors and outcomes: a prospective cohort study. *Lancet Respir Med* 2023; **11**(3): 273-82 <https://pubmed.ncbi.nlm.nih.gov/36244396>.
136. Bose S, Pascoe C, McEvoy C. Lifetime lung function trajectories and COPD: when the train derails. *Lancet Respir Med* 2023; **11**(3): 221-2 <https://pubmed.ncbi.nlm.nih.gov/36244395>.
137. Lillebøe HL, Engeset MS, Clemm HH, et al. Expiratory airflow limitation in adults born extremely preterm: A systematic review and meta-analysis. *Paediatr Respir Rev* 2024: <https://pubmed.ncbi.nlm.nih.gov/38490917>.
138. Fletcher C, Peto R. The natural history of chronic airflow obstruction. *Br Med J* 1977; **1**(6077): 1645-8 <https://pubmed.ncbi.nlm.nih.gov/871704>.
139. Mercado N, Ito K, Barnes PJ. Accelerated ageing of the lung in COPD: new concepts. *Thorax* 2015; **70**(5): 482-9 <https://pubmed.ncbi.nlm.nih.gov/25739910>.
140. Cordoba-Lanus E, Cazorla-Rivero S, Garcia-Bello MA, et al. Telomere length dynamics over 10-years and related outcomes in patients with COPD. *Respir Res* 2021; **22**(1): 56 <https://pubmed.ncbi.nlm.nih.gov/33608013>.
141. Hernandez Cordero AI, Yang CX, Li X, et al. Epigenetic marker of telomeric age is associated with exacerbations and hospitalizations in chronic obstructive pulmonary disease. *Respir Res* 2021; **22**(1): 316 <https://pubmed.ncbi.nlm.nih.gov/34937547>.
142. Hernandez Cordero AI, Yang CX, Milne S, et al. Epigenetic blood biomarkers of ageing and mortality in COPD. *Eur Respir J* 2021; **58**(6): <https://pubmed.ncbi.nlm.nih.gov/34561282>.
143. Barker DJ, Godfrey KM, Fall C, Osmond C, Winter PD, Shaheen SO. Relation of birth weight and childhood respiratory infection to adult lung function and death from chronic obstructive airways disease. *BMJ* 1991; **303**(6804): 671-5 <https://pubmed.ncbi.nlm.nih.gov/1912913>.
144. Todisco T, de Benedictis FM, Iannacci L, et al. Mild prematurity and respiratory functions. *Eur J Pediatr* 1993; **152**(1): 55-8 <https://pubmed.ncbi.nlm.nih.gov/8444206>.
145. Smith BM, Traboulsi H, Austin JHM, et al. Human airway branch variation and chronic obstructive pulmonary disease. *Proc Natl Acad Sci U S A* 2018; **115**(5): E974-E81 <https://pubmed.ncbi.nlm.nih.gov/29339516>.
146. Vameghestahbanati M, Kirby M, Tanabe N, et al. Central Airway Tree Dysanapsis Extends to the Peripheral Airways. *Am J Respir Crit Care Med* 2021; **203**(3): 378-81 <https://pubmed.ncbi.nlm.nih.gov/33137261>.
147. Leary D, Bhatwadekar SA, Parraga G, Maksym GN. Modeling stochastic and spatial heterogeneity in a human airway tree to determine variation in respiratory system resistance. *J Appl Physiol (1985)* 2012; **112**(1): 167-75 <https://pubmed.ncbi.nlm.nih.gov/21998266>.
148. Tawhai MH, Hunter P, Tschirren J, Reinhardt J, McLennan G, Hoffman EA. CT-based geometry analysis and finite element models of the human and ovine bronchial tree. *J Appl Physiol (1985)* 2004; **97**(6): 2310-21 <https://pubmed.ncbi.nlm.nih.gov/15322064>.
149. Young HM, Guo F, Eddy RL, Maksym G, Parraga G. Oscillometry and pulmonary MRI measurements of ventilation heterogeneity in obstructive lung disease: relationship to quality of life and disease control. *J Appl Physiol (1985)* 2018; **125**(1): 73-85 <https://pubmed.ncbi.nlm.nih.gov/29543132>.

150. Agusti A, Hogg JC. Update on the Pathogenesis of Chronic Obstructive Pulmonary Disease. *N Engl J Med* 2019; **381**(13): 1248-56 <https://pubmed.ncbi.nlm.nih.gov/31553836>.
151. Celli BR, Agusti A. COPD: time to improve its taxonomy? *ERJ Open Res* 2018; **4**(1): 00132-2017 <https://pubmed.ncbi.nlm.nih.gov/29707563>.
152. Zhou Y, Zhong NS, Li X, et al. Tiotropium in Early-Stage Chronic Obstructive Pulmonary Disease. *N Engl J Med* 2017; **377**(10): 923-35 <https://pubmed.ncbi.nlm.nih.gov/28877027>.
153. Martinez FJ, Han MK, Allinson JP, et al. At the Root: Defining and Halting Progression of Early Chronic Obstructive Pulmonary Disease. *Am J Respir Crit Care Med* 2018; **197**(12): 1540-51 <https://pubmed.ncbi.nlm.nih.gov/29406779>.
154. Colak Y, Afzal S, Nordestgaard BG, Lange P, Vestbo J. Importance of Early COPD in Young Adults for Development of Clinical COPD: Findings from the Copenhagen General Population Study. *Am J Respir Crit Care Med* 2021; **203**(10): 1245-56 <https://pubmed.ncbi.nlm.nih.gov/33142077>.
155. Cosio BG, Pascual-Guardia S, Borrás-Santos A, et al. Phenotypic characterisation of early COPD: a prospective case-control study. *ERJ Open Res* 2020; **6**(4): 00047-2020 <https://pubmed.ncbi.nlm.nih.gov/33043045>.
156. Çolak Y, Lange P, Vestbo J, Nordestgaard BG, Afzal S. Susceptible Young Adults and Development of COPD Later in Life. *Am J Respir Crit Care Med* 2024: <https://pubmed.ncbi.nlm.nih.gov/38364200>.
157. Han MK, Agusti A, Celli BR, et al. From GOLD 0 to Pre-COPD. *Am J Respir Crit Care Med* 2021; **203**(4): 414-23 <https://pubmed.ncbi.nlm.nih.gov/33211970>.
158. Martinez F. A. A., Celli, B.R., Han, M.K., Allinson, J., Bhatt, S.P. Treatment Trials in Pre-COPD and Young COPD: Time to Move Forward. *Am J Respir Crit Care Med* 2021; **in press**:
159. Wan ES. The Clinical Spectrum of PRISm. *Am J Respir Crit Care Med* 2022; **206**(5): 524-5 <https://pubmed.ncbi.nlm.nih.gov/35612910>.
160. Higbee DH, Granell R, Davey Smith G, Dodd JW. Prevalence, risk factors, and clinical implications of preserved ratio impaired spirometry: a UK Biobank cohort analysis. *Lancet Respir Med* 2022; **10**(2): 149-57 <https://pubmed.ncbi.nlm.nih.gov/34739861>.
161. Perez-Padilla R, Montes de Oca M, Thirion-Romero I, et al. Trajectories of Spirometric Patterns, Obstructive and PRISm, in a Population-Based Cohort in Latin America. *Int J Chron Obstruct Pulmon Dis* 2023; **18**: 1277-85 <https://pubmed.ncbi.nlm.nih.gov/37366430>.
162. Wan ES, Balte P, Schwartz JE, et al. Association Between Preserved Ratio Impaired Spirometry and Clinical Outcomes in US Adults. *JAMA* 2021; **326**(22): 2287-98 <https://pubmed.ncbi.nlm.nih.gov/34905031>.
163. Wijnant SRA, De Roos E, Kavousi M, et al. Trajectory and mortality of preserved ratio impaired spirometry: the Rotterdam Study. *Eur Respir J* 2020; **55**(1): <https://pubmed.ncbi.nlm.nih.gov/31601717>.
164. Wan ES, Hokanson JE, Regan EA, et al. Significant Spirometric Transitions and Preserved Ratio Impaired Spirometry Among Ever Smokers. *Chest* 2022; **161**(3): 651-61 <https://pubmed.ncbi.nlm.nih.gov/34592319>.
165. Washio Y, Sakata S, Fukuyama S, et al. Risks of Mortality and Airflow Limitation in Japanese Individuals with Preserved Ratio Impaired Spirometry. *Am J Respir Crit Care Med* 2022; **206**(5): 563-72 <https://pubmed.ncbi.nlm.nih.gov/35549659>.
166. Marott JL, Ingebrigtsen TS, Colak Y, Vestbo J, Lange P. Trajectory of Preserved Ratio Impaired Spirometry: Natural History and Long-Term Prognosis. *Am J Respir Crit Care Med* 2021; **204**(8): 910-20 <https://pubmed.ncbi.nlm.nih.gov/34233141>.
167. Zheng J, Zhou R, Zhang Y, et al. Preserved Ratio Impaired Spirometry in Relationship to Cardiovascular Outcomes: A Large Prospective Cohort Study. *Chest* 2023; **163**(3): 610-23 <https://pubmed.ncbi.nlm.nih.gov/36372304>.
168. Kogo M, Sato S, Muro S, et al. Longitudinal Changes and Association of Respiratory Symptoms with Preserved Ratio Impaired Spirometry (PRISm): The Nagahama Study. *Ann Am Thorac Soc* 2023; **20**(11): 1578-86 <https://pubmed.ncbi.nlm.nih.gov/37560979>.
169. Phillips DB, James MD, Vincent SG, et al. Physiological Characterization of Preserved Ratio Impaired Spirometry in the CanCOLD Study: Implications for Exertional Dyspnea and Exercise Intolerance. *Am J Respir Crit Care Med* 2024: <https://pubmed.ncbi.nlm.nih.gov/38170674>.
170. Han MK, Ye W, Wang D, et al. Bronchodilators in Tobacco-Exposed Persons with Symptoms and Preserved Lung Function. *N Engl J Med* 2022; **387**(13): 1173-84 <https://pubmed.ncbi.nlm.nih.gov/36066078>.
171. Silva GE, Sherrill DL, Guerra S, Barbee RA. Asthma as a risk factor for COPD in a longitudinal study. *Chest* 2004; **126**(1): 59-65 <https://pubmed.ncbi.nlm.nih.gov/15249443>.
172. Vonk JM, Jongepier H, Panhuysen CI, Schouten JP, Bleeker ER, Postma DS. Risk factors associated with the presence of irreversible airflow limitation and reduced transfer coefficient in patients with asthma after 26 years of follow up. *Thorax* 2003; **58**(4): 322-7 <https://pubmed.ncbi.nlm.nih.gov/12668795>.
173. Lange P, Parner J, Vestbo J, Schnohr P, Jensen G. A 15-year follow-up study of ventilatory function in adults with asthma. *N Engl J Med* 1998; **339**(17): 1194-200 <https://pubmed.ncbi.nlm.nih.gov/9780339>.
174. McGeachie MJ, Yates KP, Zhou X, et al. Patterns of Growth and Decline in Lung Function in Persistent Childhood Asthma. *N Engl J Med* 2016; **374**(19): 1842-52 <https://pubmed.ncbi.nlm.nih.gov/27168434>.
175. de Marco R, Accordini S, Marcon A, et al. Risk factors for chronic obstructive pulmonary disease in a European cohort of young adults. *Am J Respir Crit Care Med* 2011; **183**(7): 891-7 <https://pubmed.ncbi.nlm.nih.gov/20935112>.

176. Fabbri LM, Romagnoli M, Corbetta L, et al. Differences in airway inflammation in patients with fixed airflow obstruction due to asthma or chronic obstructive pulmonary disease. *Am J Respir Crit Care Med* 2003; **167**(3): 418-24 <https://pubmed.ncbi.nlm.nih.gov/12426229>.
177. To T, Zhu J, Larsen K, et al. Progression from Asthma to Chronic Obstructive Pulmonary Disease. Is Air Pollution a Risk Factor? *Am J Respir Crit Care Med* 2016; **194**(4): 429-38 <https://pubmed.ncbi.nlm.nih.gov/26950751>.
178. Rijcken B, Schouten JP, Weiss ST, Speizer FE, van der Lende R. The relationship of nonspecific bronchial responsiveness to respiratory symptoms in a random population sample. *Am Rev Respir Dis* 1987; **136**(1): 62-8 <https://pubmed.ncbi.nlm.nih.gov/3605843>.
179. Hoppers JJ, Postma DS, Rijcken B, Weiss ST, Schouten JP. Histamine airway hyper-responsiveness and mortality from chronic obstructive pulmonary disease: a cohort study. *Lancet* 2000; **356**(9238): 1313-7 <https://pubmed.ncbi.nlm.nih.gov/11073020>.
180. Tashkin DP, Altose MD, Connett JE, Kanner RE, Lee WW, Wise RA. Methacholine reactivity predicts changes in lung function over time in smokers with early chronic obstructive pulmonary disease. The Lung Health Study Research Group. *Am J Respir Crit Care Med* 1996; **153**(6 Pt 1): 1802-11 <https://pubmed.ncbi.nlm.nih.gov/8665038>.
181. de Oca MM, Halbert RJ, Lopez MV, et al. The chronic bronchitis phenotype in subjects with and without COPD: the PLATINO study. *Eur Respir J* 2012; **40**(1): 28-36 <https://pubmed.ncbi.nlm.nih.gov/22282547>.
182. Agusti A, Calverley PM, Celli B, et al. Characterisation of COPD heterogeneity in the ECLIPSE cohort. *Respir Res* 2010; **11**(1): 122 <https://pubmed.ncbi.nlm.nih.gov/20831787>.
183. Kim V, Han MK, Vance GB, et al. The chronic bronchitic phenotype of COPD: an analysis of the COPD Gene Study. *Chest* 2011; **140**(3): 626-33 <https://pubmed.ncbi.nlm.nih.gov/21474571>.
184. Lu M, Yao W, Zhong N, et al. Chronic obstructive pulmonary disease in the absence of chronic bronchitis in China. *Respirology* 2010; **15**(7): 1072-8 <https://pubmed.ncbi.nlm.nih.gov/20723142>.
185. Speizer FE, Fay ME, Dockery DW, Ferris BG, Jr. Chronic obstructive pulmonary disease mortality in six U.S. cities. *Am Rev Respir Dis* 1989; **140**(3 Pt 2): S49-55 <https://pubmed.ncbi.nlm.nih.gov/2782760>.
186. Trupin L, Earnest G, San Pedro M, et al. The occupational burden of chronic obstructive pulmonary disease. *Eur Respir J* 2003; **22**(3): 462-9 <https://pubmed.ncbi.nlm.nih.gov/14516136>.
187. Matheson MC, Benke G, Raven J, et al. Biological dust exposure in the workplace is a risk factor for chronic obstructive pulmonary disease. *Thorax* 2005; **60**(8): 645-51 <https://pubmed.ncbi.nlm.nih.gov/16061705>.
188. Pelkonen M, Notkola IL, Nissinen A, Tukiainen H, Koskela H. Thirty-year cumulative incidence of chronic bronchitis and COPD in relation to 30-year pulmonary function and 40-year mortality: a follow-up in middle-aged rural men. *Chest* 2006; **130**(4): 1129-37 <https://pubmed.ncbi.nlm.nih.gov/17035447>.
189. Miravittles M, de la Roza C, Morera J, et al. Chronic respiratory symptoms, spirometry and knowledge of COPD among general population. *Respir Med* 2006; **100**(11): 1973-80 <https://pubmed.ncbi.nlm.nih.gov/16626950>.
190. Ehrlich RI, White N, Norman R, et al. Predictors of chronic bronchitis in South African adults. *Int J Tuberc Lung Dis* 2004; **8**(3): 369-76 <https://pubmed.ncbi.nlm.nih.gov/15139477>.
191. Barish CF, Wu WC, Castell DO. Respiratory complications of gastroesophageal reflux. *Arch Intern Med* 1985; **145**(10): 1882-8 <https://pubmed.ncbi.nlm.nih.gov/2864025>.
192. Smyrniotis NA, Irwin RS, Curley FJ. Chronic cough with a history of excessive sputum production. The spectrum and frequency of causes, key components of the diagnostic evaluation, and outcome of specific therapy. *Chest* 1995; **108**(4): 991-7 <https://pubmed.ncbi.nlm.nih.gov/7555175>.
193. Fahy JV, Dickey BF. Airway mucus function and dysfunction. *N Engl J Med* 2010; **363**(23): 2233-47 <https://pubmed.ncbi.nlm.nih.gov/21121836>.
194. Rose MC, Voynow JA. Respiratory tract mucin genes and mucin glycoproteins in health and disease. *Physiol Rev* 2006; **86**(1): 245-78 <https://pubmed.ncbi.nlm.nih.gov/16371599>.
195. Thornton DJ, Rousseau K, McGuckin MA. Structure and function of the polymeric mucins in airways mucus. *Annu Rev Physiol* 2008; **70**: 459-86 <https://pubmed.ncbi.nlm.nih.gov/17850213>.
196. Tesfaigzi Y. Regulation of mucous cell metaplasia in bronchial asthma. *Curr Mol Med* 2008; **8**(5): 408-15 <https://pubmed.ncbi.nlm.nih.gov/18691068>.
197. Chen Y, Zhao YH, Di YP, Wu R. Characterization of human mucin 5B gene expression in airway epithelium and the genomic clone of the amino-terminal and 5'-flanking region. *Am J Respir Cell Mol Biol* 2001; **25**(5): 542-53 <https://pubmed.ncbi.nlm.nih.gov/11713095>.
198. Nguyen LP, Omoluabi O, Parra S, et al. Chronic exposure to beta-blockers attenuates inflammation and mucin content in a murine asthma model. *Am J Respir Cell Mol Biol* 2008; **38**(3): 256-62 <https://pubmed.ncbi.nlm.nih.gov/18096872>.
199. Hogg JC. Pathophysiology of airflow limitation in chronic obstructive pulmonary disease. *Lancet* 2004; **364**(9435): 709-21 <https://pubmed.ncbi.nlm.nih.gov/15325838>.
200. Hayashi T, Ishii A, Nakai S, Hasegawa K. Ultrastructure of goblet-cell metaplasia from Clara cell in the allergic asthmatic airway inflammation in a mouse model of asthma in vivo. *Virchows Arch* 2004; **444**(1): 66-73 <https://pubmed.ncbi.nlm.nih.gov/14648220>.
201. Bosse Y, Riesenfeld EP, Pare PD, Irvin CG. It's not all smooth muscle: non-smooth-muscle elements in control of resistance to airflow. *Annu Rev Physiol* 2010; **72**: 437-62 <https://pubmed.ncbi.nlm.nih.gov/20148684>.

202. Holtzman MJ, Byers DE, Benoit LA, et al. Immune pathways for translating viral infection into chronic airway disease. *Adv Immunol* 2009; **102**: 245-76 <https://pubmed.ncbi.nlm.nih.gov/19477323>.
203. Lappalainen U, Whitsett JA, Wert SE, Tichelaar JW, Bry K. Interleukin-1beta causes pulmonary inflammation, emphysema, and airway remodeling in the adult murine lung. *Am J Respir Cell Mol Biol* 2005; **32**(4): 311-8 <https://pubmed.ncbi.nlm.nih.gov/15668323>.
204. Deshmukh HS, Shaver C, Case LM, et al. Acrolein-activated matrix metalloproteinase 9 contributes to persistent mucin production. *Am J Respir Cell Mol Biol* 2008; **38**(4): 446-54 <https://pubmed.ncbi.nlm.nih.gov/18006877>.
205. Curran DR, Cohn L. Advances in mucous cell metaplasia: a plug for mucus as a therapeutic focus in chronic airway disease. *Am J Respir Cell Mol Biol* 2010; **42**(3): 268-75 <https://pubmed.ncbi.nlm.nih.gov/19520914>.
206. Peng J, Yang XO, Chang SH, Yang J, Dong C. IL-23 signaling enhances Th2 polarization and regulates allergic airway inflammation. *Cell Res* 2010; **20**(1): 62-71 <https://pubmed.ncbi.nlm.nih.gov/19935773>.
207. Hung LY, Velichko S, Huang F, Thai P, Wu R. Regulation of airway innate and adaptive immune responses: the IL-17 paradigm. *Crit Rev Immunol* 2008; **28**(4): 269-79 <https://pubmed.ncbi.nlm.nih.gov/19166380>.
208. Mullen JB, Wright JL, Wiggs BR, Pare PD, Hogg JC. Reassessment of inflammation of airways in chronic bronchitis. *Br Med J (Clin Res Ed)* 1985; **291**(6504): 1235-9 <https://pubmed.ncbi.nlm.nih.gov/3933614>.
209. Saetta M, Turato G, Facchini FM, et al. Inflammatory cells in the bronchial glands of smokers with chronic bronchitis. *Am J Respir Crit Care Med* 1997; **156**(5): 1633-9 <https://pubmed.ncbi.nlm.nih.gov/9372687>.
210. Hogg JC, Chu FS, Tan WC, et al. Survival after lung volume reduction in chronic obstructive pulmonary disease: insights from small airway pathology. *Am J Respir Crit Care Med* 2007; **176**(5): 454-9 <https://pubmed.ncbi.nlm.nih.gov/17556723>.
211. Caramori G, Di Gregorio C, Carlstedt I, et al. Mucin expression in peripheral airways of patients with chronic obstructive pulmonary disease. *Histopathology* 2004; **45**(5): 477-84 <https://pubmed.ncbi.nlm.nih.gov/15500651>.
212. Okajima Y, Come CE, Nardelli P, et al. Luminal Plugging on Chest CT Scan: Association With Lung Function, Quality of Life, and COPD Clinical Phenotypes. *Chest* 2020; **158**(1): 121-30 <https://pubmed.ncbi.nlm.nih.gov/32017932>.
213. Dunican EM, Elicker BM, Henry T, et al. Mucus Plugs and Emphysema in the Pathophysiology of Airflow Obstruction and Hypoxemia in Smokers. *Am J Respir Crit Care Med* 2021; **203**(8): 957-68 <https://pubmed.ncbi.nlm.nih.gov/33180550>.
214. Mettler SK, Nath HP, Grumley S, et al. Silent Airway Mucus Plugs in COPD and Clinical Implications. *Chest* 2023; <https://pubmed.ncbi.nlm.nih.gov/38013161>.
215. Diaz AA, Orejas JL, Grumley S, et al. Airway-Occluding Mucus Plugs and Mortality in Patients With Chronic Obstructive Pulmonary Disease. *Jama* 2023; **329**(21): 1832-9 <https://pubmed.ncbi.nlm.nih.gov/37210745>.
216. Burgel PR, Martin C. Mucus hypersecretion in COPD: should we only rely on symptoms? *Eur Respir Rev* 2010; **19**(116): 94-6 <https://pubmed.ncbi.nlm.nih.gov/20956176>.
217. de Marco R, Accordini S, Cerveri I, et al. Incidence of chronic obstructive pulmonary disease in a cohort of young adults according to the presence of chronic cough and phlegm. *Am J Respir Crit Care Med* 2007; **175**(1): 32-9 <https://pubmed.ncbi.nlm.nih.gov/17008642>.
218. Guerra S, Sherrill DL, Venker C, Ceccato CM, Halonen M, Martinez FD. Chronic bronchitis before age 50 years predicts incident airflow limitation and mortality risk. *Thorax* 2009; **64**(10): 894-900 <https://pubmed.ncbi.nlm.nih.gov/19581277>.
219. Allinson JP, Hardy R, Donaldson GC, Shaheen SO, Kuh D, Wedzicha JA. The Presence of Chronic Mucus Hypersecretion across Adult Life in Relation to Chronic Obstructive Pulmonary Disease Development. *Am J Respir Crit Care Med* 2016; **193**(6): 662-72 <https://pubmed.ncbi.nlm.nih.gov/26695373>.
220. Radicioni G, Ceppe A, Ford AA, et al. Airway mucin MUC5AC and MUC5B concentrations and the initiation and progression of chronic obstructive pulmonary disease: an analysis of the SPIROMICS cohort. *Lancet Respir Med* 2021; **9**(11): 1241-54 <https://pubmed.ncbi.nlm.nih.gov/34058148>.
221. Kesimer M, Ford AA, Ceppe A, et al. Airway Mucin Concentration as a Marker of Chronic Bronchitis. *N Engl J Med* 2017; **377**(10): 911-22 <https://pubmed.ncbi.nlm.nih.gov/28877023>.
222. Sherman CB, Xu X, Speizer FE, Ferris BG, Jr., Weiss ST, Dockery DW. Longitudinal lung function decline in subjects with respiratory symptoms. *Am Rev Respir Dis* 1992; **146**(4): 855-9 <https://pubmed.ncbi.nlm.nih.gov/1416410>.
223. Vestbo J, Lange P. Can GOLD Stage 0 provide information of prognostic value in chronic obstructive pulmonary disease? *Am J Respir Crit Care Med* 2002; **166**(3): 329-32 <https://pubmed.ncbi.nlm.nih.gov/12153965>.
224. Dowson LJ, Guest PJ, Stockley RA. The relationship of chronic sputum expectoration to physiologic, radiologic, and health status characteristics in alpha(1)-antitrypsin deficiency (PiZ). *Chest* 2002; **122**(4): 1247-55 <https://pubmed.ncbi.nlm.nih.gov/12377849>.
225. Vestbo J, Prescott E, Lange P. Association of chronic mucus hypersecretion with FEV1 decline and chronic obstructive pulmonary disease morbidity. Copenhagen City Heart Study Group. *Am J Respir Crit Care Med* 1996; **153**(5): 1530-5 <https://pubmed.ncbi.nlm.nih.gov/8630597>.
226. Stanescu D, Sanna A, Veriter C, et al. Airways obstruction, chronic expectoration, and rapid decline of FEV1 in smokers are associated with increased levels of sputum neutrophils. *Thorax* 1996; **51**(3): 267-71 <https://pubmed.ncbi.nlm.nih.gov/8779129>.

227. Peto R, Speizer FE, Cochrane AL, et al. The relevance in adults of air-flow obstruction, but not of mucus hypersecretion, to mortality from chronic lung disease. Results from 20 years of prospective observation. *Am Rev Respir Dis* 1983; **128**(3): 491-500 <https://pubmed.ncbi.nlm.nih.gov/6614643>.
228. Ebi-Kryston KL. Respiratory symptoms and pulmonary function as predictors of 10-year mortality from respiratory disease, cardiovascular disease, and all causes in the Whitehall Study. *J Clin Epidemiol* 1988; **41**(3): 251-60 <https://pubmed.ncbi.nlm.nih.gov/3339378>.
229. Ebi-Kryston KL. Predicting 15 year chronic bronchitis mortality in the Whitehall Study. *J Epidemiol Community Health* 1989; **43**(2): 168-72 <https://pubmed.ncbi.nlm.nih.gov/2592906>.
230. Wiles FJ, Hnizdo E. Relevance of airflow obstruction and mucus hypersecretion to mortality. *Respir Med* 1991; **85**(1): 27-35 <https://pubmed.ncbi.nlm.nih.gov/2014356>.
231. Lange P, Nyboe J, Appleyard M, Jensen G, Schnohr P. Relation of ventilatory impairment and of chronic mucus hypersecretion to mortality from obstructive lung disease and from all causes. *Thorax* 1990; **45**(8): 579-85 <https://pubmed.ncbi.nlm.nih.gov/2402719>.
232. Annesi I, Kauffmann F. Is respiratory mucus hypersecretion really an innocent disorder? A 22-year mortality survey of 1,061 working men. *Am Rev Respir Dis* 1986; **134**(4): 688-93 <https://pubmed.ncbi.nlm.nih.gov/3767125>.
233. Prescott E, Lange P, Vestbo J. Chronic mucus hypersecretion in COPD and death from pulmonary infection. *Eur Respir J* 1995; **8**(8): 1333-8 <https://pubmed.ncbi.nlm.nih.gov/7489800>.
234. Kim V, Sternberg AL, Washko G, et al. Severe chronic bronchitis in advanced emphysema increases mortality and hospitalizations. *COPD* 2013; **10**(6): 667-78 <https://pubmed.ncbi.nlm.nih.gov/23978192>.
235. Wu F, Fan H, Liu J, et al. Association Between Non-obstructive Chronic Bronchitis and Incident Chronic Obstructive Pulmonary Disease and All-Cause Mortality: A Systematic Review and Meta-Analysis. *Front Med (Lausanne)* 2021; **8**: 805192 <https://pubmed.ncbi.nlm.nih.gov/35145979>.
236. Fortis S, Shannon ZK, Garcia CJ, et al. Association of Nonobstructive Chronic Bronchitis With All-Cause Mortality: A Systematic Literature Review and Meta-analysis. *Chest* 2022; **162**(1): 92-100 <https://pubmed.ncbi.nlm.nih.gov/35150657>.
237. Allinson JP, Hardy R, Donaldson GC, Shaheen SO, Kuh D, Wedzicha JA. Combined Impact of Smoking and Early-Life Exposures on Adult Lung Function Trajectories. *Am J Respir Crit Care Med* 2017; **196**(8): 1021-30 <https://pubmed.ncbi.nlm.nih.gov/28530117>.
238. Martinez-Garcia MA, Faner R, Oscullo G, et al. Chronic Bronchial Infection Is Associated with More Rapid Lung Function Decline in Chronic Obstructive Pulmonary Disease. *Ann Am Thorac Soc* 2022; **19**(11): 1842-7 <https://pubmed.ncbi.nlm.nih.gov/35666811>.
239. Fan H, Wu F, Liu J, et al. Pulmonary tuberculosis as a risk factor for chronic obstructive pulmonary disease: a systematic review and meta-analysis. *Ann Transl Med* 2021; **9**(5): 390 <https://pubmed.ncbi.nlm.nih.gov/33842611>.
240. Byrne AL, Marais BJ, Mitnick CD, Lecca L, Marks GB. Tuberculosis and chronic respiratory disease: a systematic review. *Int J Infect Dis* 2015; **32**: 138-46 <https://pubmed.ncbi.nlm.nih.gov/25809770>.
241. Menezes AM, Hallal PC, Perez-Padilla R, et al. Tuberculosis and airflow obstruction: evidence from the PLATINO study in Latin America. *Eur Respir J* 2007; **30**(6): 1180-5 <https://pubmed.ncbi.nlm.nih.gov/17804445>.
242. Jordan TS, Spencer EM, Davies P. Tuberculosis, bronchiectasis and chronic airflow obstruction. *Respirology* 2010; **15**(4): 623-8 <https://pubmed.ncbi.nlm.nih.gov/20409028>.
243. Bigna JJ, Kenne AM, Asangbeh SL, Sibetcheu AT. Prevalence of chronic obstructive pulmonary disease in the global population with HIV: a systematic review and meta-analysis. *Lancet Glob Health* 2018; **6**(2): e193-e202 <https://pubmed.ncbi.nlm.nih.gov/29254748>.
244. Thudium RF, Ronit A, Afzal S, et al. Faster lung function decline in people living with HIV despite adequate treatment: a longitudinal matched cohort study. *Thorax* 2023; **78**(6): 535-42 <https://pubmed.ncbi.nlm.nih.gov/36639241>.
245. Hernandez Cordero AI, Yang CX, Obeidat M, et al. DNA methylation is associated with airflow obstruction in patients living with HIV. *Thorax* 2021; **76**(5): 448-55 <https://pubmed.ncbi.nlm.nih.gov/33443234>.
246. Lee H, Kovacs C, Mattman A, et al. The impact of IgG subclass deficiency on the risk of mortality in hospitalized patients with COPD. *Respir Res* 2022; **23**(1): 141 <https://pubmed.ncbi.nlm.nih.gov/35641962>.
247. Landis SH, Muellerova H, Mannino DM, et al. Continuing to Confront COPD International Patient Survey: methods, COPD prevalence, and disease burden in 2012-2013. *Int J Chron Obstruct Pulmon Dis* 2014; **9**: 597-611 <https://pubmed.ncbi.nlm.nih.gov/24944511>.
248. Foreman MG, Zhang L, Murphy J, et al. Early-onset chronic obstructive pulmonary disease is associated with female sex, maternal factors, and African American race in the COPD Gene Study. *Am J Respir Crit Care Med* 2011; **184**(4): 414-20 <https://pubmed.ncbi.nlm.nih.gov/21562134>.
249. Lopez Varela MV, Montes de Oca M, Halbert RJ, et al. Sex-related differences in COPD in five Latin American cities: the PLATINO study. *Eur Respir J* 2010; **36**(5): 1034-41 <https://pubmed.ncbi.nlm.nih.gov/20378599>.
250. Silverman EK, Weiss ST, Drazen JM, et al. Gender-related differences in severe, early-onset chronic obstructive pulmonary disease. *Am J Respir Crit Care Med* 2000; **162**(6): 2152-8 <https://pubmed.ncbi.nlm.nih.gov/11112130>.
251. Amaral AFS, Strachan DP, Burney PGJ, Jarvis DL. Female Smokers Are at Greater Risk of Airflow Obstruction Than Male Smokers. UK Biobank. *Am J Respir Crit Care Med* 2017; **195**(9): 1226-35 <https://pubmed.ncbi.nlm.nih.gov/28075609>.

252. Martinez FJ, Curtis JL, Sciruba F, et al. Sex differences in severe pulmonary emphysema. *Am J Respir Crit Care Med* 2007; **176**(3): 243-52 <https://pubmed.ncbi.nlm.nih.gov/17431226>.
253. Tam A, Churg A, Wright JL, et al. Sex Differences in Airway Remodeling in a Mouse Model of Chronic Obstructive Pulmonary Disease. *Am J Respir Crit Care Med* 2016; **193**(8): 825-34 <https://pubmed.ncbi.nlm.nih.gov/26599602>.
254. Liang C, Chung HF, Dobson A, Sandin S, Weiderpass E, Mishra GD. Female reproductive histories and the risk of chronic obstructive pulmonary disease. *Thorax* 2024; <https://pubmed.ncbi.nlm.nih.gov/38350732>.
255. Bhakta NR, Bime C, Kaminsky DA, et al. Race and Ethnicity in Pulmonary Function Test Interpretation: An Official American Thoracic Society Statement. *Am J Respir Crit Care Med* 2023; **207**(8): 978-95 <https://pubmed.ncbi.nlm.nih.gov/36973004>.
256. Townend J, Minelli C, Mortimer K, et al. The association between chronic airflow obstruction and poverty in 12 sites of the multinational BOLD study. *Eur Respir J* 2017; **49**(6): <https://pubmed.ncbi.nlm.nih.gov/28572124>.
257. Beran D, Zar HJ, Perrin C, Menezes AM, Burney P, Forum of International Respiratory Societies working group c. Burden of asthma and chronic obstructive pulmonary disease and access to essential medicines in low-income and middle-income countries. *Lancet Respir Med* 2015; **3**(2): 159-70 <https://pubmed.ncbi.nlm.nih.gov/25680912>.
258. Gershon AS, Warner L, Cascagnette P, Victor JC, To T. Lifetime risk of developing chronic obstructive pulmonary disease: a longitudinal population study. *Lancet* 2011; **378**(9795): 991-6 <https://pubmed.ncbi.nlm.nih.gov/21907862>.
259. Hogg JC, Timens W. The pathology of chronic obstructive pulmonary disease. *Annu Rev Pathol* 2009; **4**: 435-59 <https://pubmed.ncbi.nlm.nih.gov/18954287>.
260. Barnes PJ. Inflammatory mechanisms in patients with chronic obstructive pulmonary disease. *J Allergy Clin Immunol* 2016; **138**(1): 16-27 <https://pubmed.ncbi.nlm.nih.gov/27373322>.
261. Barnes PJ. Cellular and molecular mechanisms of chronic obstructive pulmonary disease. *Clin Chest Med* 2014; **35**(1): 71-86 <https://pubmed.ncbi.nlm.nih.gov/24507838>.
262. Sze MA, Dimitriu PA, Suzuki M, et al. Host Response to the Lung Microbiome in Chronic Obstructive Pulmonary Disease. *Am J Respir Crit Care Med* 2015; **192**(4): 438-45 <https://pubmed.ncbi.nlm.nih.gov/25945594>.
263. Lee SH, Goswami S, Grudo A, et al. Antielastin autoimmunity in tobacco smoking-induced emphysema. *Nat Med* 2007; **13**(5): 567-9 <https://pubmed.ncbi.nlm.nih.gov/17450149>.
264. Barnes PJ. Immunology of asthma and chronic obstructive pulmonary disease. *Nat Rev Immunol* 2008; **8**(3): 183-92 <https://pubmed.ncbi.nlm.nih.gov/18274560>.
265. Global Initiative for Asthma (GINA). 2017 Asthma, COPD and Asthma-COPD Overlap Syndrome (ACOS) available here: <https://ginasthma.org/wp-content/uploads/2019/11/GINA-GOLD-2017-overlap-pocket-guide-wms-2017-ACO.pdf> [accessed Oct 2024].
266. Domej W, Oettl K, Renner W. Oxidative stress and free radicals in COPD--implications and relevance for treatment. *Int J Chron Obstruct Pulmon Dis* 2014; **9**: 1207-24 <https://pubmed.ncbi.nlm.nih.gov/25378921>.
267. Malhotra D, Thimmulappa R, Vij N, et al. Heightened endoplasmic reticulum stress in the lungs of patients with chronic obstructive pulmonary disease: the role of Nrf2-regulated proteasomal activity. *Am J Respir Crit Care Med* 2009; **180**(12): 1196-207 <https://pubmed.ncbi.nlm.nih.gov/19797762>.
268. Stockley RA. Neutrophils and protease/antiprotease imbalance. *Am J Respir Crit Care Med* 1999; **160**(5 Pt 2): S49-52 <https://pubmed.ncbi.nlm.nih.gov/10556170>.
269. Johnson SR. Untangling the protease web in COPD: metalloproteinases in the silent zone. *Thorax* 2016; **71**(2): 105-6 <https://pubmed.ncbi.nlm.nih.gov/26769014>.
270. Katzenstein AL, Mukhopadhyay S, Myers JL. Diagnosis of usual interstitial pneumonia and distinction from other fibrosing interstitial lung diseases. *Hum Pathol* 2008; **39**(9): 1275-94 <https://pubmed.ncbi.nlm.nih.gov/18706349>.
271. Washko GR, Hunninghake GM, Fernandez IE, et al. Lung volumes and emphysema in smokers with interstitial lung abnormalities. *N Engl J Med* 2011; **364**(10): 897-906 <https://pubmed.ncbi.nlm.nih.gov/21388308>.
272. Putman RK, Hatabu H, Araki T, et al. Association Between Interstitial Lung Abnormalities and All-Cause Mortality. *JAMA* 2016; **315**(7): 672-81 <https://pubmed.ncbi.nlm.nih.gov/26881370>.
273. Churg A, Tai H, Coulthard T, Wang R, Wright JL. Cigarette smoke drives small airway remodeling by induction of growth factors in the airway wall. *Am J Respir Crit Care Med* 2006; **174**(12): 1327-34 <https://pubmed.ncbi.nlm.nih.gov/17008639>.
274. Rennard SI, Wachenfeldt K. Rationale and emerging approaches for targeting lung repair and regeneration in the treatment of chronic obstructive pulmonary disease. *Proc Am Thorac Soc* 2011; **8**(4): 368-75 <https://pubmed.ncbi.nlm.nih.gov/21816994>.
275. Hogg JC, McDonough JE, Gosselink JV, Hayashi S. What drives the peripheral lung-remodeling process in chronic obstructive pulmonary disease? *Proc Am Thorac Soc* 2009; **6**(8): 668-72 <https://pubmed.ncbi.nlm.nih.gov/20008873>.
276. Peinado VI, Barbera JA, Ramirez J, et al. Endothelial dysfunction in pulmonary arteries of patients with mild COPD. *Am J Physiol* 1998; **274**(6): L908-13 <https://pubmed.ncbi.nlm.nih.gov/9609729>.
277. Song Z, Meng Y, Fricker M, et al. The role of gut-lung axis in COPD: Pathogenesis, immune response, and prospective treatment. *Heliyon* 2024; **10**(9): e30612 <https://pubmed.ncbi.nlm.nih.gov/38742057>.
278. Dicker AJ, Huang JTJ, Lonergan M, et al. The sputum microbiome, airway inflammation, and mortality in chronic obstructive pulmonary disease. *J Allergy Clin Immunol* 2021; **147**(1): 158-67 <https://pubmed.ncbi.nlm.nih.gov/32353489>.

279. Kayongo A, Robertson NM, Siddharthan T, et al. Airway microbiome-immune crosstalk in chronic obstructive pulmonary disease. *Front Immunol* 2022; **13**: 1085551 <https://pubmed.ncbi.nlm.nih.gov/36741369>.
280. Sulaiman I, Wu BG, Chung M, et al. Lower Airway Dysbiosis Augments Lung Inflammatory Injury in Mild-to-Moderate Chronic Obstructive Pulmonary Disease. *Am J Respir Crit Care Med* 2023; **208**(10): 1101-14 <https://pubmed.ncbi.nlm.nih.gov/37677136>.
281. Lea S, Higham A, Beech A, Singh D. How inhaled corticosteroids target inflammation in COPD. *Eur Respir Rev* 2023; **32**(170): <https://pubmed.ncbi.nlm.nih.gov/37852657>.
282. Wang Z, Bafadhel M, Haldar K, et al. Lung microbiome dynamics in COPD exacerbations. *Eur Respir J* 2016; **47**(4): 1082-92 <https://pubmed.ncbi.nlm.nih.gov/26917613>.
283. Wang Z, Locantore N, Haldar K, et al. Inflammatory Endotype-associated Airway Microbiome in Chronic Obstructive Pulmonary Disease Clinical Stability and Exacerbations: A Multicohort Longitudinal Analysis. *Am J Respir Crit Care Med* 2021; **203**(12): 1488-502 <https://pubmed.ncbi.nlm.nih.gov/33332995>.
284. Opron K, Begley LA, Erb-Downward JR, et al. Loss of Airway Phylogenetic Diversity Is Associated with Clinical and Pathobiological Markers of Disease Development in Chronic Obstructive Pulmonary Disease. *Am J Respir Crit Care Med* 2024; **210**(2): 186-200 <https://pubmed.ncbi.nlm.nih.gov/38261629>.
285. McDonough JE, Yuan R, Suzuki M, et al. Small-airway obstruction and emphysema in chronic obstructive pulmonary disease. *N Engl J Med* 2011; **365**(17): 1567-75 <https://pubmed.ncbi.nlm.nih.gov/22029978>.
286. Hogg JC, Chu F, Utokaparch S, et al. The nature of small-airway obstruction in chronic obstructive pulmonary disease. *N Engl J Med* 2004; **350**(26): 2645-53 <https://pubmed.ncbi.nlm.nih.gov/15215480>.
287. O'Donnell DE, Laveneziana P. The clinical importance of dynamic lung hyperinflation in COPD. *COPD* 2006; **3**(4): 219-32 <https://pubmed.ncbi.nlm.nih.gov/17361503>.
288. Gagnon P, Guenette JA, Langer D, et al. Pathogenesis of hyperinflation in chronic obstructive pulmonary disease. *Int J Chron Obstruct Pulmon Dis* 2014; **9**: 187-201 <https://pubmed.ncbi.nlm.nih.gov/24600216>.
289. O'Donnell DE, Lam M, Webb KA. Spirometric correlates of improvement in exercise performance after anticholinergic therapy in chronic obstructive pulmonary disease. *Am J Respir Crit Care Med* 1999; **160**(2): 542-9 <https://pubmed.ncbi.nlm.nih.gov/10430726>.
290. O'Donnell DE, Webb KA. Exertional breathlessness in patients with chronic airflow limitation. The role of lung hyperinflation. *Am Rev Respir Dis* 1993; **148**(5): 1351-7 <https://pubmed.ncbi.nlm.nih.gov/8239175>.
291. O'Donnell DE, Laveneziana P. Dyspnea and activity limitation in COPD: mechanical factors. *COPD* 2007; **4**(3): 225-36 <https://pubmed.ncbi.nlm.nih.gov/17729066>.
292. O'Donnell DE, Webb KA. The major limitation to exercise performance in COPD is dynamic hyperinflation. *J Appl Physiol* (1985) 2008; **105**(2): 753-5; discussion 5-7 <https://pubmed.ncbi.nlm.nih.gov/18678624>.
293. O'Donnell DE, Revill SM, Webb KA. Dynamic hyperinflation and exercise intolerance in chronic obstructive pulmonary disease. *Am J Respir Crit Care Med* 2001; **164**(5): 770-7 <https://pubmed.ncbi.nlm.nih.gov/11549531>.
294. Ozgur ES, Nayci SA, Ozge C, Tasdelen B. An integrated index combined by dynamic hyperinflation and exercise capacity in the prediction of morbidity and mortality in COPD. *Respir Care* 2012; **57**(9): 1452-9 <https://pubmed.ncbi.nlm.nih.gov/22348294>.
295. Albuquerque AL, Nery LE, Villaca DS, et al. Inspiratory fraction and exercise impairment in COPD patients GOLD stages II-III. *Eur Respir J* 2006; **28**(5): 939-44 <https://pubmed.ncbi.nlm.nih.gov/16870665>.
296. Casanova C, Cote C, de Torres JP, et al. Inspiratory-to-total lung capacity ratio predicts mortality in patients with chronic obstructive pulmonary disease. *Am J Respir Crit Care Med* 2005; **171**(6): 591-7 <https://pubmed.ncbi.nlm.nih.gov/15591470>.
297. Jubran A, Tobin MJ. Pathophysiologic basis of acute respiratory distress in patients who fail a trial of weaning from mechanical ventilation. *Am J Respir Crit Care Med* 1997; **155**(3): 906-15 <https://pubmed.ncbi.nlm.nih.gov/9117025>.
298. Tantucci C, Donati P, Nicosia F, et al. Inspiratory capacity predicts mortality in patients with chronic obstructive pulmonary disease. *Respir Med* 2008; **102**(4): 613-9 <https://pubmed.ncbi.nlm.nih.gov/18083020>.
299. Hyatt RE. Expiratory flow limitation. *J Appl Physiol Respir Environ Exerc Physiol* 1983; **55**(1 Pt 1): 1-7 <https://pubmed.ncbi.nlm.nih.gov/6350246>.
300. Gagnon P, Saey D, Provencher S, et al. Walking exercise response to bronchodilation in mild COPD: a randomized trial. *Respir Med* 2012; **106**(12): 1695-705 <https://pubmed.ncbi.nlm.nih.gov/22999808>.
301. Deesomchok A, Webb KA, Forkert L, et al. Lung hyperinflation and its reversibility in patients with airway obstruction of varying severity. *COPD* 2010; **7**(6): 428-37 <https://pubmed.ncbi.nlm.nih.gov/21166631>.
302. O'Donnell CR, Bankier AA, Stiebellehner L, Reilly JJ, Brown R, Loring SH. Comparison of plethysmographic and helium dilution lung volumes: which is best for COPD? *Chest* 2010; **137**(5): 1108-15 <https://pubmed.ncbi.nlm.nih.gov/20022972>.
303. Wanger J, Clausen JL, Coates A, et al. Standardisation of the measurement of lung volumes. *Eur Respir J* 2005; **26**(3): 511-22 <https://pubmed.ncbi.nlm.nih.gov/16135736>.
304. Tantucci C, Duguet A, Similowski T, Zelter M, Derenne JP, Milic-Emili J. Effect of salbutamol on dynamic hyperinflation in chronic obstructive pulmonary disease patients. *Eur Respir J* 1998; **12**(4): 799-804 <https://pubmed.ncbi.nlm.nih.gov/9817148>.

305. O'Donnell DE, Voduc N, Fitzpatrick M, Webb KA. Effect of salmeterol on the ventilatory response to exercise in chronic obstructive pulmonary disease. *Eur Respir J* 2004; **24**(1): 86-94 <https://pubmed.ncbi.nlm.nih.gov/15293609>.
306. O'Donnell DE, Fluge T, Gerken F, et al. Effects of tiotropium on lung hyperinflation, dyspnoea and exercise tolerance in COPD. *Eur Respir J* 2004; **23**(6): 832-40 <https://pubmed.ncbi.nlm.nih.gov/15218994>.
307. O'Donnell DE, D'Arsigny C, Webb KA. Effects of hyperoxia on ventilatory limitation during exercise in advanced chronic obstructive pulmonary disease. *Am J Respir Crit Care Med* 2001; **163**(4): 892-8 <https://pubmed.ncbi.nlm.nih.gov/11282762>.
308. Somfay A, Porszasz J, Lee SM, Casaburi R. Dose-response effect of oxygen on hyperinflation and exercise endurance in nonhypoxaemic COPD patients. *Eur Respir J* 2001; **18**(1): 77-84 <https://pubmed.ncbi.nlm.nih.gov/11510809>.
309. Palange P, Valli G, Onorati P, et al. Effect of heliox on lung dynamic hyperinflation, dyspnea, and exercise endurance capacity in COPD patients. *J Appl Physiol (1985)* 2004; **97**(5): 1637-42 <https://pubmed.ncbi.nlm.nih.gov/15234959>.
310. Porszasz J, Emtner M, Goto S, Somfay A, Whipp BJ, Casaburi R. Exercise training decreases ventilatory requirements and exercise-induced hyperinflation at submaximal intensities in patients with COPD. *Chest* 2005; **128**(4): 2025-34 <https://pubmed.ncbi.nlm.nih.gov/16236851>.
311. Spahija J, Marchie M, Ghezzi H, Grassino A. Factors discriminating spontaneous pursed-lips breathing use in patients with COPD. *COPD* 2010; **7**(4): 254-61 <https://pubmed.ncbi.nlm.nih.gov/20673034>.
312. Petrovic M, Reiter M, Zipko H, Pohl W, Wanke T. Effects of inspiratory muscle training on dynamic hyperinflation in patients with COPD. *Int J Chron Obstruct Pulmon Dis* 2012; **7**: 797-805 <https://pubmed.ncbi.nlm.nih.gov/23233798>.
313. Fishman A, Martinez F, Naunheim K, et al. A randomized trial comparing lung-volume-reduction surgery with medical therapy for severe emphysema. *N Engl J Med* 2003; **348**(21): 2059-73 <https://pubmed.ncbi.nlm.nih.gov/12759479>.
314. Criner GJ, Delage A, Voelker K, et al. Improving Lung Function in Severe Heterogeneous Emphysema with the Spiration Valve System (EMPROVE). A Multicenter, Open-Label Randomized Controlled Clinical Trial. *Am J Respir Crit Care Med* 2019; **200**(11): 1354-62 <https://pubmed.ncbi.nlm.nih.gov/31365298>.
315. Criner GJ, Sue R, Wright S, et al. A Multicenter Randomized Controlled Trial of Zephyr Endobronchial Valve Treatment in Heterogeneous Emphysema (LIBERATE). *Am J Respir Crit Care Med* 2018; **198**(9): 1151-64 <https://pubmed.ncbi.nlm.nih.gov/29787288>.
316. Rodriguez-Roisin R, Drakulovic M, Rodriguez DA, Roca J, Barbera JA, Wagner PD. Ventilation-perfusion imbalance and chronic obstructive pulmonary disease staging severity. *J Appl Physiol (1985)* 2009; **106**(6): 1902-8 <https://pubmed.ncbi.nlm.nih.gov/19372303>.
317. Elbehairy AF, Ciavaglia CE, Webb KA, et al. Pulmonary Gas Exchange Abnormalities in Mild Chronic Obstructive Pulmonary Disease. Implications for Dyspnea and Exercise Intolerance. *Am J Respir Crit Care Med* 2015; **191**(12): 1384-94 <https://pubmed.ncbi.nlm.nih.gov/25826478>.
318. Sakao S, Voelkel NF, Tatsumi K. The vascular bed in COPD: pulmonary hypertension and pulmonary vascular alterations. *Eur Respir Rev* 2014; **23**(133): 350-5 <https://pubmed.ncbi.nlm.nih.gov/25176971>.
319. Iyer KS, Newell JD, Jr., Jin D, et al. Quantitative Dual-Energy Computed Tomography Supports a Vascular Etiology of Smoking-induced Inflammatory Lung Disease. *Am J Respir Crit Care Med* 2016; **193**(6): 652-61 <https://pubmed.ncbi.nlm.nih.gov/26569033>.
320. Alford SK, van Beek EJ, McLennan G, Hoffman EA. Heterogeneity of pulmonary perfusion as a mechanistic image-based phenotype in emphysema susceptible smokers. *Proc Natl Acad Sci U S A* 2010; **107**(16): 7485-90 <https://pubmed.ncbi.nlm.nih.gov/20368443>.
321. Peinado VI, Pizarro S, Barbera JA. Pulmonary vascular involvement in COPD. *Chest* 2008; **134**(4): 808-14 <https://pubmed.ncbi.nlm.nih.gov/18842913>.
322. Kovacs G, Agusti A, Barbera JA, et al. Pulmonary Vascular Involvement in Chronic Obstructive Pulmonary Disease. Is There a Pulmonary Vascular Phenotype? *Am J Respir Crit Care Med* 2018; **198**(8): 1000-11 <https://pubmed.ncbi.nlm.nih.gov/29746142>.
323. Zhang L, Liu Y, Zhao S, et al. The Incidence and Prevalence of Pulmonary Hypertension in the COPD Population: A Systematic Review and Meta-Analysis. *Int J Chron Obstruct Pulmon Dis* 2022; **17**: 1365-79 <https://pubmed.ncbi.nlm.nih.gov/35711174>.
324. Kovacs G, Avian A, Bachmaier G, et al. Severe Pulmonary Hypertension in COPD: Impact on Survival and Diagnostic Approach. *Chest* 2022; **162**(1): 202-12 <https://pubmed.ncbi.nlm.nih.gov/35092746>.
325. Wells JM, Washko GR, Han MK, et al. Pulmonary arterial enlargement and acute exacerbations of COPD. *N Engl J Med* 2012; **367**(10): 913-21 <https://pubmed.ncbi.nlm.nih.gov/22938715>.
326. Parker CM, Voduc N, Aaron SD, Webb KA, O'Donnell DE. Physiological changes during symptom recovery from moderate exacerbations of COPD. *Eur Respir J* 2005; **26**(3): 420-8 <https://pubmed.ncbi.nlm.nih.gov/16135722>.
327. Barbera JA, Roca J, Ferrer A, et al. Mechanisms of worsening gas exchange during acute exacerbations of chronic obstructive pulmonary disease. *Eur Respir J* 1997; **10**(6): 1285-91 <https://pubmed.ncbi.nlm.nih.gov/9192930>.
328. Celli BR, Fabbri LM, Aaron SD, et al. An Updated Definition and Severity Classification of Chronic Obstructive Pulmonary Disease Exacerbations: The Rome Proposal. *Am J Respir Crit Care Med* 2021; **204**(11): 1251-8 <https://pubmed.ncbi.nlm.nih.gov/34570991>.
329. Miller J, Edwards LD, Agusti A, et al. Comorbidity, systemic inflammation and outcomes in the ECLIPSE cohort. *Respir Med* 2013; **107**(9): 1376-84 <https://pubmed.ncbi.nlm.nih.gov/23791463>.

330. Joo H, Yoon HK, Hwang YI, et al. Application of the Lancet Commission COPD classification to COPD Cohort Population in South Korea. *Respir Med* 2024; **230**: 107679 <https://pubmed.ncbi.nlm.nih.gov/38797345>.
331. Fabbri LM, Celli BR, Agustí A, et al. COPD and multimorbidity: recognising and addressing a syndemic occurrence. *Lancet Respir Med* 2023; **11**(11): 1020-34 <https://pubmed.ncbi.nlm.nih.gov/37696283>.
332. Dharmage S, Agusti A. Personal communication. 2022:
333. Stolz D, Mkorombindo T, Schumann DM, et al. Towards the elimination of chronic obstructive pulmonary disease: a Lancet Commission. *Lancet* 2022; **400**(10356): 921-72 <https://pubmed.ncbi.nlm.nih.gov/36075255>.
334. Kessler R, Partridge MR, Miravittles M, et al. Symptom variability in patients with severe COPD: a pan-European cross-sectional study. *Eur Respir J* 2011; **37**(2): 264-72 <https://pubmed.ncbi.nlm.nih.gov/21115606>.
335. Montes de Oca M, Perez-Padilla R, Talamo C, et al. Acute bronchodilator responsiveness in subjects with and without airflow obstruction in five Latin American cities: the PLATINO study. *Pulm Pharmacol Ther* 2010; **23**(1): 29-35 <https://pubmed.ncbi.nlm.nih.gov/19818867>.
336. Miravittles M, Worth H, Soler Cataluna JJ, et al. Observational study to characterise 24-hour COPD symptoms and their relationship with patient-reported outcomes: results from the ASSESS study. *Respir Res* 2014; **15**(1): 122 <https://pubmed.ncbi.nlm.nih.gov/25331383>.
337. Laviolette L, Laveneziana P, Faculty ERSRS. Dyspnoea: a multidimensional and multidisciplinary approach. *Eur Respir J* 2014; **43**(6): 1750-62 <https://pubmed.ncbi.nlm.nih.gov/24525437>.
338. Elliott MW, Adams L, Cockcroft A, MacRae KD, Murphy K, Guz A. The language of breathlessness. Use of verbal descriptors by patients with cardiopulmonary disease. *Am Rev Respir Dis* 1991; **144**(4): 826-32 <https://pubmed.ncbi.nlm.nih.gov/1928956>.
339. Phillips DB, Elbehairy AF, James MD, et al. Impaired Ventilatory Efficiency, Dyspnea, and Exercise Intolerance in Chronic Obstructive Pulmonary Disease: Results from the CanCOLD Study. *Am J Respir Crit Care Med* 2022; **205**(12): 1391-402 <https://pubmed.ncbi.nlm.nih.gov/35333135>.
340. Mullerova H, Lu C, Li H, Tabberer M. Prevalence and burden of breathlessness in patients with chronic obstructive pulmonary disease managed in primary care. *PLoS One* 2014; **9**(1): e85540 <https://pubmed.ncbi.nlm.nih.gov/24427316>.
341. Lapperre T, Bodtger U, Kjærsgaard Klein D, et al. Dysfunctional breathing impacts symptom burden in Chronic Obstructive Pulmonary Disease (COPD). *European Respiratory Journal* 2020; **56**(suppl 64): 124
342. Vidotto LS, Carvalho CRF, Harvey A, Jones M. Dysfunctional breathing: what do we know? *J Bras Pneumol* 2019; **45**(1): e20170347 <https://pubmed.ncbi.nlm.nih.gov/30758427>.
343. Verberkt CA, van den Beuken-van Everdingen MHJ, Schols J, Hameleers N, Wouters EFM, Janssen DJA. Effect of Sustained-Release Morphine for Refractory Breathlessness in Chronic Obstructive Pulmonary Disease on Health Status: A Randomized Clinical Trial. *JAMA Intern Med* 2020; **180**(10): 1306-14 <https://pubmed.ncbi.nlm.nih.gov/32804188>.
344. Lewthwaite H, Jensen D, Ekstrom M. How to Assess Breathlessness in Chronic Obstructive Pulmonary Disease. *Int J Chron Obstruct Pulmon Dis* 2021; **16**: 1581-98 <https://pubmed.ncbi.nlm.nih.gov/34113091>.
345. O'Donnell DE, Milne KM, James MD, de Torres JP, Neder JA. Dyspnea in COPD: New Mechanistic Insights and Management Implications. *Adv Ther* 2020; **37**(1): 41-60 <https://pubmed.ncbi.nlm.nih.gov/31673990>.
346. Cho SH, Lin HC, Ghoshal AG, et al. Respiratory disease in the Asia-Pacific region: Cough as a key symptom. *Allergy Asthma Proc* 2016; **37**(2): 131-40 <https://pubmed.ncbi.nlm.nih.gov/26802834>.
347. Medical Research Council Committee on the Aetiology of Chronic Bronchitis. Definition and classification of chronic bronchitis for clinical and epidemiological purposes. A report to the Medical Research Council by their Committee on the Aetiology of Chronic Bronchitis. *Lancet* 1965; **1**(7389): 775-9 <https://pubmed.ncbi.nlm.nih.gov/4165081>.
348. Du Q, Jin J, Liu X, Sun Y. Bronchiectasis as a Comorbidity of Chronic Obstructive Pulmonary Disease: A Systematic Review and Meta-Analysis. *PLoS One* 2016; **11**(3): e0150532 <https://pubmed.ncbi.nlm.nih.gov/26978269>.
349. Ni Y, Shi G, Yu Y, Hao J, Chen T, Song H. Clinical characteristics of patients with chronic obstructive pulmonary disease with comorbid bronchiectasis: a systemic review and meta-analysis. *Int J Chron Obstruct Pulmon Dis* 2015; **10**: 1465-75 <https://pubmed.ncbi.nlm.nih.gov/26251586>.
350. Soler N, Esperatti M, Ewig S, Huerta A, Agusti C, Torres A. Sputum purulence-guided antibiotic use in hospitalised patients with exacerbations of COPD. *Eur Respir J* 2012; **40**(6): 1344-53 <https://pubmed.ncbi.nlm.nih.gov/22523352>.
351. Brusse-Keizer MG, Grotenhuis AJ, Kerstjens HA, et al. Relation of sputum colour to bacterial load in acute exacerbations of COPD. *Respir Med* 2009; **103**(4): 601-6 <https://pubmed.ncbi.nlm.nih.gov/19027281>.
352. Stockley RA, O'Brien C, Pye A, Hill SL. Relationship of sputum color to nature and outpatient management of acute exacerbations of COPD. *Chest* 2000; **117**(6): 1638-45 <https://pubmed.ncbi.nlm.nih.gov/10858396>.
353. Goertz YMJ, Looijmans M, Prins JB, et al. Fatigue in patients with chronic obstructive pulmonary disease: protocol of the Dutch multicentre, longitudinal, observational FANTASTIGUE study. *BMJ Open* 2018; **8**(4): e021745 <https://pubmed.ncbi.nlm.nih.gov/29643168>.
354. Ream E, Richardson A. Fatigue in patients with cancer and chronic obstructive airways disease: a phenomenological enquiry. *Int J Nurs Stud* 1997; **34**(1): 44-53 <https://pubmed.ncbi.nlm.nih.gov/9055120>.
355. Small SP, Lamb M. Measurement of fatigue in chronic obstructive pulmonary disease and in asthma. *Int J Nurs Stud* 2000; **37**(2): 127-33 <https://pubmed.ncbi.nlm.nih.gov/10684954>.
356. von Haehling S, Anker SD. Cachexia as a major underestimated and unmet medical need: facts and numbers. *J Cachexia Sarcopenia Muscle* 2010; **1**(1): 1-5 <https://pubmed.ncbi.nlm.nih.gov/21475699>.

357. Schols AM, Soeters PB, Dingemans AM, Mostert R, Frantzen PJ, Wouters EF. Prevalence and characteristics of nutritional depletion in patients with stable COPD eligible for pulmonary rehabilitation. *Am Rev Respir Dis* 1993; **147**(5): 1151-6 <https://pubmed.ncbi.nlm.nih.gov/8484624>.
358. Attaway AH, Welch N, Hatipoglu U, Zein JG, Dasarathy S. Muscle loss contributes to higher morbidity and mortality in COPD: An analysis of national trends. *Respirology* 2021; **26**(1): 62-71 <https://pubmed.ncbi.nlm.nih.gov/32542761>.
359. Rutten EP, Calverley PM, Casaburi R, et al. Changes in body composition in patients with chronic obstructive pulmonary disease: do they influence patient-related outcomes? *Ann Nutr Metab* 2013; **63**(3): 239-47 <https://pubmed.ncbi.nlm.nih.gov/24216978>.
360. Schols AM, Broekhuizen R, Weling-Scheepers CA, Wouters EF. Body composition and mortality in chronic obstructive pulmonary disease. *Am J Clin Nutr* 2005; **82**(1): 53-9 <https://pubmed.ncbi.nlm.nih.gov/16002800>.
361. Hanania NA, Mullerova H, Locantore NW, et al. Determinants of depression in the ECLIPSE chronic obstructive pulmonary disease cohort. *Am J Respir Crit Care Med* 2011; **183**(5): 604-11 <https://pubmed.ncbi.nlm.nih.gov/20889909>.
362. Blakemore A, Dickens C, Chew-Graham CA, et al. Depression predicts emergency care use in people with chronic obstructive pulmonary disease: a large cohort study in primary care. *Int J Chron Obstruct Pulmon Dis* 2019; **14**: 1343-53 <https://pubmed.ncbi.nlm.nih.gov/31388297>.
363. Agusti A, Rapsomaniki E, Beasley R, et al. Treatable traits in the NOVELTY study. *Respirology* 2022; **27**(11): 929-40 <https://pubmed.ncbi.nlm.nih.gov/35861464>.
364. Holleman DR, Jr., Simel DL. Does the clinical examination predict airflow limitation? *JAMA* 1995; **273**(4): 313-9 <https://pubmed.ncbi.nlm.nih.gov/7815660>.
365. Kesten S, Chapman KR. Physician perceptions and management of COPD. *Chest* 1993; **104**(1): 254-8 <https://pubmed.ncbi.nlm.nih.gov/8325079>.
366. Miller MR, Hankinson J, Brusasco V, et al. Standardisation of spirometry. *Eur Respir J* 2005; **26**(2): 319-38 <https://pubmed.ncbi.nlm.nih.gov/16055882>.
367. Pellegrino R, Viegi G, Brusasco V, et al. Interpretative strategies for lung function tests. *Eur Respir J* 2005; **26**(5): 948-68 <https://pubmed.ncbi.nlm.nih.gov/16264058>.
368. Colak Y, Nordestgaard BG, Vestbo J, Lange P, Afzal S. Prognostic significance of chronic respiratory symptoms in individuals with normal spirometry. *Eur Respir J* 2019; **54**(3): <https://pubmed.ncbi.nlm.nih.gov/31248954>.
369. Jackson H, Hubbard R. Detecting chronic obstructive pulmonary disease using peak flow rate: cross sectional survey. *BMJ* 2003; **327**(7416): 653-4 <https://pubmed.ncbi.nlm.nih.gov/14500437>.
370. Quanjer PH, Stanojevic S, Cole TJ, et al. Multi-ethnic reference values for spirometry for the 3-95-yr age range: the global lung function 2012 equations. *Eur Respir J* 2012; **40**(6): 1324-43 <https://pubmed.ncbi.nlm.nih.gov/22743675>.
371. Stanojevic S, Kaminsky DA, Miller MR, et al. ERS/ATS technical standard on interpretive strategies for routine lung function tests. *Eur Respir J* 2022; **60**(1): <https://pubmed.ncbi.nlm.nih.gov/34949706>.
372. Walker PP, Calverley PM. The volumetric response to bronchodilators in stable chronic obstructive pulmonary disease. *COPD* 2008; **5**(3): 147-52 <https://pubmed.ncbi.nlm.nih.gov/18568838>.
373. Calverley PM, Albert P, Walker PP. Bronchodilator reversibility in chronic obstructive pulmonary disease: use and limitations. *Lancet Respir Med* 2013; **1**(7): 564-73 <https://pubmed.ncbi.nlm.nih.gov/24461617>.
374. Enright PL, Beck KC, Sherrill DL. Repeatability of spirometry in 18,000 adult patients. *Am J Respir Crit Care Med* 2004; **169**(2): 235-8 <https://pubmed.ncbi.nlm.nih.gov/14604836>.
375. Fortis S, Eberlein M, Georgopoulos D, Comellas AP. Predictive value of prebronchodilator and postbronchodilator spirometry for COPD features and outcomes. *BMJ Open Respir Res* 2017; **4**(1): e000213 <https://pubmed.ncbi.nlm.nih.gov/29435342>.
376. Buhr RG, Barjaktarevic IZ, Quibrera PM, et al. Reversible Airflow Obstruction Predicts Future Chronic Obstructive Pulmonary Disease Development in the SPIROMICS Cohort: An Observational Cohort Study. *Am J Respir Crit Care Med* 2022; **206**(5): 554-62 <https://pubmed.ncbi.nlm.nih.gov/35549640>.
377. Albert P, Agusti A, Edwards L, et al. Bronchodilator responsiveness as a phenotypic characteristic of established chronic obstructive pulmonary disease. *Thorax* 2012; **67**(8): 701-8 <https://pubmed.ncbi.nlm.nih.gov/22696176>.
378. Hansen JE, Porszasz J. Counterpoint: Is an increase in FEV(1) and/or FVC \geq 12% of control and \geq 200 mL the best way to assess positive bronchodilator response? No. *Chest* 2014; **146**(3): 538-41 <https://pubmed.ncbi.nlm.nih.gov/25180718>.
379. van Dijk W, Tan W, Li P, et al. Clinical relevance of fixed ratio vs lower limit of normal of FEV1/FVC in COPD: patient-reported outcomes from the CanCOLD cohort. *Ann Fam Med* 2015; **13**(1): 41-8 <https://pubmed.ncbi.nlm.nih.gov/25583891>.
380. Guder G, Brenner S, Angermann CE, et al. "GOLD or lower limit of normal definition? A comparison with expert-based diagnosis of chronic obstructive pulmonary disease in a prospective cohort-study". *Respir Res* 2012; **13**(1): 13 <https://pubmed.ncbi.nlm.nih.gov/22309369>.
381. Bhatt SP, Sieren JC, Dransfield MT, et al. Comparison of spirometric thresholds in diagnosing smoking-related airflow obstruction. *Thorax* 2014; **69**(5): 409-14 <https://pubmed.ncbi.nlm.nih.gov/23525095>.
382. Çolak Y, Afzal S, Nordestgaard BG, Vestbo J, Lange P. Young and middle-aged adults with airflow limitation according to lower limit of normal but not fixed ratio have high morbidity and poor survival: a population-based prospective cohort study. *Eur Respir J* 2018; **51**(3): <https://pubmed.ncbi.nlm.nih.gov/29449425>.

383. Vaz Fragoso CA, McAvay G, Van Ness PH, et al. Phenotype of normal spirometry in an aging population. *Am J Respir Crit Care Med* 2015; **192**(7): 817-25 <https://pubmed.ncbi.nlm.nih.gov/26114439>.
384. Vaz Fragoso CA, McAvay G, Van Ness PH, et al. Phenotype of Spirometric Impairment in an Aging Population. *Am J Respir Crit Care Med* 2016; **193**(7): 727-35 <https://pubmed.ncbi.nlm.nih.gov/26540012>.
385. Malinowski A, Zhou X, Andersson A, et al. Consequences of Using Post- or Prebronchodilator Reference Values in Interpreting Spirometry. *Am J Respir Crit Care Med* 2023; **208**(4): 461-71 <https://pubmed.ncbi.nlm.nih.gov/37339507>.
386. Bhatt SP, Balte PP, Schwartz JE, et al. Discriminative Accuracy of FEV1:FVC Thresholds for COPD-Related Hospitalization and Mortality. *JAMA* 2019; **321**(24): 2438-47 <https://pubmed.ncbi.nlm.nih.gov/31237643>.
387. Aaron SD, Tan WC, Bourbeau J, et al. Diagnostic Instability and Reversals of Chronic Obstructive Pulmonary Disease Diagnosis in Individuals with Mild to Moderate Airflow Obstruction. *Am J Respir Crit Care Med* 2017; **196**(3): 306-14 <https://pubmed.ncbi.nlm.nih.gov/28267373>.
388. Schermer TR, Robberts B, Crockett AJ, et al. Should the diagnosis of COPD be based on a single spirometry test? *NPJ Prim Care Respir Med* 2016; **26**: 16059 <https://pubmed.ncbi.nlm.nih.gov/27684728>.
389. Bowerman C, Bhakta NR, Brazzale D, et al. A Race-neutral Approach to the Interpretation of Lung Function Measurements. *Am J Respir Crit Care Med* 2023; **207**(6): 768-74 <https://pubmed.ncbi.nlm.nih.gov/36383197>.
390. Diao JA, He Y, Khazanchi R, et al. Implications of Race Adjustment in Lung-Function Equations. *N Engl J Med* 2024; **390**(22): 2083-97 <https://pubmed.ncbi.nlm.nih.gov/38767252>.
391. Pomeroy E, Stock JT, Wells JCK. Population history and ecology, in addition to climate, influence human stature and body proportions. *Sci Rep* 2021; **11**(1): 274 <https://pubmed.ncbi.nlm.nih.gov/33431970>.
392. Wang RJ. Beyond Race-Specific Spirometry Reference Equations: What Comes Next? *Am J Respir Crit Care Med* 2024; **209**(1): 117-8 <https://pubmed.ncbi.nlm.nih.gov/37595271>.
393. Burton RF, Nevill AM, Stewart AD, Daniell N, Olds T. Statistical approaches to relationships between sitting height and leg length in adults. *Ann Hum Biol* 2013; **40**(1): 64-9 <https://pubmed.ncbi.nlm.nih.gov/23301801>.
394. Allinson JP, Afzal S, Colak Y, et al. Changes in lung function in European adults born between 1884 and 1996 and implications for the diagnosis of lung disease: a cross-sectional analysis of ten population-based studies. *Lancet Respir Med* 2022; **10**(1): 83-94 <https://pubmed.ncbi.nlm.nih.gov/34619103>.
395. Schiavi E, Ryu MH, Martini L, et al. Application of the ERS/ATS Spirometry Standards and Race-Neutral Equations in the COPD Gene Study. *Am J Respir Crit Care Med* 2024; <https://pubmed.ncbi.nlm.nih.gov/38607551>.
396. Backman H, Blomberg A, Lundquist A, et al. Lung Function Trajectories and Associated Mortality among Adults with and without Airway Obstruction. *Am J Respir Crit Care Med* 2023; **208**(10): 1063-74 <https://pubmed.ncbi.nlm.nih.gov/37460250>.
397. European Respiratory Society. Recommendation from ERS Group 9.1 (Respiratory function technologists /Scientists). Lung function testing during COVID-19 pandemic and beyond; online document available here: <https://ers.app.box.com/s/zs1uu88wy51monr0ewd990itoz4tsn2h> [accessed Oct 2024].
398. American Thoracic Society. Pulmonary Function Laboratories: Advice Regarding COVID-19; online article available here: <https://www.thoracic.org/professionals/clinical-resources/disease-related-resources/pulmonary-function-laboratories.php> [accessed Oct 2024].
399. Borg BM, Osadnik C, Adam K, et al. Pulmonary function testing during SARS-CoV-2: An ANZSRS/TSANZ position statement. *Respirology* 2022; **27**(9): 688-719 <https://pubmed.ncbi.nlm.nih.gov/35981737>.
400. British Thoracic Society. Guidance for the resumption and continuation of urgent and elective outpatient respiratory services. Available online at: <https://www.brit-thoracic.org.uk/covid-19/covid-19-resumption-and-continuation-of-respiratory-services> [accessed Oct 2024].
401. Wilson KC, Kaminsky DA, Michaud G, et al. Restoring Pulmonary and Sleep Services as the COVID-19 Pandemic Lessens. From an Association of Pulmonary, Critical Care, and Sleep Division Directors and American Thoracic Society-coordinated Task Force. *Ann Am Thorac Soc* 2020; **17**(11): 1343-51 <https://pubmed.ncbi.nlm.nih.gov/32663071>.
402. Martinez FJ, Mannino D, Leidy NK, et al. A New Approach for Identifying Patients with Undiagnosed Chronic Obstructive Pulmonary Disease. *Am J Respir Crit Care Med* 2017; **195**(6): 748-56 <https://pubmed.ncbi.nlm.nih.gov/27783539>.
403. Jithoo A, Enright PL, Burney P, et al. Case-finding options for COPD: results from the Burden of Obstructive Lung Disease study. *Eur Respir J* 2013; **41**(3): 548-55 <https://pubmed.ncbi.nlm.nih.gov/22743668>.
404. Mahboub B, Alzaabi A, Soriano JB, et al. Case-finding of chronic obstructive pulmonary disease with questionnaire, peak flow measurements and spirometry: a cross-sectional study. *BMC Res Notes* 2014; **7**: 241 <https://pubmed.ncbi.nlm.nih.gov/24739210>.
405. Perez-Padilla R, Vollmer WM, Vazquez-Garcia JC, et al. Can a normal peak expiratory flow exclude severe chronic obstructive pulmonary disease? *Int J Tuberc Lung Dis* 2009; **13**(3): 387-93 <https://pubmed.ncbi.nlm.nih.gov/19275802>.
406. Aggarwal AN, Gupta D, Jindal SK. The relationship between FEV1 and peak expiratory flow in patients with airways obstruction is poor. *Chest* 2006; **130**(5): 1454-61 <https://pubmed.ncbi.nlm.nih.gov/17099024>.
407. Pothirat C, Chaiwong W, Phetsuk N, et al. Peak expiratory flow rate as a surrogate for forced expiratory volume in 1 second in COPD severity classification in Thailand. *Int J Chron Obstruct Pulmon Dis* 2015; **10**: 1213-8 <https://pubmed.ncbi.nlm.nih.gov/26150713>.
408. Llewellyn P, Sawyer G, Lewis S, et al. The relationship between FEV1 and PEF in the assessment of the severity of airways obstruction. *Respirology* 2002; **7**(4): 333-7.

409. Carpenter DM, Jurdi R, Roberts CA, Hernandez M, Horne R, Chan A. A Review of Portable Electronic Spirometers: Implications for Asthma Self-Management. *Curr Allergy Asthma Rep* 2018; **18**(10): 53 <https://pubmed.ncbi.nlm.nih.gov/30145683>.
410. Ramos Hernandez C, Nunez Fernandez M, Pallares Sanmartin A, et al. Validation of the portable Air-Smart Spirometer. *PLoS One* 2018; **13**(2): e0192789 <https://pubmed.ncbi.nlm.nih.gov/29474502>.
411. Qaseem A, Snow V, Shekelle P, et al. Diagnosis and management of stable chronic obstructive pulmonary disease: a clinical practice guideline from the American College of Physicians. *Ann Intern Med* 2007; **147**(9): 633-8 <https://pubmed.ncbi.nlm.nih.gov/17975186>.
412. U. S. Preventive Services Task Force, Mangione CM, Barry MJ, et al. Screening for Chronic Obstructive Pulmonary Disease: US Preventive Services Task Force Reaffirmation Recommendation Statement. *JAMA* 2022; **327**(18): 1806-11 <https://pubmed.ncbi.nlm.nih.gov/35536260>.
413. Hill K, Goldstein RS, Guyatt GH, et al. Prevalence and underdiagnosis of chronic obstructive pulmonary disease among patients at risk in primary care. *CMAJ* 2010; **182**(7): 673-8 <https://pubmed.ncbi.nlm.nih.gov/20371646>.
414. Lopez Varela MV, Montes de Oca M, Rey A, et al. Development of a simple screening tool for opportunistic COPD case finding in primary care in Latin America: The PUMA study. *Respirology* 2016; **21**(7): 1227-34 <https://pubmed.ncbi.nlm.nih.gov/27319305>.
415. Kim T, Choi H, Seo JI, et al. Prevalence, Trend, and Risk Factors for Early Chronic Obstructive Pulmonary Disease: An Analysis of the Nationwide Population-Based Survey from 2010 to 2019 in South Korea. *Copd* 2023; **20**(1): 153-61 <https://pubmed.ncbi.nlm.nih.gov/37036446>.
416. Tammemagi MC, Lam SC, McWilliams AM, Sin DD. Incremental value of pulmonary function and sputum DNA image cytometry in lung cancer risk prediction. *Cancer Prev Res (Phila)* 2011; **4**(4): 552-61 <https://pubmed.ncbi.nlm.nih.gov/21411501>.
417. de-Torres JP, Wilson DO, Sanchez-Salcedo P, et al. Lung cancer in patients with chronic obstructive pulmonary disease. Development and validation of the COPD Lung Cancer Screening Score. *Am J Respir Crit Care Med* 2015; **191**(3): 285-91 <https://pubmed.ncbi.nlm.nih.gov/25522175>.
418. Haroon S, Adab P, Riley RD, Fitzmaurice D, Jordan RE. Predicting risk of undiagnosed COPD: development and validation of the TargetCOPD score. *Eur Respir J* 2017; **49**(6): 1602191 <https://pubmed.ncbi.nlm.nih.gov/28642308>.
419. Lambe T, Adab P, Jordan RE, et al. Model-based evaluation of the long-term cost-effectiveness of systematic case-finding for COPD in primary care. *Thorax* 2019; **74**(8): 730-9 <https://pubmed.ncbi.nlm.nih.gov/31285359>.
420. Tan WC, Sin DD, Bourbeau J, et al. Characteristics of COPD in never-smokers and ever-smokers in the general population: results from the CanCOLD study. *Thorax* 2015; **70**(9): 822-9 <https://pubmed.ncbi.nlm.nih.gov/26048404>.
421. Han MK, Steenrod AW, Bacci ED, et al. Identifying Patients with Undiagnosed COPD in Primary Care Settings: Insight from Screening Tools and Epidemiologic Studies. *Chronic Obstr Pulm Dis* 2015; **2**(2): 103-21 <https://pubmed.ncbi.nlm.nih.gov/26236776>.
422. Siddharthan T, Wosu AC, Pollard SL, et al. A Novel Case-Finding Instrument for Chronic Obstructive Pulmonary Disease in Low- and Middle-Income Country Settings. *Int J Chron Obstruct Pulmon Dis* 2020; **15**: 2769-77 <https://pubmed.ncbi.nlm.nih.gov/33173289>.
423. Dirven JA, Tange HJ, Muris JW, van Haaren KM, Vink G, van Schayck OC. Early detection of COPD in general practice: implementation, workload and socioeconomic status. A mixed methods observational study. *Prim Care Respir J* 2013; **22**(3): 338-43 <https://pubmed.ncbi.nlm.nih.gov/23966213>.
424. Le Rouzic O, Roche N, Cortot AB, et al. Defining the "Frequent Exacerbator" Phenotype in COPD: A Hypothesis-Free Approach. *Chest* 2018; **153**(5): 1106-15 <https://pubmed.ncbi.nlm.nih.gov/29054347>.
425. Jordan RE, Adab P, Sitch A, et al. Targeted case finding for chronic obstructive pulmonary disease versus routine practice in primary care (TargetCOPD): a cluster-randomised controlled trial. *Lancet Respir Med* 2016; **4**(9): 720-30 <https://pubmed.ncbi.nlm.nih.gov/27444687>.
426. Haroon S, Jordan R, Takwoingi Y, Adab P. Diagnostic accuracy of screening tests for COPD: a systematic review and meta-analysis. *BMJ Open* 2015; **5**(10): e008133 <https://pubmed.ncbi.nlm.nih.gov/26450427>.
427. Huynh C, Whitmore GA, Vandemheen KL, et al. Derivation and validation of the UCAP-Q case-finding questionnaire to detect undiagnosed asthma and COPD. *Eur Respir J* 2022; **60**(3): <https://pubmed.ncbi.nlm.nih.gov/35332067>.
428. Pan Z, Dickens AP, Chi C, et al. Accuracy and cost-effectiveness of different screening strategies for identifying undiagnosed COPD among primary care patients (>=40 years) in China: a cross-sectional screening test accuracy study: findings from the Breathe Well group. *BMJ Open* 2021; **11**(9): e051811 <https://pubmed.ncbi.nlm.nih.gov/34556515>.
429. Zhou J, Li X, Wang X, Yu N, Wang W. Accuracy of portable spirometers in the diagnosis of chronic obstructive pulmonary disease A meta-analysis. *NPJ Prim Care Respir Med* 2022; **32**(1): 15 <https://pubmed.ncbi.nlm.nih.gov/35440665>.
430. Siddharthan T, Pollard SL, Quaderi SA, et al. Discriminative Accuracy of Chronic Obstructive Pulmonary Disease Screening Instruments in 3 Low- and Middle-Income Country Settings. *JAMA* 2022; **327**(2): 151-60 <https://pubmed.ncbi.nlm.nih.gov/35015039>.
431. Tamaki K, Sakihara E, Miyata H, et al. Utility of Self-Administered Questionnaires for Identifying Individuals at Risk of COPD in Japan: The OCEAN (Okinawa COPD case finding Assessment) Study. *Int J Chron Obstruct Pulmon Dis* 2021; **16**: 1771-82 <https://pubmed.ncbi.nlm.nih.gov/34168439>.

432. Sogbetun F, Eschenbacher WL, Welge JA, Panos RJ. A comparison of five surveys that identify individuals at risk for airflow obstruction and chronic obstructive pulmonary disease. *Respir Med* 2016; **120**: 1-9 <https://pubmed.ncbi.nlm.nih.gov/27817804>.
433. Martinez FJ, Han MK, Lopez C, et al. Discriminative Accuracy of the CAPTURE Tool for Identifying Chronic Obstructive Pulmonary Disease in US Primary Care Settings. *Jama* 2023; **329**(6): 490-501 <https://pubmed.ncbi.nlm.nih.gov/36786790>.
434. Yawn BP, Duvall K, Peabody J, et al. The impact of screening tools on diagnosis of chronic obstructive pulmonary disease in primary care. *Am J Prev Med* 2014; **47**(5): 563-75 <https://pubmed.ncbi.nlm.nih.gov/25241196>.
435. Bertens LC, Reitsma JB, van Mourik Y, et al. COPD detected with screening: impact on patient management and prognosis. *Eur Respir J* 2014; **44**(6): 1571-8 <https://pubmed.ncbi.nlm.nih.gov/24925924>.
436. Yawn BP, Martinez FJ. POINT: Can Screening for COPD Improve Outcomes? Yes. *Chest* 2020; **157**(1): 7-9 <https://pubmed.ncbi.nlm.nih.gov/31916966>.
437. Campos M, Hagenlocker B, Lascano J, Riley L. Impact of a Computerized Clinical Decision Support System to Improve Chronic Obstructive Pulmonary Disease Diagnosis and Testing for Alpha-1 Antitrypsin Deficiency. *Ann Am Thorac Soc* 2023; **20**(8): 1116-23 <https://pubmed.ncbi.nlm.nih.gov/36989247>.
438. Yawn BP, Han M, Make BM, et al. Protocol Summary of the COPD Assessment in Primary Care To Identify Undiagnosed Respiratory Disease and Exacerbation Risk (CAPTURE) Validation in Primary Care Study. *Chronic Obstr Pulm Dis* 2021; **8**(1): 60-75 <https://pubmed.ncbi.nlm.nih.gov/33156981>.
439. Siddharthan T, Pollard SL, Quaderi SA, et al. Effectiveness-implementation of COPD case finding and self-management action plans in low- and middle-income countries: global excellence in COPD outcomes (GECO) study protocol. *Trials* 2018; **19**(1): 571 <https://pubmed.ncbi.nlm.nih.gov/30340648>.
440. Li Y, Wen F, Ma Q, et al. Use of CAPTURE to Identify Individuals Who May or May Not Require Treatment for Chronic Obstructive Pulmonary Disease. *Am J Respir Crit Care Med* 2023; **208**(4): 435-41 <https://pubmed.ncbi.nlm.nih.gov/37315325>.
441. Webber EM, Lin JS, Thomas RG. Screening for Chronic Obstructive Pulmonary Disease: Updated Evidence Report and Systematic Review for the US Preventive Services Task Force. *JAMA* 2022; **327**(18): 1812-6 <https://pubmed.ncbi.nlm.nih.gov/35536261>.
442. de Koning HJ, van der Aalst CM, de Jong PA, et al. Reduced Lung-Cancer Mortality with Volume CT Screening in a Randomized Trial. *N Engl J Med* 2020; **382**(6): 503-13 <https://pubmed.ncbi.nlm.nih.gov/31995683>.
443. National Lung Screening Trial Research Team, Aberle DR, Adams AM, et al. Reduced lung-cancer mortality with low-dose computed tomographic screening. *N Engl J Med* 2011; **365**(5): 395-409 <https://pubmed.ncbi.nlm.nih.gov/21714641>.
444. Perrotta F, D'Agnano V, Scialò F, et al. Evolving concepts in COPD and lung cancer: a narrative review. *Minerva Med* 2022; **113**(3): 436-48 <https://pubmed.ncbi.nlm.nih.gov/35156786>.
445. Ruparel M, Quaife SL, Dickson JL, et al. Prevalence, Symptom Burden, and Underdiagnosis of Chronic Obstructive Pulmonary Disease in a Lung Cancer Screening Cohort. *Ann Am Thorac Soc* 2020; **17**(7): 869-78 <https://pubmed.ncbi.nlm.nih.gov/32164439>.
446. Young RP, Hopkins RJ. Diagnosing COPD and targeted lung cancer screening. *Eur Respir J* 2012; **40**(4): 1063-4 <https://pubmed.ncbi.nlm.nih.gov/23024333>.
447. Hopkins RJ, Duan F, Chiles C, et al. Reduced Expiratory Flow Rate among Heavy Smokers Increases Lung Cancer Risk. Results from the National Lung Screening Trial-American College of Radiology Imaging Network Cohort. *Ann Am Thorac Soc* 2017; **14**(3): 392-402 <https://pubmed.ncbi.nlm.nih.gov/28076701>.
448. Yu Y, Xiao W, Du LY, et al. Acupuncture for dyspnea and breathing physiology in chronic respiratory diseases: A systematic review and meta-analysis of randomized controlled trials. *Heliyon* 2024; **10**(10): e31176 <https://pubmed.ncbi.nlm.nih.gov/38813170>.
449. Balata H, Harvey J, Barber PV, et al. Spirometry performed as part of the Manchester community-based lung cancer screening programme detects a high prevalence of airflow obstruction in individuals without a prior diagnosis of COPD. *Thorax* 2020; **75**(8): 655-60 <https://pubmed.ncbi.nlm.nih.gov/32444437>.
450. Undrunas A, Kasprzyk P, Rajca A, Kuziemski K, Rzyman W, Zdrojewski T. Prevalence, symptom burden and under-diagnosis of chronic obstructive pulmonary disease in Polish lung cancer screening population: a cohort observational study. *BMJ Open* 2022; **12**(4): e055007 <https://pubmed.ncbi.nlm.nih.gov/35410926>.
451. Carr LL, Jacobson S, Lynch DA, et al. Features of COPD as Predictors of Lung Cancer. *Chest* 2018; **153**(6): 1326-35 <https://pubmed.ncbi.nlm.nih.gov/29452098>.
452. Maldonado F, Bartholmai BJ, Swensen SJ, Midthun DE, Decker PA, Jett JR. Are airflow obstruction and radiographic evidence of emphysema risk factors for lung cancer? A nested case-control study using quantitative emphysema analysis. *Chest* 2010; **138**(6): 1295-302 <https://pubmed.ncbi.nlm.nih.gov/20348193>.
453. Kishi K, Gurney JW, Schroeder DR, Scanlon PD, Swensen SJ, Jett JR. The correlation of emphysema or airway obstruction with the risk of lung cancer: a matched case-controlled study. *Eur Respir J* 2002; **19**(6): 1093-8 <https://pubmed.ncbi.nlm.nih.gov/12108862>.
454. Wilson DO, Weissfeld JL, Balkan A, et al. Association of radiographic emphysema and airflow obstruction with lung cancer. *Am J Respir Crit Care Med* 2008; **178**(7): 738-44 <https://pubmed.ncbi.nlm.nih.gov/18565949>.

455. Sanchez-Salcedo P, Wilson DO, de-Torres JP, et al. Improving selection criteria for lung cancer screening. The potential role of emphysema. *Am J Respir Crit Care Med* 2015; **191**(8): 924-31 <https://pubmed.ncbi.nlm.nih.gov/25668622>.
456. Balkan A, Bulut Y, Fuhrman CR, et al. COPD phenotypes in a lung cancer screening population. *Clin Respir J* 2016; **10**(1): 48-53 <https://pubmed.ncbi.nlm.nih.gov/24989058>.
457. Labaki WW, Xia M, Murray S, et al. Quantitative Emphysema on Low-Dose CT Imaging of the Chest and Risk of Lung Cancer and Airflow Obstruction: An Analysis of the National Lung Screening Trial. *Chest* 2021; **159**(5): 1812-20 <https://pubmed.ncbi.nlm.nih.gov/33326807>.
458. Tang LYW, Coxson HO, Lam S, Leipsic J, Tam RC, Sin DD. Towards large-scale case-finding: training and validation of residual networks for detection of chronic obstructive pulmonary disease using low-dose CT. *Lancet Digit Health* 2020; **2**(5): e259-e67 <https://pubmed.ncbi.nlm.nih.gov/33328058>.
459. Bradley C, Boland A, Clarke L, et al. Diagnosis and treatment outcomes from prebronchodilator spirometry performed alongside lung cancer screening in a Lung Health Check programme. *Thorax* 2023; **78**(6): 543-50 <https://pubmed.ncbi.nlm.nih.gov/36972979>.
460. Crosbie PA, Balata H, Evison M, et al. Implementing lung cancer screening: baseline results from a community-based 'Lung Health Check' pilot in deprived areas of Manchester. *Thorax* 2019; **74**(4): 405-9 <https://pubmed.ncbi.nlm.nih.gov/29440588>.
461. Tisi S, Creamer AW, Dickson J, et al. Prevalence and clinical characteristics of non-malignant CT detected incidental findings in the SUMMIT lung cancer screening cohort. *BMJ Open Respir Res* 2023; **10**(1): <https://pubmed.ncbi.nlm.nih.gov/37321665>.
462. Koo HK, Jin KN, Kim DK, Chung HS, Lee CH. Association of incidental emphysema with annual lung function decline and future development of airflow limitation. *Int J Chron Obstruct Pulmon Dis* 2016; **11**: 161-6 <https://pubmed.ncbi.nlm.nih.gov/26893550>.
463. Mohamed Hoessein FA, de Hoop B, Zanen P, et al. CT-quantified emphysema in male heavy smokers: association with lung function decline. *Thorax* 2011; **66**(9): 782-7 <https://pubmed.ncbi.nlm.nih.gov/21474499>.
464. Roberts HR, Wells AU, Milne DG, et al. Airflow obstruction in bronchiectasis: correlation between computed tomography features and pulmonary function tests. *Thorax* 2000; **55**(3): 198-204 <https://pubmed.ncbi.nlm.nih.gov/10679538>.
465. Vestbo J, Edwards LD, Scanlon PD, et al. Changes in forced expiratory volume in 1 second over time in COPD. *N Engl J Med* 2011; **365**(13): 1184-92 <https://pubmed.ncbi.nlm.nih.gov/21991892>.
466. Halpin DM. Do the 'missing millions' of COPD patients want to be found? *Thorax* 2023; **78**(6): 531-2 <https://pubmed.ncbi.nlm.nih.gov/36972980>.
467. Jones PW. Health status and the spiral of decline. *COPD* 2009; **6**(1): 59-63 <https://pubmed.ncbi.nlm.nih.gov/19229709>.
468. Han MK, Muellerova H, Curran-Everett D, et al. GOLD 2011 disease severity classification in COPD Gene: a prospective cohort study. *Lancet Respir Med* 2013; **1**(1): 43-50 <https://pubmed.ncbi.nlm.nih.gov/24321803>.
469. American Thoracic Society (ATS). Surveillance for respiratory hazards in the occupational setting *Am Rev Respir Dis* 1982; **126**: 952-6
470. Bestall JC, Paul EA, Garrod R, Garnham R, Jones PW, Wedzicha JA. Usefulness of the Medical Research Council (MRC) dyspnoea scale as a measure of disability in patients with chronic obstructive pulmonary disease. *Thorax* 1999; **54**(7): 581-6 <https://pubmed.ncbi.nlm.nih.gov/10377201>.
471. Sundh J, Janson C, Lisspers K, Stallberg B, Montgomery S. The Dyspnoea, Obstruction, Smoking, Exacerbation (DOSE) index is predictive of mortality in COPD. *Prim Care Respir J* 2012; **21**(3): 295-301 <https://pubmed.ncbi.nlm.nih.gov/22786813>.
472. Nishimura K, Izumi T, Tsukino M, Oga T. Dyspnea is a better predictor of 5-year survival than airflow obstruction in patients with COPD. *Chest* 2002; **121**(5): 1434-40 <https://pubmed.ncbi.nlm.nih.gov/12006425>.
473. Jones PW. Health status measurement in chronic obstructive pulmonary disease. *Thorax* 2001; **56**(11): 880-7 <https://pubmed.ncbi.nlm.nih.gov/11641515>.
474. Guyatt GH, Berman LB, Townsend M, Pugsley SO, Chambers LW. A measure of quality of life for clinical trials in chronic lung disease. *Thorax* 1987; **42**(10): 773-8 <https://pubmed.ncbi.nlm.nih.gov/3321537>.
475. Jones PW, Quirk FH, Baveystock CM, Littlejohns P. A self-complete measure of health status for chronic airflow limitation. The St. George's Respiratory Questionnaire. *Am Rev Respir Dis* 1992; **145**(6): 1321-7 <https://pubmed.ncbi.nlm.nih.gov/1595997>.
476. Jones PW, Harding G, Berry P, Wiklund I, Chen WH, Kline Leidy N. Development and first validation of the COPD Assessment Test. *Eur Respir J* 2009; **34**(3): 648-54 <https://pubmed.ncbi.nlm.nih.gov/19720809>.
477. Karloh M, Fleig Mayer A, Maurici R, Pizzichini MMM, Jones PW, Pizzichini E. The COPD Assessment Test: What Do We Know So Far?: A Systematic Review and Meta-Analysis About Clinical Outcomes Prediction and Classification of Patients Into GOLD Stages. *Chest* 2016; **149**(2): 413-25 <https://pubmed.ncbi.nlm.nih.gov/26513112>.
478. Nishimura K, Mitsuma S, Kobayashi A, et al. COPD and disease-specific health status in a working population. *Respir Res* 2013; **14**(1): 61 <https://pubmed.ncbi.nlm.nih.gov/23725096>.
479. Miravittles M, Soriano JB, Garcia-Rio F, et al. Prevalence of COPD in Spain: impact of undiagnosed COPD on quality of life and daily life activities. *Thorax* 2009; **64**(10): 863-8 <https://pubmed.ncbi.nlm.nih.gov/19553233>.

480. Jones PW, Tabberer M, Chen WH. Creating scenarios of the impact of COPD and their relationship to COPD Assessment Test (CAT) scores. *BMC Pulm Med* 2011; **11**: 42 <https://pubmed.ncbi.nlm.nih.gov/21835018>.
481. Jones PW, Adamek L, Nadeau G, Banik N. Comparisons of health status scores with MRC grades in COPD: implications for the GOLD 2011 classification. *Eur Respir J* 2013; **42**(3): 647-54 <https://pubmed.ncbi.nlm.nih.gov/23258783>.
482. Hurst JR, Wedzicha JA. What is (and what is not) a COPD exacerbation: thoughts from the new GOLD guidelines. *Thorax* 2007; **62**(3): 198-9 <https://pubmed.ncbi.nlm.nih.gov/17329557>.
483. Wedzicha JA, Seemungal TA. COPD exacerbations: defining their cause and prevention. *Lancet* 2007; **370**(9589): 786-96 <https://pubmed.ncbi.nlm.nih.gov/17765528>.
484. Seemungal TA, Donaldson GC, Paul EA, Bestall JC, Jeffries DJ, Wedzicha JA. Effect of exacerbation on quality of life in patients with chronic obstructive pulmonary disease. *Am J Respir Crit Care Med* 1998; **157**(5 Pt 1): 1418-22 <https://pubmed.ncbi.nlm.nih.gov/9603117>.
485. Burge S, Wedzicha JA. COPD exacerbations: definitions and classifications. *Eur Respir J Suppl* 2003; **41**: 46s-53s <https://pubmed.ncbi.nlm.nih.gov/12795331>.
486. Soler-Cataluna JJ, Martinez-Garcia MA, Roman Sanchez P, Salcedo E, Navarro M, Ochando R. Severe acute exacerbations and mortality in patients with chronic obstructive pulmonary disease. *Thorax* 2005; **60**(11): 925-31 <https://pubmed.ncbi.nlm.nih.gov/16055622>.
487. Hurst JR, Vestbo J, Anzueto A, et al. Susceptibility to exacerbation in chronic obstructive pulmonary disease. *N Engl J Med* 2010; **363**(12): 1128-38 <https://pubmed.ncbi.nlm.nih.gov/20843247>.
488. Han MK, Quibrera PM, Carretta EE, et al. Frequency of exacerbations in patients with chronic obstructive pulmonary disease: an analysis of the SPIROMICS cohort. *Lancet Respir Med* 2017; **5**(8): 619-26 <https://pubmed.ncbi.nlm.nih.gov/28668356>.
489. Mullerova H, Maselli DJ, Locantore N, et al. Hospitalized exacerbations of COPD: risk factors and outcomes in the ECLIPSE cohort. *Chest* 2015; **147**(4): 999-1007 <https://pubmed.ncbi.nlm.nih.gov/25356881>.
490. Soriano JB, Lamprecht B, Ramirez AS, et al. Mortality prediction in chronic obstructive pulmonary disease comparing the GOLD 2007 and 2011 staging systems: a pooled analysis of individual patient data. *Lancet Respir Med* 2015; **3**(6): 443-50 <https://pubmed.ncbi.nlm.nih.gov/25995071>.
491. Bafadhel M, Peterson S, De Blas MA, et al. Predictors of exacerbation risk and response to budesonide in patients with chronic obstructive pulmonary disease: a post-hoc analysis of three randomised trials. *Lancet Respir Med* 2018; **6**(2): 117-26 <https://pubmed.ncbi.nlm.nih.gov/29331313>.
492. Siddiqui SH, Guasconi A, Vestbo J, et al. Blood Eosinophils: A Biomarker of Response to Extrafine Beclomethasone/Formoterol in Chronic Obstructive Pulmonary Disease. *Am J Respir Crit Care Med* 2015; **192**(4): 523-5 <https://pubmed.ncbi.nlm.nih.gov/26051430>.
493. Papi A, Vestbo J, Fabbri L, et al. Extrafine inhaled triple therapy versus dual bronchodilator therapy in chronic obstructive pulmonary disease (TRIBUTE): a double-blind, parallel group, randomised controlled trial. *Lancet* 2018; **391**(10125): 1076-84 <https://pubmed.ncbi.nlm.nih.gov/29429593>.
494. Pascoe S, Locantore N, Dransfield MT, Barnes NC, Pavord ID. Blood eosinophil counts, exacerbations, and response to the addition of inhaled fluticasone furoate to vilanterol in patients with chronic obstructive pulmonary disease: a secondary analysis of data from two parallel randomised controlled trials. *Lancet Respir Med* 2015; **3**(6): 435-42 <https://pubmed.ncbi.nlm.nih.gov/25878028>.
495. Vestbo J, Papi A, Corradi M, et al. Single inhaler extrafine triple therapy versus long-acting muscarinic antagonist therapy for chronic obstructive pulmonary disease (TRINITY): a double-blind, parallel group, randomised controlled trial. *Lancet* 2017; **389**(10082): 1919-29 <https://pubmed.ncbi.nlm.nih.gov/28385353>.
496. Lipson DA, Barnhart F, Brealey N, et al. Once-Daily Single-Inhaler Triple versus Dual Therapy in Patients with COPD. *N Engl J Med* 2018; **378**(18): 1671-80 <https://pubmed.ncbi.nlm.nih.gov/29668352>.
497. Hartl S, Breyer MK, Burghuber OC, et al. Blood eosinophil count in the general population: typical values and potential confounders. *Eur Respir J* 2020; **55**(5): 1901874 <https://pubmed.ncbi.nlm.nih.gov/32060069>.
498. Kolsum U, Southworth T, Jackson N, Singh D. Blood eosinophil counts in COPD patients compared to controls. *Eur Respir J* 2019; **54**(4): 1900633 <https://pubmed.ncbi.nlm.nih.gov/31221811>.
499. George L, Taylor AR, Esteve-Codina A, et al. Blood eosinophil count and airway epithelial transcriptome relationships in COPD versus asthma. *Allergy* 2020; **75**(2): 370-80 <https://pubmed.ncbi.nlm.nih.gov/31506971>.
500. Higham A, Beech A, Wolosianka S, et al. Type 2 inflammation in eosinophilic chronic obstructive pulmonary disease. *Allergy* 2021; **76**(6): 1861-4 <https://pubmed.ncbi.nlm.nih.gov/33206402>.
501. Singh D, Agusti A, Martinez FJ, et al. Blood Eosinophils and Chronic Obstructive Pulmonary Disease: A Global Initiative for Chronic Obstructive Lung Disease Science Committee 2022 Review. *Am J Respir Crit Care Med* 2022; **206**(1): 17-24 <https://pubmed.ncbi.nlm.nih.gov/35737975>.
502. Landis SH, Suruki R, Hilton E, Compton C, Galwey NW. Stability of Blood Eosinophil Count in Patients with COPD in the UK Clinical Practice Research Datalink. *COPD* 2017; **14**(4): 382-8 <https://pubmed.ncbi.nlm.nih.gov/28569614>.
503. Oshagbemi OA, Burden AM, Braeken DCW, et al. Stability of Blood Eosinophils in Patients with Chronic Obstructive Pulmonary Disease and in Control Subjects, and the Impact of Sex, Age, Smoking, and Baseline Counts. *Am J Respir Crit Care Med* 2017; **195**(10): 1402-4 <https://pubmed.ncbi.nlm.nih.gov/28165763>.

504. Southworth T, Beech G, Foden P, Kolsum U, Singh D. The reproducibility of COPD blood eosinophil counts. *Eur Respir J* 2018; **52**(1): <https://pubmed.ncbi.nlm.nih.gov/29724922>.
505. Casanova C, Celli BR, de-Torres JP, et al. Prevalence of persistent blood eosinophilia: relation to outcomes in patients with COPD. *Eur Respir J* 2017; **50**(5): <https://pubmed.ncbi.nlm.nih.gov/29167301>.
506. Vedel-Krogh S, Nielsen SF, Lange P, Vestbo J, Nordestgaard BG. Blood Eosinophils and Exacerbations in Chronic Obstructive Pulmonary Disease. The Copenhagen General Population Study. *Am J Respir Crit Care Med* 2016; **193**(9): 965-74 <https://pubmed.ncbi.nlm.nih.gov/26641631>.
507. Yun JH, Lamb A, Chase R, et al. Blood eosinophil count thresholds and exacerbations in patients with chronic obstructive pulmonary disease. *J Allergy Clin Immunol* 2018; **141**(6): 2037-47 e10 <https://pubmed.ncbi.nlm.nih.gov/29709670>.
508. Tan WC, Bourbeau J, Nadeau G, et al. High eosinophil counts predict decline in FEV(1): results from the CanCOLD study. *Eur Respir J* 2021; **57**(5): <https://pubmed.ncbi.nlm.nih.gov/33303555>.
509. Park HY, Chang Y, Kang D, et al. Blood eosinophil counts and the development of obstructive lung disease: the Kangbuk Samsung Health Study. *Eur Respir J* 2021; **58**(4): <https://pubmed.ncbi.nlm.nih.gov/33737406>.
510. Mannino DM, Thorn D, Swensen A, Holguin F. Prevalence and outcomes of diabetes, hypertension and cardiovascular disease in COPD. *Eur Respir J* 2008; **32**(4): 962-9 <https://pubmed.ncbi.nlm.nih.gov/18579551>.
511. Soriano JB, Visick GT, Muellerova H, Payvandi N, Hansell AL. Patterns of comorbidities in newly diagnosed COPD and asthma in primary care. *Chest* 2005; **128**(4): 2099-107 <https://pubmed.ncbi.nlm.nih.gov/16236861>.
512. National Institute for Health and Care Excellence. Multimorbidity: clinical assessment and management; NICE guideline [NG56] Published date: 21 September 2016 [accessed Oct 2024]. 2016. <https://www.nice.org.uk/guidance/ng56>.
513. Vanfleteren LE, Spruit MA, Groenen M, et al. Clusters of comorbidities based on validated objective measurements and systemic inflammation in patients with chronic obstructive pulmonary disease. *Am J Respir Crit Care Med* 2013; **187**(7): 728-35 <https://pubmed.ncbi.nlm.nih.gov/23392440>.
514. Brenner DR, Boffetta P, Duell EJ, et al. Previous lung diseases and lung cancer risk: a pooled analysis from the International Lung Cancer Consortium. *Am J Epidemiol* 2012; **176**(7): 573-85 <https://pubmed.ncbi.nlm.nih.gov/22986146>.
515. Fry JS, Hamling JS, Lee PN. Systematic review with meta-analysis of the epidemiological evidence relating FEV1 decline to lung cancer risk. *BMC Cancer* 2012; **12**: 498 <https://pubmed.ncbi.nlm.nih.gov/23101666>.
516. Wagner PD. Possible mechanisms underlying the development of cachexia in COPD. *Eur Respir J* 2008; **31**(3): 492-501 <https://pubmed.ncbi.nlm.nih.gov/18310396>.
517. Maltais F, Decramer M, Casaburi R, et al. An official American Thoracic Society/European Respiratory Society statement: update on limb muscle dysfunction in chronic obstructive pulmonary disease. *Am J Respir Crit Care Med* 2014; **189**(9): e15-62 <https://pubmed.ncbi.nlm.nih.gov/24787074>.
518. Agusti A, Böhm M, Celli B, et al. GOLD COPD DOCUMENT 2023: a brief update for practicing cardiologists. *Clin Res Cardiol* 2024; **113**(2): 195-204 <https://pubmed.ncbi.nlm.nih.gov/37233751>.
519. Global Initiative for Chronic Obstructive Lung Disease (GOLD). Global strategy for the diagnosis, management, and prevention of chronic obstructive pulmonary disease. 2024 Report. <http://www.goldcopd.org/>.
520. Sin DD, Anthonisen NR, Soriano JB, Agusti AG. Mortality in COPD: Role of comorbidities. *Eur Respir J* 2006; **28**(6): 1245-57 <https://pubmed.ncbi.nlm.nih.gov/17138679>.
521. Agustí A, Edwards LD, Rennard SI, et al. Persistent systemic inflammation is associated with poor clinical outcomes in COPD: a novel phenotype. *PLoS One* 2012; **7**(5): e37483 <https://pubmed.ncbi.nlm.nih.gov/22624038>.
522. Hurst JR, Gale CP. MACE in COPD: addressing cardiopulmonary risk. *Lancet Respir Med* 2024; **12**(5): 345-8 <https://pubmed.ncbi.nlm.nih.gov/38437859>.
523. Singh D, Han MK, Hawkins NM, et al. Implications of Cardiopulmonary Risk for the Management of COPD: A Narrative Review. *Adv Ther* 2024; **41**(6): 2151-67 <https://pubmed.ncbi.nlm.nih.gov/38664329>.
524. Zhou L, Yang H, Zhang Y, et al. Predictive value of lung function measures for cardiovascular risk: a large prospective cohort study. *Thorax* 2024; **79**(3): 250-8 <https://pubmed.ncbi.nlm.nih.gov/38050152>.
525. Vogelmeier CF, Rhodes K, Garbe E, et al. Elucidating the risk of cardiopulmonary consequences of an exacerbation of COPD: results of the EXACOS-CV study in Germany. *BMJ Open Respir Res* 2024; **11**(1): <https://pubmed.ncbi.nlm.nih.gov/38555102>.
526. Graul EL, Nordon C, Rhodes K, et al. Temporal Risk of Nonfatal Cardiovascular Events After Chronic Obstructive Pulmonary Disease Exacerbation: A Population-based Study. *Am J Respir Crit Care Med* 2024; **209**(8): 960-72 <https://pubmed.ncbi.nlm.nih.gov/38127850>.
527. Kunisaki KM, Dransfield MT, Anderson JA, et al. Exacerbations of Chronic Obstructive Pulmonary Disease and Cardiac Events. A Post Hoc Cohort Analysis from the SUMMIT Randomized Clinical Trial. *Am J Respir Crit Care Med* 2018; **198**(1): 51-7 <https://pubmed.ncbi.nlm.nih.gov/29442524>.
528. Celli BR, Fabbri LM, Aaron SD, et al. Differential Diagnosis of Suspected Chronic Obstructive Pulmonary Disease Exacerbations in the Acute Care Setting: Best Practice. *Am J Respir Crit Care Med* 2023; **207**(9): 1134-44 <https://pubmed.ncbi.nlm.nih.gov/36701677>.

529. Goossens LM, Leimer I, Metzdorf N, Becker K, Rutten-van Molken MP. Does the 2013 GOLD classification improve the ability to predict lung function decline, exacerbations and mortality: a post-hoc analysis of the 4-year UPLIFT trial. *BMC Pulm Med* 2014; **14**: 163 <https://pubmed.ncbi.nlm.nih.gov/25326750>.
530. Kim J, Yoon HI, Oh YM, et al. Lung function decline rates according to GOLD group in patients with chronic obstructive pulmonary disease. *Int J Chron Obstruct Pulmon Dis* 2015; **10**: 1819-27 <https://pubmed.ncbi.nlm.nih.gov/26379432>.
531. Blakemore WS, Forster RE, Morton JW, Ogilvie CM. A standardized breath holding technique for the clinical measurement of the diffusing capacity of the lung for carbon monoxide. *J Clin Invest* 1957; **36**(1 Part 1): 1-17 <https://pubmed.ncbi.nlm.nih.gov/13398477>.
532. American Thoracic Society (ATS). Lung function testing: selection of reference values and interpretative strategies. American Thoracic Society. *Am Rev Respir Dis* 1991; **144**(5): 1202-18 <https://pubmed.ncbi.nlm.nih.gov/1952453>.
533. MacIntyre N, Crapo RO, Viegi G, et al. Standardisation of the single-breath determination of carbon monoxide uptake in the lung. *Eur Respir J* 2005; **26**(4): 720-35 <https://pubmed.ncbi.nlm.nih.gov/16204605>.
534. Stanojevic S, Graham BL, Cooper BG, et al. Official ERS technical standards: Global Lung Function Initiative reference values for the carbon monoxide transfer factor for Caucasians. *Eur Respir J* 2017; **50**(3): <https://pubmed.ncbi.nlm.nih.gov/28893868>.
535. Gochicoa-Rangel L, Perez-Padilla R, Vazquez-Garcia JC, et al. Long-Term Stability of a Portable Carbon Monoxide Single-Breath Diffusing Capacity Instrument. *Respir Care* 2017; **62**(2): 231-5 <https://pubmed.ncbi.nlm.nih.gov/27677305>.
536. Balasubramanian A, MacIntyre NR, Henderson RJ, et al. Diffusing Capacity of Carbon Monoxide in Assessment of COPD. *Chest* 2019; **156**(6): 1111-9 <https://pubmed.ncbi.nlm.nih.gov/31352035>.
537. Elbehairy AF, O'Donnell CD, Abd Elhameed A, et al. Low resting diffusion capacity, dyspnea, and exercise intolerance in chronic obstructive pulmonary disease. *J Appl Physiol (1985)* 2019; **127**(4): 1107-16 <https://pubmed.ncbi.nlm.nih.gov/31369329>.
538. Farkhooy A, Janson C, Arnardottir RH, Malinowski A, Emtner M, Hedenstrom H. Impaired carbon monoxide diffusing capacity is the strongest predictor of exercise intolerance in COPD. *COPD* 2013; **10**(2): 180-5 <https://pubmed.ncbi.nlm.nih.gov/23547629>.
539. Balasubramanian A, Putcha N, MacIntyre NR, et al. Diffusing Capacity and Mortality in Chronic Obstructive Pulmonary Disease. *Ann Am Thorac Soc* 2023; **20**(1): 38-46 <https://pubmed.ncbi.nlm.nih.gov/35969416>.
540. Boutou AK, Shrikrishna D, Tanner RJ, et al. Lung function indices for predicting mortality in COPD. *Eur Respir J* 2013; **42**(3): 616-25 <https://pubmed.ncbi.nlm.nih.gov/23349449>.
541. de-Torres JP, O'Donnell DE, Marin JM, et al. Clinical and Prognostic Impact of Low Diffusing Capacity for Carbon Monoxide Values in Patients With Global Initiative for Obstructive Lung Disease I COPD. *Chest* 2021; **160**(3): 872-8 <https://pubmed.ncbi.nlm.nih.gov/33901498>.
542. Haruna A, Muro S, Nakano Y, et al. CT scan findings of emphysema predict mortality in COPD. *Chest* 2010; **138**(3): 635-40 <https://pubmed.ncbi.nlm.nih.gov/20382712>.
543. Balasubramanian A, Gearhart AS, Putcha N, et al. Diffusing Capacity as a Predictor of Hospitalizations in a Clinical Cohort of Chronic Obstructive Pulmonary Disease. *Ann Am Thorac Soc* 2024; **21**(2): 243-50 <https://pubmed.ncbi.nlm.nih.gov/37870393>.
544. Ferguson MK, Gaisert HA, Grab JD, Sheng S. Pulmonary complications after lung resection in the absence of chronic obstructive pulmonary disease: the predictive role of diffusing capacity. *J Thorac Cardiovasc Surg* 2009; **138**(6): 1297-302 <https://pubmed.ncbi.nlm.nih.gov/19783010>.
545. Harvey BG, Strulovici-Barel Y, Kaner RJ, et al. Risk of COPD with obstruction in active smokers with normal spirometry and reduced diffusion capacity. *Eur Respir J* 2015; **46**(6): 1589-97 <https://pubmed.ncbi.nlm.nih.gov/26541521>.
546. Casanova C, Gonzalez-Davila E, Martinez-Gonzalez C, et al. Natural Course of the Diffusing Capacity of the Lungs for Carbon Monoxide in COPD: Importance of Sex. *Chest* 2021; **160**(2): 481-90 <https://pubmed.ncbi.nlm.nih.gov/33878339>.
547. Kang J, Oh YM, Lee JH, et al. Distinctive patterns of pulmonary function change according to baseline lung volume and diffusing capacity. *Int J Tuberc Lung Dis* 2020; **24**(6): 597-605 <https://pubmed.ncbi.nlm.nih.gov/32553011>.
548. Lacasse Y, Theriault S, St-Pierre B, et al. Oximetry neither to prescribe long-term oxygen therapy nor to screen for severe hypoxaemia. *ERJ Open Res* 2021; **7**(4): <https://pubmed.ncbi.nlm.nih.gov/34671670>.
549. Scioscia G, Blanco I, Arismendi E, et al. Different dyspnoea perception in COPD patients with frequent and infrequent exacerbations. *Thorax* 2017; **72**(2): 117-21 <https://pubmed.ncbi.nlm.nih.gov/27586869>.
550. Durheim MT, Smith PJ, Babyak MA, et al. Six-minute-walk distance and accelerometry predict outcomes in chronic obstructive pulmonary disease independent of Global Initiative for Chronic Obstructive Lung Disease 2011 Group. *Ann Am Thorac Soc* 2015; **12**(3): 349-56 <https://pubmed.ncbi.nlm.nih.gov/25568929>.
551. Pinto-Plata VM, Cote C, Cabral H, Taylor J, Celli BR. The 6-min walk distance: change over time and value as a predictor of survival in severe COPD. *Eur Respir J* 2004; **23**(1): 28-33 <https://pubmed.ncbi.nlm.nih.gov/14738227>.
552. Oga T, Nishimura K, Tsukino M, Sato S, Hajiro T. Analysis of the factors related to mortality in chronic obstructive pulmonary disease: role of exercise capacity and health status. *Am J Respir Crit Care Med* 2003; **167**(4): 544-9 <https://pubmed.ncbi.nlm.nih.gov/12446268>.
553. Polkey MI, Spruit MA, Edwards LD, et al. Six-minute-walk test in chronic obstructive pulmonary disease: minimal clinically important difference for death or hospitalization. *Am J Respir Crit Care Med* 2013; **187**(4): 382-6 <https://pubmed.ncbi.nlm.nih.gov/23262518>.

554. Celli B, Tetzlaff K, Criner G, et al. The 6-Minute-Walk Distance Test as a Chronic Obstructive Pulmonary Disease Stratification Tool. Insights from the COPD Biomarker Qualification Consortium. *Am J Respir Crit Care Med* 2016; **194**(12): 1483-93 <https://pubmed.ncbi.nlm.nih.gov/27332504>.
555. Revill SM, Morgan MD, Singh SJ, Williams J, Hardman AE. The endurance shuttle walk: a new field test for the assessment of endurance capacity in chronic obstructive pulmonary disease. *Thorax* 1999; **54**(3): 213-22 <https://pubmed.ncbi.nlm.nih.gov/10325896>.
556. Casanova C, Cote CG, Marin JM, et al. The 6-min walking distance: long-term follow up in patients with COPD. *Eur Respir J* 2007; **29**(3): 535-40 <https://pubmed.ncbi.nlm.nih.gov/17107991>.
557. Puente-Maestu L, Palange P, Casaburi R, et al. Use of exercise testing in the evaluation of interventional efficacy: an official ERS statement. *Eur Respir J* 2016; **47**(2): 429-60 <https://pubmed.ncbi.nlm.nih.gov/26797036>.
558. Beekman E, Mesters I, Hendriks EJ, et al. Course length of 30 metres versus 10 metres has a significant influence on six-minute walk distance in patients with COPD: an experimental crossover study. *J Physiother* 2013; **59**(3): 169-76 <https://pubmed.ncbi.nlm.nih.gov/23896332>.
559. Waschki B, Kirsten A, Holz O, et al. Physical activity is the strongest predictor of all-cause mortality in patients with COPD: a prospective cohort study. *Chest* 2011; **140**(2): 331-42 <https://pubmed.ncbi.nlm.nih.gov/21273294>.
560. Klooster K, ten Hacken NH, Hartman JE, Kerstjens HA, van Rikooft EM, Slebos DJ. Endobronchial Valves for Emphysema without Interlobar Collateral Ventilation. *N Engl J Med* 2015; **373**(24): 2325-35 <https://pubmed.ncbi.nlm.nih.gov/26650153>.
561. Ezponda A, Casanova C, Divo M, et al. Chest CT-assessed comorbidities and all-cause mortality risk in COPD patients in the BODE cohort. *Respirology* 2022; **27**(4): 286-93 <https://pubmed.ncbi.nlm.nih.gov/35132732>.
562. Gu S, Leader J, Zheng B, et al. Direct assessment of lung function in COPD using CT densitometric measures. *Physiol Meas* 2014; **35**(5): 833-45 <https://pubmed.ncbi.nlm.nih.gov/24710855>.
563. Han MK, Kazerooni EA, Lynch DA, et al. Chronic obstructive pulmonary disease exacerbations in the COPDGen study: associated radiologic phenotypes. *Radiology* 2011; **261**(1): 274-82 <https://pubmed.ncbi.nlm.nih.gov/21788524>.
564. Vestbo J, Edwards LD, Scanlon PD, et al. Changes in forced expiratory volume in 1 second over time in COPD. *N Engl J Med* 2011; **365**(13): 1184-92 <https://pubmed.ncbi.nlm.nih.gov/21991892>.
565. Martinez-Garcia MA, de la Rosa-Carrillo D, Soler-Cataluna JJ, et al. Bronchial Infection and Temporal Evolution of Bronchiectasis in Patients With Chronic Obstructive Pulmonary Disease. *Clin Infect Dis* 2021; **72**(3): 403-10 <https://pubmed.ncbi.nlm.nih.gov/31967312>.
566. Martinez CH, Chen YH, Westgate PM, et al. Relationship between quantitative CT metrics and health status and BODE in chronic obstructive pulmonary disease. *Thorax* 2012; **67**(5): 399-406 <https://pubmed.ncbi.nlm.nih.gov/22514236>.
567. Nakano Y, Wong JC, de Jong PA, et al. The prediction of small airway dimensions using computed tomography. *Am J Respir Crit Care Med* 2005; **171**(2): 142-6 <https://pubmed.ncbi.nlm.nih.gov/15516531>.
568. Galban CJ, Han MK, Boes JL, et al. Computed tomography-based biomarker provides unique signature for diagnosis of COPD phenotypes and disease progression. *Nat Med* 2012; **18**(11): 1711-5 <https://pubmed.ncbi.nlm.nih.gov/23042237>.
569. Vasilescu DM, Martinez FJ, Marchetti N, et al. Noninvasive Imaging Biomarker Identifies Small Airway Damage in Severe Chronic Obstructive Pulmonary Disease. *Am J Respir Crit Care Med* 2019; **200**(5): 575-81 <https://pubmed.ncbi.nlm.nih.gov/30794432>.
570. Bhatt SP, Soler X, Wang X, et al. Association between Functional Small Airway Disease and FEV1 Decline in Chronic Obstructive Pulmonary Disease. *Am J Respir Crit Care Med* 2016; **194**(2): 178-84 <https://pubmed.ncbi.nlm.nih.gov/26808615>.
571. Hatabu H, Hunninghake GM, Richeldi L, et al. Interstitial lung abnormalities detected incidentally on CT: a Position Paper from the Fleischner Society. *Lancet Respir Med* 2020; **8**(7): 726-37 <https://pubmed.ncbi.nlm.nih.gov/32649920>.
572. Rose JA, Menon AA, Hino T, et al. Suspected Interstitial Lung Disease in COPDGen Study. *Am J Respir Crit Care Med* 2023; **207**(1): 60-8 <https://pubmed.ncbi.nlm.nih.gov/35930450>.
573. Ash SY, Choi B, Oh A, Lynch DA, Humphries SM. Deep Learning Assessment of Progression of Emphysema and Fibrotic Interstitial Lung Abnormality. *Am J Respir Crit Care Med* 2023; **208**(6): 666-75 <https://pubmed.ncbi.nlm.nih.gov/37364281>.
574. Putman RK, Gudmundsson G, Axelsson GT, et al. Imaging Patterns Are Associated with Interstitial Lung Abnormality Progression and Mortality. *Am J Respir Crit Care Med* 2019; **200**(2): 175-83 <https://pubmed.ncbi.nlm.nih.gov/30673508>.
575. WHO meeting participants. Alpha 1-antitrypsin deficiency: memorandum from a WHO meeting. *Bull World Health Organ* 1997; **75**(5): 397-415 <https://pubmed.ncbi.nlm.nih.gov/9447774>.
576. Miravittles M, Dirksen A, Ferrarotti I, et al. European Respiratory Society statement: diagnosis and treatment of pulmonary disease in alpha(1)-antitrypsin deficiency. *Eur Respir J* 2017; **50**(5): <https://pubmed.ncbi.nlm.nih.gov/29191952>.
577. Parr DG, Stoel BC, Stolk J, Stockley RA. Pattern of emphysema distribution in alpha1-antitrypsin deficiency influences lung function impairment. *Am J Respir Crit Care Med* 2004; **170**(11): 1172-8 <https://pubmed.ncbi.nlm.nih.gov/15306534>.
578. Guerra B, Haile SR, Lamprecht B, et al. Large-scale external validation and comparison of prognostic models: an application to chronic obstructive pulmonary disease. *BMC Med* 2018; **16**(1): 33 <https://pubmed.ncbi.nlm.nih.gov/29495970>.

579. Celli BR, Cote CG, Marin JM, et al. The body-mass index, airflow obstruction, dyspnea, and exercise capacity index in chronic obstructive pulmonary disease. *N Engl J Med* 2004; **350**(10): 1005-12
<https://pubmed.ncbi.nlm.nih.gov/14999112>.
580. Jones RC, Donaldson GC, Chavannes NH, et al. Derivation and validation of a composite index of severity in chronic obstructive pulmonary disease: the DOSE Index. *Am J Respir Crit Care Med* 2009; **180**(12): 1189-95
<https://pubmed.ncbi.nlm.nih.gov/19797160>.
581. Puhan MA, Garcia-Aymerich J, Frey M, et al. Expansion of the prognostic assessment of patients with chronic obstructive pulmonary disease: the updated BODE index and the ADO index. *Lancet* 2009; **374**(9691): 704-11
<https://pubmed.ncbi.nlm.nih.gov/19716962>.
582. Stockley RA, Halpin DMG, Celli BR, Singh D. Chronic Obstructive Pulmonary Disease Biomarkers and Their Interpretation. *Am J Respir Crit Care Med* 2019; **199**(10): 1195-204 <https://pubmed.ncbi.nlm.nih.gov/30592902>.
583. Agusti A, Bel E, Thomas M, et al. Treatable traits: toward precision medicine of chronic airway diseases. *Eur Respir J* 2016; **47**(2): 410-9 <https://pubmed.ncbi.nlm.nih.gov/26828055>.
584. Agusti A, Fabbri LM, Singh D, et al. Inhaled corticosteroids in COPD: friend or foe? *Eur Respir J* 2018; **52**(6): 1801219
<https://pubmed.ncbi.nlm.nih.gov/30190269>.
585. Montes de Oca M. Smoking Cessation/Vaccinations. *Clin Chest Med* 2020; **41**(3): 495-512
<https://pubmed.ncbi.nlm.nih.gov/32800202>.
586. Willemse BW, Postma DS, Timens W, ten Hacken NH. The impact of smoking cessation on respiratory symptoms, lung function, airway hyperresponsiveness and inflammation. *Eur Respir J* 2004; **23**(3): 464-76
<https://pubmed.ncbi.nlm.nih.gov/15065840>.
587. Bauer CMT, Morissette MC, Stampfli MR. The influence of cigarette smoking on viral infections: translating bench science to impact COPD pathogenesis and acute exacerbations of COPD clinically. *Chest* 2013; **143**(1): 196-206
<https://pubmed.ncbi.nlm.nih.gov/23276842>.
588. Crowley TJ, Macdonald MJ, Walter MI. Behavioral anti-smoking trial in chronic obstructive pulmonary disease patients. *Psychopharmacology (Berl)* 1995; **119**(2): 193-204 <https://pubmed.ncbi.nlm.nih.gov/7659767>.
589. Jimenez-Ruiz CA, Masa F, Miravittles M, et al. Smoking characteristics: differences in attitudes and dependence between healthy smokers and smokers with COPD. *Chest* 2001; **119**(5): 1365-70
<https://pubmed.ncbi.nlm.nih.gov/11348940>.
590. Shahab L, Jarvis MJ, Britton J, West R. Prevalence, diagnosis and relation to tobacco dependence of chronic obstructive pulmonary disease in a nationally representative population sample. *Thorax* 2006; **61**(12): 1043-7
<https://pubmed.ncbi.nlm.nih.gov/17040932>.
591. Wagena EJ, Arrindell WA, Wouters EF, van Schayck CP. Are patients with COPD psychologically distressed? *Eur Respir J* 2005; **26**(2): 242-8 <https://pubmed.ncbi.nlm.nih.gov/16055871>.
592. van Eerd EA, van der Meer RM, van Schayck OC, Kotz D. Smoking cessation for people with chronic obstructive pulmonary disease. *Cochrane Database Syst Rev* 2016; **2016**(8): CD010744 <https://pubmed.ncbi.nlm.nih.gov/27545342>.
593. Hoogendoorn M, Feenstra TL, Hoogenveen RT, Rutten-van Molken MP. Long-term effectiveness and cost-effectiveness of smoking cessation interventions in patients with COPD. *Thorax* 2010; **65**(8): 711-8
<https://pubmed.ncbi.nlm.nih.gov/20685746>.
594. Wei X, Guo K, Shang X, et al. Effects of different interventions on smoking cessation in chronic obstructive pulmonary disease patients: A systematic review and network meta-analysis. *Int J Nurs Stud* 2022; **136**: 104362
<https://pubmed.ncbi.nlm.nih.gov/36206617>.
595. Heatherton TF, Kozlowski LT, Frecker RC, Fagerstrom KO. The Fagerstrom Test for Nicotine Dependence: a revision of the Fagerstrom Tolerance Questionnaire. *Br J Addict* 1991; **86**(9): 1119-27 <https://pubmed.ncbi.nlm.nih.gov/1932883>.
596. John U, Meyer C, Schumann A, et al. A short form of the Fagerstrom Test for Nicotine Dependence and the Heaviness of Smoking Index in two adult population samples. *Addict Behav* 2004; **29**(6): 1207-12
<https://pubmed.ncbi.nlm.nih.gov/15236824>.
597. Frazer K, Callinan JE, McHugh J, et al. Legislative smoking bans for reducing harms from secondhand smoke exposure, smoking prevalence and tobacco consumption. *Cochrane Database Syst Rev* 2016; **2**(2): CD005992
<https://pubmed.ncbi.nlm.nih.gov/26842828>.
598. The Tobacco Use and Dependence Clinical Practice Guideline Panel. A clinical practice guideline for treating tobacco use and dependence: A US Public Health Service report. The Tobacco Use and Dependence Clinical Practice Guideline Panel, Staff, and Consortium Representatives. *JAMA* 2000; **283**(24): 3244-54 <https://pubmed.ncbi.nlm.nih.gov/10866874>.
599. The tobacco use and dependence clinical practice guideline panel s, and consortium representatives,. A clinical practice guideline for treating tobacco use and dependence. *JAMA* 2000; **28**: 3244-54
600. Clinical Practice Guideline Treating Tobacco U, Dependence Update Panel L, Staff. A clinical practice guideline for treating tobacco use and dependence: 2008 update. A U.S. Public Health Service report. *Am J Prev Med* 2008; **35**(2): 158-76 <https://pubmed.ncbi.nlm.nih.gov/18617085>.
601. Glynn TJ, Manley M, Smoking T, Cancer P. How to help your patients stop smoking: a National Cancer Institute manual for physicians. [Bethesda, Md.]: Smoking, Tobacco, and Cancer Program, Division of Cancer Prevention and Control, National Cancer Institute, U.S. Dept. of Health and Human Services, Public Health Service, National Institutes of Health; 1990.

602. Stead LF, Buitrago D, Preciado N, Sanchez G, Hartmann-Boyce J, Lancaster T. Physician advice for smoking cessation. *Cochrane Database Syst Rev* 2013; **2013**(5): CD000165 <https://pubmed.ncbi.nlm.nih.gov/23728631>.
603. Strassmann R, Bausch B, Spaar A, Kleijnen J, Braendli O, Puhan MA. Smoking cessation interventions in COPD: a network meta-analysis of randomised trials. *Eur Respir J* 2009; **34**(3): 634-40 <https://pubmed.ncbi.nlm.nih.gov/19357145>.
604. Semenza JC, Rubin CH, Falter KH, et al. Heat-related deaths during the July 1995 heat wave in Chicago. *N Engl J Med* 1996; **335**(2): 84-90 <https://pubmed.ncbi.nlm.nih.gov/8649494>.
605. Tan J, Zheng Y, Song G, Kalkstein LS, Kalkstein AJ, Tang X. Heat wave impacts on mortality in Shanghai, 1998 and 2003. *Int J Biometeorol* 2007; **51**(3): 193-200 <https://pubmed.ncbi.nlm.nih.gov/17039379>.
606. Robine JM, Cheung SL, Le Roy S, et al. Death toll exceeded 70,000 in Europe during the summer of 2003. *C R Biol* 2008; **331**(2): 171-8 <https://pubmed.ncbi.nlm.nih.gov/18241810>.
607. Azhar GS, Mavalankar D, Nori-Sarma A, et al. Heat-related mortality in India: excess all-cause mortality associated with the 2010 Ahmedabad heat wave. *PLoS One* 2014; **9**(3): e91831 <https://pubmed.ncbi.nlm.nih.gov/24633076>.
608. Mazdiyasi O, AghaKouchak A, Davis SJ, et al. Increasing probability of mortality during Indian heat waves. *Sci Adv* 2017; **3**(6): e1700066 <https://pubmed.ncbi.nlm.nih.gov/28630921>.
609. Yoon L, Richardson GRA, Gorman M. Reflections on a Century of Extreme Heat Event-Related Mortality Reporting in Canada. *Geohealth* 2024; **8**(2): e2023GH000895 <https://pubmed.ncbi.nlm.nih.gov/38371353>.
610. Green H, Bailey J, Schwarz L, Vanos J, Ebi K, Benmarhnia T. Impact of heat on mortality and morbidity in low and middle income countries: A review of the epidemiological evidence and considerations for future research. *Environ Res* 2019; **171**: 80-91 <https://pubmed.ncbi.nlm.nih.gov/30660921>.
611. The Eurowinter Group. Cold exposure and winter mortality from ischaemic heart disease, cerebrovascular disease, respiratory disease, and all causes in warm and cold regions of Europe. *Lancet* 1997; **349**(9062): 1341-6 <https://pubmed.ncbi.nlm.nih.gov/9149695>.
612. Curriero FC, Heiner KS, Samet JM, Zeger SL, Strug L, Patz JA. Temperature and mortality in 11 cities of the eastern United States. *Am J Epidemiol* 2002; **155**(1): 80-7 <https://pubmed.ncbi.nlm.nih.gov/11772788>.
613. Braga AL, Zanobetti A, Schwartz J. The effect of weather on respiratory and cardiovascular deaths in 12 U.S. cities. *Environ Health Perspect* 2002; **110**(9): 859-63 <https://pubmed.ncbi.nlm.nih.gov/12204818>.
614. Analitis A, Katsouyanni K, Biggeri A, et al. Effects of cold weather on mortality: results from 15 European cities within the PHEWE project. *Am J Epidemiol* 2008; **168**(12): 1397-408 <https://pubmed.ncbi.nlm.nih.gov/18952849>.
615. Basu R, Samet JM. Relation between elevated ambient temperature and mortality: a review of the epidemiologic evidence. *Epidemiol Rev* 2002; **24**(2): 190-202 <https://pubmed.ncbi.nlm.nih.gov/12762092>.
616. Ye X, Wolff R, Yu W, Vaneckova P, Pan X, Tong S. Ambient temperature and morbidity: a review of epidemiological evidence. *Environ Health Perspect* 2012; **120**(1): 19-28 <https://pubmed.ncbi.nlm.nih.gov/21824855>.
617. Gasparrini A, Guo Y, Hashizume M, et al. Mortality risk attributable to high and low ambient temperature: a multicountry observational study. *Lancet* 2015; **386**(9991): 369-75 <https://pubmed.ncbi.nlm.nih.gov/26003380>.
618. Rocklöv J, Ebi K, Forsberg B. Mortality related to temperature and persistent extreme temperatures: a study of cause-specific and age-stratified mortality. *Occup Environ Med* 2011; **68**(7): 531-6 <https://pubmed.ncbi.nlm.nih.gov/20962034>.
619. Fischer PH, Brunekreef B, Lebreit E. Air pollution related deaths during the 2003 heat wave in the Netherlands. *Atmospheric Environment* 2004; **38**(8): 1083-5
620. Stedman JR. The predicted number of air pollution related deaths in the UK during the August 2003 heatwave. *Atmospheric Environment* 2004; **38**(8): 1087-90
621. Schwartz J. Who is sensitive to extremes of temperature?: A case-only analysis. *Epidemiology* 2005; **16**(1): 67-72 <https://pubmed.ncbi.nlm.nih.gov/15613947>.
622. Davie GS, Baker MG, Hales S, Carlin JB. Trends and determinants of excess winter mortality in New Zealand: 1980 to 2000. *BMC Public Health* 2007; **7**: 263 <https://pubmed.ncbi.nlm.nih.gov/17892590>.
623. Hansel NN, McCormack MC, Kim V. The Effects of Air Pollution and Temperature on COPD. *Copd* 2016; **13**(3): 372-9 <https://pubmed.ncbi.nlm.nih.gov/26683097>.
624. Burkart KG, Brauer M, Aravkin AY, et al. Estimating the cause-specific relative risks of non-optimal temperature on daily mortality: a two-part modelling approach applied to the Global Burden of Disease Study. *Lancet* 2021; **398**(10301): 685-97 <https://pubmed.ncbi.nlm.nih.gov/34419204>.
625. Bai J, Cui J, Yu C. Burden of chronic obstructive pulmonary disease attributable to non-optimal temperature from 1990 to 2019: a systematic analysis from the Global Burden of Disease Study 2019. *Environ Sci Pollut Res Int* 2023; **30**(26): 68836-47 <https://pubmed.ncbi.nlm.nih.gov/37129808>.
626. Lin S, Luo M, Walker RJ, Liu X, Hwang SA, Chinery R. Extreme high temperatures and hospital admissions for respiratory and cardiovascular diseases. *Epidemiology* 2009; **20**(5): 738-46 <https://pubmed.ncbi.nlm.nih.gov/19593155>.
627. Anderson GB, Dominici F, Wang Y, McCormack MC, Bell ML, Peng RD. Heat-related emergency hospitalizations for respiratory diseases in the Medicare population. *Am J Respir Crit Care Med* 2013; **187**(10): 1098-103 <https://pubmed.ncbi.nlm.nih.gov/23491405>.
628. Gronlund CJ, Zanobetti A, Schwartz JD, Wellenius GA, O'Neill MS. Heat, heat waves, and hospital admissions among the elderly in the United States, 1992-2006. *Environ Health Perspect* 2014; **122**(11): 1187-92 <https://pubmed.ncbi.nlm.nih.gov/24905551>.

629. Tseng CM, Chen YT, Ou SM, et al. The effect of cold temperature on increased exacerbation of chronic obstructive pulmonary disease: a nationwide study. *PLoS ONE* 2013; **8**(3): e57066 <https://pubmed.ncbi.nlm.nih.gov/23554858>.
630. Teare J, Mathee A, Naicker N, et al. Dwelling Characteristics Influence Indoor Temperature and May Pose Health Threats in LMICs. *Ann Glob Health* 2020; **86**(1): 91 <https://pubmed.ncbi.nlm.nih.gov/32832385>.
631. Tamerius J, Perzanowski M, Acosta L, et al. Socioeconomic and Outdoor Meteorological Determinants of Indoor Temperature and Humidity in New York City Dwellings. *Weather Clim Soc* 2013; **5**(2): 168-79 <https://pubmed.ncbi.nlm.nih.gov/24077420>.
632. Wallace LA, Emmerich SJ, Howard-Reed C. Continuous measurements of air change rates in an occupied house for 1 year: the effect of temperature, wind, fans, and windows. *J Expo Anal Environ Epidemiol* 2002; **12**(4): 296-306 <https://pubmed.ncbi.nlm.nih.gov/12087436>.
633. White-Newsome JL, Sánchez BN, Jolliet O, et al. Climate change and health: indoor heat exposure in vulnerable populations. *Environ Res* 2012; **112**: 20-7 <https://pubmed.ncbi.nlm.nih.gov/22071034>.
634. Franck U, Krüger M, Schwarz N, Grossmann K, Röder S, Schlink U. Heat stress in urban areas: Indoor and outdoor temperatures in different urban structure types and subjectively reported well-being during a heat wave in the city of Leipzig. *Meteorol Z* 2013; **22**(2): 167-77
635. Wilkinson P, Landon M, Armstrong B, Stevenson S, McKee M. Cold comfort: the social and environmental determinants of excess winter death in England, 1986-1996. York: Joseph Rowntree Foundation; 2001.
636. Donaldson GC, Seemungal T, Jeffries DJ, Wedzicha JA. Effect of temperature on lung function and symptoms in chronic obstructive pulmonary disease. *Eur Respir J* 1999; **13**(4): 844-9
637. Viggers H, Howden-Chapman P, Ingham T, et al. Warm homes for older people: aims and methods of a randomised community-based trial for people with COPD. *BMC Public Health* 2013; **13**: 176 <https://pubmed.ncbi.nlm.nih.gov/23442368>.
638. Scheerens C, Nurhussien L, Aglan A, et al. The impact of personal and outdoor temperature exposure during cold and warm seasons on lung function and respiratory symptoms in COPD. *ERJ Open Res* 2022; **8**(1): <https://pubmed.ncbi.nlm.nih.gov/35295231>.
639. McCormack MC, Paulin LM, Gummerson CE, Peng RD, Diette GB, Hansel NN. Colder temperature is associated with increased COPD morbidity. *Eur Respir J* 2017; **49**(6): <https://pubmed.ncbi.nlm.nih.gov/28663313>.
640. Mu Z, Chen PL, Geng FH, et al. Synergistic effects of temperature and humidity on the symptoms of COPD patients. *Int J Biometeorol* 2017: <https://pubmed.ncbi.nlm.nih.gov/28567499>.
641. Osman LM, Ayres JG, Garden C, Reglitz K, Lyon J, Douglas JG. Home warmth and health status of COPD patients. *Eur J Public Health* 2008; **18**(4): 399-405 <https://pubmed.ncbi.nlm.nih.gov/18367496>.
642. Jacob D, Winner D. Effect of climate change on air quality. *Atmos Environ* 2009; **43**: 51-63
643. De Sario M, Katsouyanni K, Michelozzi P. Climate change, extreme weather events, air pollution and respiratory health in Europe. *Eur Respir J* 2013; **42**(3): 826-43 <https://pubmed.ncbi.nlm.nih.gov/23314896>.
644. Anenberg SC, Haines S, Wang E, Nassikas N, Kinney PL. Synergistic health effects of air pollution, temperature, and pollen exposure: a systematic review of epidemiological evidence. *Environ Health* 2020; **19**(1): 130 <https://pubmed.ncbi.nlm.nih.gov/33287833>.
645. Stafoggia M, Michelozzi P, Schneider A, et al. Joint effect of heat and air pollution on mortality in 620 cities of 36 countries. *Environ Int* 2023; **181**: 108258 <https://pubmed.ncbi.nlm.nih.gov/37837748>.
646. Hansel NN, McCormack MC, Kim V. The Effects of Air Pollution and Temperature on COPD. *COPD* 2015: 1-8 <https://pubmed.ncbi.nlm.nih.gov/26683097>.
647. Basu R, Feng WY, Ostro BD. Characterizing temperature and mortality in nine California counties. *Epidemiology* 2008; **19**(1): 138-45 <https://pubmed.ncbi.nlm.nih.gov/18091422>.
648. Zanobetti A, Schwartz J. Temperature and mortality in nine US cities. *Epidemiology* 2008; **19**(4): 563-70 <https://pubmed.ncbi.nlm.nih.gov/18467963>.
649. Wong CM, Ma S, Hedley AJ, Lam TH. Effect of air pollution on daily mortality in Hong Kong. *Environ Health Perspect* 2001; **109**(4): 335-40 <https://pubmed.ncbi.nlm.nih.gov/11335180>.
650. Zhang Y, Huang W, London SJ, et al. Ozone and daily mortality in Shanghai, China. *Environ Health Perspect* 2006; **114**(8): 1227-32 <https://pubmed.ncbi.nlm.nih.gov/16882530>.
651. Li G, Zhou M, Cai Y, Zhang Y, Pan X. Does temperature enhance acute mortality effects of ambient particle pollution in Tianjin City, China. *Sci Total Environ* 2011; **409**(10): 1811-7 <https://pubmed.ncbi.nlm.nih.gov/21376370>.
652. Analitis A, Michelozzi P, D'Ippoliti D, et al. Effects of heat waves on mortality: effect modification and confounding by air pollutants. *Epidemiology* 2014; **25**(1): 15-22 <https://pubmed.ncbi.nlm.nih.gov/24162013>.
653. Qiu H, Tan K, Long F, et al. The Burden of COPD Morbidity Attributable to the Interaction between Ambient Air Pollution and Temperature in Chengdu, China. *Int J Environ Res Public Health* 2018; **15**(3): <https://pubmed.ncbi.nlm.nih.gov/29534476>.
654. Bell ML, Ebisu K, Peng RD, et al. Seasonal and regional short-term effects of fine particles on hospital admissions in 202 US counties, 1999-2005. *Am J Epidemiol* 2008; **168**(11): 1301-10 <https://pubmed.ncbi.nlm.nih.gov/18854492>.
655. Ko FW, Tam W, Wong TW, et al. Temporal relationship between air pollutants and hospital admissions for chronic obstructive pulmonary disease in Hong Kong. *Thorax* 2007; **62**(9): 780-5 <https://pubmed.ncbi.nlm.nih.gov/17311838>.

656. Ren C, Williams GM, Tong S. Does particulate matter modify the association between temperature and cardiorespiratory diseases? *Environ Health Perspect* 2006; **114**(11): 1690-6 <https://pubmed.ncbi.nlm.nih.gov/17107854>.
657. McCormack MC, Belli AJ, Waugh D, et al. Respiratory Effects of Indoor Heat and the Interaction with Air Pollution in Chronic Obstructive Pulmonary Disease. *Ann Am Thorac Soc* 2016; **13**(12): 2125-31 <https://pubmed.ncbi.nlm.nih.gov/27684429>.
658. World Health Organisation (WHO). WHO Housing and Health Guidelines. Executive summary. Geneva: World Health Organization; 2018.
659. World Health Organisation (WHO). Heat and Health. Geneva: World Health Organisation; 2018.
660. Wongsurakiat P, Maranetra KN, Wasi C, Kositanont U, Dejsomritrutai W, Charoenratanakul S. Acute respiratory illness in patients with COPD and the effectiveness of influenza vaccination: a randomized controlled study. *Chest* 2004; **125**(6): 2011-20 <https://pubmed.ncbi.nlm.nih.gov/15189916>.
661. Zahhar JA, Salamattullah HK, Almutairi MB, et al. Influenza vaccine effect on risk of stroke occurrence: a systematic review and meta-analysis. *Front Neurol* 2023; **14**: 1324677 <https://pubmed.ncbi.nlm.nih.gov/38269000>.
662. Poole PJ, Chacko E, Wood-Baker RW, Cates CJ. Influenza vaccine for patients with chronic obstructive pulmonary disease. *Cochrane Database Syst Rev* 2006; (1): CD002733 <https://pubmed.ncbi.nlm.nih.gov/16437444>.
663. Wongsurakiat P, Lertakyamanee J, Maranetra KN, Jongriratanakul S, Sangkaew S. Economic evaluation of influenza vaccination in Thai chronic obstructive pulmonary disease patients. *J Med Assoc Thai* 2003; **86**(6): 497-508 <https://pubmed.ncbi.nlm.nih.gov/12924797>.
664. Nichol KL, Margolis KL, Wuorenma J, Von Sternberg T. The efficacy and cost effectiveness of vaccination against influenza among elderly persons living in the community. *N Engl J Med* 1994; **331**(12): 778-84 <https://pubmed.ncbi.nlm.nih.gov/8065407>.
665. Fiore AE, Shay DK, Broder K, et al. Prevention and control of seasonal influenza with vaccines: recommendations of the Advisory Committee on Immunization Practices (ACIP), 2009. *MMWR Recomm Rep* 2009; **58**(RR-8): 1-52 <https://pubmed.ncbi.nlm.nih.gov/19644442>.
666. Edwards KM, Dupont WD, Westrich MK, Plummer WD, Jr., Palmer PS, Wright PF. A randomized controlled trial of cold-adapted and inactivated vaccines for the prevention of influenza A disease. *J Infect Dis* 1994; **169**(1): 68-76 <https://pubmed.ncbi.nlm.nih.gov/8277200>.
667. Hak E, van Essen GA, Buskens E, Stalman W, de Melker RA. Is immunising all patients with chronic lung disease in the community against influenza cost effective? Evidence from a general practice based clinical prospective cohort study in Utrecht, The Netherlands. *J Epidemiol Community Health* 1998; **52**(2): 120-5 <https://pubmed.ncbi.nlm.nih.gov/9578860>.
668. Grohskopf LA, Ferdinands JM, Blanton LH, Broder KR, Loehr J. Prevention and Control of Seasonal Influenza with Vaccines: Recommendations of the Advisory Committee on Immunization Practices - United States, 2024-25 Influenza Season. *MMWR Recomm Rep* 2024; **73**(5): 1-25 <https://pubmed.ncbi.nlm.nih.gov/39197095>.
669. Huang CL, Nguyen PA, Kuo PL, Iqbal U, Hsu YH, Jian WS. Influenza vaccination and reduction in risk of ischemic heart disease among chronic obstructive pulmonary elderly. *Comput Methods Programs Biomed* 2013; **111**(2): 507-11 <https://pubmed.ncbi.nlm.nih.gov/23769164>.
670. Kobayashi M, Leidner AJ, Gierke R, et al. Use of 21-Valent Pneumococcal Conjugate Vaccine Among U.S. Adults: Recommendations of the Advisory Committee on Immunization Practices - United States, 2024. *MMWR Morb Mortal Wkly Rep* 2024; **73**(36): 793-8 <https://pubmed.ncbi.nlm.nih.gov/39264843>.
671. Kobayashi M, Pilishvili T, Farrar JL, et al. Pneumococcal Vaccine for Adults Aged \geq 19 Years: Recommendations of the Advisory Committee on Immunization Practices, United States, 2023. *MMWR Recomm Rep* 2023; **72**(3): 1-39 <https://pubmed.ncbi.nlm.nih.gov/37669242>.
672. Walters JA, Smith S, Poole P, Granger RH, Wood-Baker R. Injectable vaccines for preventing pneumococcal infection in patients with chronic obstructive pulmonary disease. *Cochrane Database Syst Rev* 2010; (11): CD001390 <https://pubmed.ncbi.nlm.nih.gov/21069668>.
673. Walters JA, Tang JN, Poole P, Wood-Baker R. Pneumococcal vaccines for preventing pneumonia in chronic obstructive pulmonary disease. *Cochrane Database Syst Rev* 2017; **1**(1): CD001390 <https://pubmed.ncbi.nlm.nih.gov/28116747>.
674. Alfageme I, Vazquez R, Reyes N, et al. Clinical efficacy of anti-pneumococcal vaccination in patients with COPD. *Thorax* 2006; **61**(3): 189-95 <https://pubmed.ncbi.nlm.nih.gov/16227328>.
675. Dransfield MT, Harnden S, Burton RL, et al. Long-term comparative immunogenicity of protein conjugate and free polysaccharide pneumococcal vaccines in chronic obstructive pulmonary disease. *Clin Infect Dis* 2012; **55**(5): e35-44 <https://pubmed.ncbi.nlm.nih.gov/22652582>.
676. Bonten MJ, Huijts SM, Bolkenbaas M, et al. Polysaccharide conjugate vaccine against pneumococcal pneumonia in adults. *N Engl J Med* 2015; **372**(12): 1114-25 <https://pubmed.ncbi.nlm.nih.gov/25785969>.
677. Platt H, Omole T, Cardona J, et al. Safety, tolerability, and immunogenicity of a 21-valent pneumococcal conjugate vaccine, V116, in healthy adults: phase 1/2, randomised, double-blind, active comparator-controlled, multicentre, US-based trial. *Lancet Infect Dis* 2023; **23**(2): 233-46 <https://pubmed.ncbi.nlm.nih.gov/36116461>.
678. Ignatova GL, Avdeev SN, Antonov VN. Comparative effectiveness of pneumococcal vaccination with PPV23 and PCV13 in COPD patients over a 5-year follow-up cohort study. *Sci Rep* 2021; **11**(1): 15948 <https://pubmed.ncbi.nlm.nih.gov/34354113>.

679. Ofori-Anyinam O, Leroux-Roels G, Drame M, et al. Immunogenicity and safety of an inactivated quadrivalent influenza vaccine co-administered with a 23-valent pneumococcal polysaccharide vaccine versus separate administration, in adults ≥ 50 years of age: Results from a phase III, randomized, non-inferiority trial. *Vaccine* 2017; **35**(46): 6321-8 <https://pubmed.ncbi.nlm.nih.gov/28987445>.
680. Cong B, Dighero I, Zhang T, Chung A, Nair H, Li Y. Understanding the age spectrum of respiratory syncytial virus associated hospitalisation and mortality burden based on statistical modelling methods: a systematic analysis. *BMC Med* 2023; **21**(1): 224 <https://pubmed.ncbi.nlm.nih.gov/37365569>.
681. Melgar M, Britton A, Roper LE, et al. Use of Respiratory Syncytial Virus Vaccines in Older Adults: Recommendations of the Advisory Committee on Immunization Practices - United States, 2023. *MMWR Morb Mortal Wkly Rep* 2023; **72**(29): 793-801 <https://pubmed.ncbi.nlm.nih.gov/37471262>.
682. Woodruff RC, Melgar M, Pham H, et al. Acute Cardiac Events in Hospitalized Older Adults With Respiratory Syncytial Virus Infection. *JAMA Intern Med* 2024; **184**(6): 602-11 <https://pubmed.ncbi.nlm.nih.gov/38619857>.
683. Wiseman DJ, Thwaites RS, Ritchie AI, et al. RSV-related Community COPD Exacerbations and Novel Diagnostics: A Binational Prospective Cohort Study. *Am J Respir Crit Care Med* 2024; <https://pubmed.ncbi.nlm.nih.gov/38502541>.
684. Walsh EE, Perez Marc G, Zareba AM, et al. Efficacy and Safety of a Bivalent RSV Prefusion F Vaccine in Older Adults. *N Engl J Med* 2023; **388**(16): 1465-77 <https://pubmed.ncbi.nlm.nih.gov/37018468>.
685. Papi A, Ison MG, Langley JM, et al. Respiratory Syncytial Virus Prefusion F Protein Vaccine in Older Adults. *N Engl J Med* 2023; **388**(7): 595-608 <https://pubmed.ncbi.nlm.nih.gov/36791160>.
686. Britton A, Roper LE, Kotton CN, et al. Use of Respiratory Syncytial Virus Vaccines in Adults Aged ≥ 60 Years: Updated Recommendations of the Advisory Committee on Immunization Practices - United States, 2024. *MMWR Morb Mortal Wkly Rep* 2024; **73**(32): 696-702 <https://pubmed.ncbi.nlm.nih.gov/39146277>.
687. Ison MG, Papi A, Athan E, et al. Efficacy and Safety of Respiratory Syncytial Virus (RSV) Prefusion F Protein Vaccine (RSVPreF3 OA) in Older Adults Over 2 RSV Seasons. *Clin Infect Dis* 2024; **78**(6): 1732-44 <https://pubmed.ncbi.nlm.nih.gov/38253338>.
688. Surie D, Self WH, Zhu Y, et al. RSV Vaccine Effectiveness Against Hospitalization Among US Adults 60 Years and Older. *Jama* 2024; **332**(13): 1105-7 <https://pubmed.ncbi.nlm.nih.gov/39230920>.
689. Hause AM, Moro PL, Baggs J, et al. Early Safety Findings Among Persons Aged ≥ 60 Years Who Received a Respiratory Syncytial Virus Vaccine - United States, May 3, 2023-April 14, 2024. *MMWR Morb Mortal Wkly Rep* 2024; **73**(21): 489-94 <https://pubmed.ncbi.nlm.nih.gov/38814851>.
690. Naeger S, Pool V, Macina D. Increased Burden of Pertussis Among Adolescents and Adults With Asthma or COPD in the United States, 2007 to 2019. *Chest* 2024; **165**(6): 1352-61 <https://pubmed.ncbi.nlm.nih.gov/38128608>.
691. Centers for Disease Control and Prevention Mortality and Morbidity Weekly Report. Use of Tetanus Toxoid, Reduced Diphtheria Toxoid, and Acellular Pertussis Vaccines: Updated Recommendations of the Advisory Committee on Immunization Practices — United States, 2019, online article available here: <https://www.cdc.gov/mmwr/volumes/69/wr/mm6903a5.htm> [accessed Oct 2024].
692. Centers for Disease Control and Prevention. Lung Disease including Asthma and Adult Vaccination, online information available here: <https://www.cdc.gov/vaccines-adults/recommended-vaccines/> [accessed Oct 2024].
693. Thompson MG, Stenehjem E, Grannis S, et al. Effectiveness of Covid-19 Vaccines in Ambulatory and Inpatient Care Settings. *N Engl J Med* 2021; **385**(15): 1355-71 <https://pubmed.ncbi.nlm.nih.gov/34496194>.
694. Kwok WC, Leung SHI, Tam TCC, et al. Efficacy of mRNA and Inactivated Whole Virus Vaccines Against COVID-19 in Patients with Chronic Respiratory Diseases. *Int J Chron Obstruct Pulmon Dis* 2023; **18**: 47-56 <https://pubmed.ncbi.nlm.nih.gov/36698687>.
695. Maltais F, Bjermer L, Kerwin EM, et al. Efficacy of umeclidinium/vilanterol versus umeclidinium and salmeterol monotherapies in symptomatic patients with COPD not receiving inhaled corticosteroids: the EMAX randomised trial. *Respir Res* 2019; **20**(1): 238 <https://pubmed.ncbi.nlm.nih.gov/31666084>.
696. Lange P, Marott JL, Vestbo J, et al. Prediction of the clinical course of chronic obstructive pulmonary disease, using the new GOLD classification: a study of the general population. *Am J Respir Crit Care Med* 2012; **186**(10): 975-81 <https://pubmed.ncbi.nlm.nih.gov/22997207>.
697. Agusti A, Edwards LD, Celli B, et al. Characteristics, stability and outcomes of the 2011 GOLD COPD groups in the ECLIPSE cohort. *Eur Respir J* 2013; **42**(3): 636-46 <https://pubmed.ncbi.nlm.nih.gov/23766334>.
698. Oba Y, Keeney E, Ghatehorde N, Dias S. Dual combination therapy versus long-acting bronchodilators alone for chronic obstructive pulmonary disease (COPD): a systematic review and network meta-analysis. *Cochrane Database Syst Rev* 2018; **12**(12): CD012620 <https://pubmed.ncbi.nlm.nih.gov/30521694>.
699. Rabe KF, Martinez FJ, Ferguson GT, et al. Triple Inhaled Therapy at Two Glucocorticoid Doses in Moderate-to-Very-Severe COPD. *N Engl J Med* 2020; **383**(1): 35-48 <https://pubmed.ncbi.nlm.nih.gov/32579807>.
700. Bhatt SP, Rabe KF, Hanania NA, et al. Dupilumab for COPD with Blood Eosinophil Evidence of Type 2 Inflammation. *N Engl J Med* 2024; **390**(24): 2274-83 <https://pubmed.ncbi.nlm.nih.gov/38767614>.
701. Bhatt SP, Rabe KF, Hanania NA, et al. Dupilumab for COPD with Type 2 Inflammation Indicated by Eosinophil Counts. *N Engl J Med* 2023; **389**(3): 205-14 <https://pubmed.ncbi.nlm.nih.gov/37272521>.
702. Fieldes M, Bourguignon C, Assou S, et al. Targeted therapy in eosinophilic chronic obstructive pulmonary disease. *ERJ Open Res* 2021; **7**(2): <https://pubmed.ncbi.nlm.nih.gov/33855061>.

703. Karner C, Cates CJ. Long-acting beta(2)-agonist in addition to tiotropium versus either tiotropium or long-acting beta(2)-agonist alone for chronic obstructive pulmonary disease. *Cochrane Database Syst Rev* 2012; **4**(4): CD008989 <https://pubmed.ncbi.nlm.nih.gov/22513969>.
704. Albert RK, Connett J, Bailey WC, et al. Azithromycin for prevention of exacerbations of COPD. *N Engl J Med* 2011; **365**(8): 689-98 <https://pubmed.ncbi.nlm.nih.gov/21864166>.
705. Han MK, Tayob N, Murray S, et al. Predictors of chronic obstructive pulmonary disease exacerbation reduction in response to daily azithromycin therapy. *Am J Respir Crit Care Med* 2014; **189**(12): 1503-8 <https://pubmed.ncbi.nlm.nih.gov/24779680>.
706. Martinez FJ, Calverley PM, Goehring UM, Brose M, Fabbri LM, Rabe KF. Effect of roflumilast on exacerbations in patients with severe chronic obstructive pulmonary disease uncontrolled by combination therapy (REACT): a multicentre randomised controlled trial. *Lancet* 2015; **385**(9971): 857-66 <https://pubmed.ncbi.nlm.nih.gov/25684586>.
707. Martinez FJ, Rabe KF, Sethi S, et al. Effect of Roflumilast and Inhaled Corticosteroid/Long-Acting Beta-2-Agonist on Chronic Obstructive Pulmonary Disease Exacerbations (RE2SPOND) A Randomized Clinical Trial. *Am J Respir Crit Care Med* 2016; **194**(5): 559-67
708. Rabe KF, Calverley PMA, Martinez FJ, Fabbri LM. Effect of roflumilast in patients with severe COPD and a history of hospitalisation. *Eur Respir J* 2017; **50**(1): <https://pubmed.ncbi.nlm.nih.gov/28679611>.
709. Chapman KR, Hurst JR, Frent SM, et al. Long-Term Triple Therapy De-escalation to Indacaterol/Glycopyrronium in Patients with Chronic Obstructive Pulmonary Disease (SUNSET): A Randomized, Double-Blind, Triple-Dummy Clinical Trial. *Am J Respir Crit Care Med* 2018; **198**(3): 329-39 <https://pubmed.ncbi.nlm.nih.gov/29779416>.
710. Calverley PMA, Tetzlaff K, Vogelmeier C, et al. Eosinophilia, Frequent Exacerbations, and Steroid Response in Chronic Obstructive Pulmonary Disease. *Am J Respir Crit Care Med* 2017; **196**(9): 1219-21 <https://pubmed.ncbi.nlm.nih.gov/28306321>.
711. Capstick T, Attack K, The Leeds Teaching Hospitals NHS Trust. The Leeds Inhaler Device Guide: Inhaler Technique Instructions for Healthcare Professionals and Patients. 1st Edition. Available at <https://cpe.org.uk/wp-content/uploads/2016/02/90445-Inhaler-Device-Guide.pdf> [accessed Oct 2024]. 2018:
712. Laube BL, Janssens HM, de Jongh FH, et al. What the pulmonary specialist should know about the new inhalation therapies. *Eur Respir J* 2011; **37**(6): 1308-31 <https://pubmed.ncbi.nlm.nih.gov/21310878>.
713. Asthma + Lung UK. Using your inhalers. Available at <https://www.asthma.org.uk/advice/inhalers-medicines-treatments/using-inhalers/> [accessed Oct 2024].
714. Janknegt R, Kooistra J, Metting E, Dekhuijzen R. Rational selection of inhalation devices in the treatment of chronic obstructive pulmonary disease by means of the System of Objectified Judgement Analysis (SOJA). *Eur J Hosp Pharm* 2021; **28**(2): e4 <https://pubmed.ncbi.nlm.nih.gov/32920532>.
715. Ciciliani AM, Langguth P, Wachtel H. Handling forces for the use of different inhaler devices. *Int J Pharm* 2019; **560**: 315-21 <https://pubmed.ncbi.nlm.nih.gov/30711617>.
716. Klijn SL, Hiligsmann M, Evers S, Roman-Rodriguez M, van der Molen T, van Boven JFM. Effectiveness and success factors of educational inhaler technique interventions in asthma & COPD patients: a systematic review. *NPJ Prim Care Respir Med* 2017; **27**(1): 24 <https://pubmed.ncbi.nlm.nih.gov/28408742>.
717. Pernigotti D, Stonham C, Panigone S, et al. Reducing carbon footprint of inhalers: analysis of climate and clinical implications of different scenarios in five European countries. *BMJ Open Respir Res* 2021; **8**(1): <https://pubmed.ncbi.nlm.nih.gov/34872967>.
718. Carpenter DM, Roberts CA, Sage AJ, George J, Horne R. A Review of Electronic Devices to Assess Inhaler Technique. *Curr Allergy Asthma Rep* 2017; **17**(3): 17 <https://pubmed.ncbi.nlm.nih.gov/28290015>.
719. Chan AH, Harrison J, Black PN, Mitchell EA, Foster JM. Using electronic monitoring devices to measure inhaler adherence: a practical guide for clinicians. *J Allergy Clin Immunol Pract* 2015; **3**(3): 335-49 e1-5 <https://pubmed.ncbi.nlm.nih.gov/25840665>.
720. Bowler R, Allinder M, Jacobson S, et al. Real-world use of rescue inhaler sensors, electronic symptom questionnaires and physical activity monitors in COPD. *BMJ Open Respir Res* 2019; **6**(1): e000350 <https://pubmed.ncbi.nlm.nih.gov/30956796>.
721. J WHK, Wouters H, Bosnic-Anticevich S, et al. Factors associated with health status and exacerbations in COPD maintenance therapy with dry powder inhalers. *NPJ Prim Care Respir Med* 2022; **32**(1): 18 <https://pubmed.ncbi.nlm.nih.gov/35618739>.
722. Clark AR, Weers JG, Dhand R. The Confusing World of Dry Powder Inhalers: It Is All About Inspiratory Pressures, Not Inspiratory Flow Rates. *J Aerosol Med Pulm Drug Deliv* 2020; **33**(1): 1-11 <https://pubmed.ncbi.nlm.nih.gov/31613682>.
723. Mahler DA, Halpin DMG. Peak Inspiratory Flow as a Predictive Therapeutic Biomarker in COPD. *Chest* 2021; **160**(2): 491-8 <https://pubmed.ncbi.nlm.nih.gov/33812852>.
724. Leving MT, van Boven JFM, Bosnic-Anticevich SZ, et al. Suboptimal Peak Inspiratory Flow and Critical Inhalation Errors are Associated with Higher COPD-Related Healthcare Costs. *Int J Chron Obstruct Pulmon Dis* 2022; **17**: 2401-15 <https://pubmed.ncbi.nlm.nih.gov/36185173>.
725. Halpin DMG, Worsley S, Ismaila AS, et al. INTREPID: single- versus multiple-inhaler triple therapy for COPD in usual clinical practice. *ERJ Open Res* 2021; **7**(2): 00950-2020 <https://pubmed.ncbi.nlm.nih.gov/34109236>.

726. Souza ML, Meneghini AC, Ferraz E, Vianna EO, Borges MC. Knowledge of and technique for using inhalation devices among asthma patients and COPD patients. *J Bras Pneumol* 2009; **35**(9): 824-31 <https://pubmed.ncbi.nlm.nih.gov/19820807>.
727. Melani AS, Bonavia M, Cilenti V, et al. Inhaler mishandling remains common in real life and is associated with reduced disease control. *Respir Med* 2011; **105**(6): 930-8 <https://pubmed.ncbi.nlm.nih.gov/21367593>.
728. Sanchis J, Gich I, Pedersen S, Aerosol Drug Management Improvement T. Systematic Review of Errors in Inhaler Use: Has Patient Technique Improved Over Time? *Chest* 2016; **150**(2): 394-406 <https://pubmed.ncbi.nlm.nih.gov/27060726>.
729. Cho-Reyes S, Celli BR, Dembek C, Yeh K, Navaie M. Inhalation Technique Errors with Metered-Dose Inhalers Among Patients with Obstructive Lung Diseases: A Systematic Review and Meta-Analysis of U.S. Studies. *Chronic Obstr Pulm Dis* 2019; **6**(3): 267-80 <https://pubmed.ncbi.nlm.nih.gov/31342732>.
730. van der Palen J, Klein JJ, Schildkamp AM. Comparison of a new multidose powder inhaler (Diskus/Accuhaler) and the Turbuhaler regarding preference and ease of use. *J Asthma* 1998; **35**(2): 147-52 <https://pubmed.ncbi.nlm.nih.gov/9576140>.
731. van der Palen J, van der Valk P, Goosens M, Groothuis-Oudshoorn K, Brusse-Keizer M. A randomised cross-over trial investigating the ease of use and preference of two dry powder inhalers in patients with asthma or chronic obstructive pulmonary disease. *Expert Opin Drug Deliv* 2013; **10**(9): 1171-8 <https://pubmed.ncbi.nlm.nih.gov/23815552>.
732. Van Der Palen J, Eijsvogel MM, Kuipers BF, Schipper M, Vermue NA. Comparison of the Diskus inhaler and the Handihaler regarding preference and ease of use. *J Aerosol Med* 2007; **20**(1): 38-44 <https://pubmed.ncbi.nlm.nih.gov/17388751>.
733. van der Palen J, Klein JJ, Kerkhoff AH, van Herwaarden CL. Evaluation of the effectiveness of four different inhalers in patients with chronic obstructive pulmonary disease. *Thorax* 1995; **50**(11): 1183-7 <https://pubmed.ncbi.nlm.nih.gov/8553275>.
734. van der Palen J, Ginko T, Kroker A, et al. Preference, satisfaction and errors with two dry powder inhalers in patients with COPD. *Expert Opin Drug Deliv* 2013; **10**(8): 1023-31 <https://pubmed.ncbi.nlm.nih.gov/23745954>.
735. Pascual S, Feimer J, De Soyza A, et al. Preference, satisfaction and critical errors with Genuair and Breezhaler inhalers in patients with COPD: a randomised, cross-over, multicentre study. *NPJ Prim Care Respir Med* 2015; **25**: 15018 <https://pubmed.ncbi.nlm.nih.gov/25927321>.
736. Yawn BP, Colice GL, Hodder R. Practical aspects of inhaler use in the management of chronic obstructive pulmonary disease in the primary care setting. *Int J Chron Obstruct Pulmon Dis* 2012; **7**: 495-502 <https://pubmed.ncbi.nlm.nih.gov/22888221>.
737. Sulaiman I, Cushen B, Greene G, et al. Objective Assessment of Adherence to Inhalers by Patients with Chronic Obstructive Pulmonary Disease. *Am J Respir Crit Care Med* 2017; **195**(10): 1333-43 <https://pubmed.ncbi.nlm.nih.gov/27409253>.
738. Clark B, Wells BJ, Saha AK, et al. Low Peak Inspiratory Flow Rates are Common Among COPD Inpatients and are Associated with Increased Healthcare Resource Utilization: A Retrospective Cohort Study. *Int J Chron Obstruct Pulmon Dis* 2022; **17**: 1483-94 <https://pubmed.ncbi.nlm.nih.gov/35791340>.
739. Barbara S, Kritikos V, Bosnic-Anticevich S. Inhaler technique: does age matter? A systematic review. *Eur Respir Rev* 2017; **26**(146): <https://pubmed.ncbi.nlm.nih.gov/29212836>.
740. Gray SL, Williams DM, Pulliam CC, Sirgo MA, Bishop AL, Donohue JF. Characteristics predicting incorrect metered-dose inhaler technique in older subjects. *Arch Intern Med* 1996; **156**(9): 984-8 <https://pubmed.ncbi.nlm.nih.gov/8624178>.
741. Maricoto T, Santos D, Carvalho C, Teles I, Correia-de-Sousa J, Taborda-Barata L. Assessment of Poor Inhaler Technique in Older Patients with Asthma or COPD: A Predictive Tool for Clinical Risk and Inhaler Performance. *Drugs Aging* 2020; **37**(8): 605-16 <https://pubmed.ncbi.nlm.nih.gov/32602039>.
742. Barrons R, Pegram A, Borries A. Inhaler device selection: special considerations in elderly patients with chronic obstructive pulmonary disease. *Am J Health Syst Pharm* 2011; **68**(13): 1221-32 <https://pubmed.ncbi.nlm.nih.gov/21690428>.
743. Ho SF, MS OM, Steward JA, Breay P, Burr ML. Inhaler technique in older people in the community. *Age Ageing* 2004; **33**(2): 185-8 <https://pubmed.ncbi.nlm.nih.gov/14960436>.
744. Newman SP. Spacer devices for metered dose inhalers. *Clin Pharmacokinet* 2004; **43**(6): 349-60 <https://pubmed.ncbi.nlm.nih.gov/15086274>.
745. Mitchell JP, Nagel MW. Valved holding chambers (VHCs) for use with pressurised metered-dose inhalers (pMDIs): a review of causes of inconsistent medication delivery. *Prim Care Respir J* 2007; **16**(4): 207-14 <https://pubmed.ncbi.nlm.nih.gov/17625786>.
746. Dantic DE. A critical review of the effectiveness of "teach-back" technique in teaching COPD patients self-management using respiratory inhalers. *Health Educ J* 2014; **73**: 41-50
747. Jia X, Zhou S, Luo D, Zhao X, Zhou Y, Cui YM. Effect of pharmacist-led interventions on medication adherence and inhalation technique in adult patients with asthma or COPD: A systematic review and meta-analysis. *J Clin Pharm Ther* 2020; **45**(5): 904-17 <https://pubmed.ncbi.nlm.nih.gov/32107837>.
748. Willard-Grace R, Chirinos C, Wolf J, et al. Lay Health Coaching to Increase Appropriate Inhaler Use in COPD: A Randomized Controlled Trial. *Ann Fam Med* 2020; **18**(1): 5-14 <https://pubmed.ncbi.nlm.nih.gov/31937527>.

749. Sulaiman I, Greene G, MacHale E, et al. A randomised clinical trial of feedback on inhaler adherence and technique in patients with severe uncontrolled asthma. *Eur Respir J* 2018; **51**(1): <https://pubmed.ncbi.nlm.nih.gov/29301919>.
750. Spruit MA, Singh SJ, Garvey C, et al. An official American Thoracic Society/European Respiratory Society statement: key concepts and advances in pulmonary rehabilitation. *Am J Respir Crit Care Med* 2013; **188**(8): e13-64 <https://pubmed.ncbi.nlm.nih.gov/24127811>.
751. Rochester CL, Alison JA, Carlin B, et al. Pulmonary Rehabilitation for Adults with Chronic Respiratory Disease: An Official American Thoracic Society Clinical Practice Guideline. *Am J Respir Crit Care Med* 2023; **208**(4): e7-e26 <https://pubmed.ncbi.nlm.nih.gov/37581410>.
752. Vogiatzis I, Rochester CL, Spruit MA, Troosters T, Clini EM, American Thoracic Society/European Respiratory Society Task Force on Policy in Pulmonary R. Increasing implementation and delivery of pulmonary rehabilitation: key messages from the new ATS/ERS policy statement. *Eur Respir J* 2016; **47**(5): 1336-41 <https://pubmed.ncbi.nlm.nih.gov/27132269>.
753. Garvey C, Bayles MP, Hamm LF, et al. Pulmonary Rehabilitation Exercise Prescription in Chronic Obstructive Pulmonary Disease: Review of Selected Guidelines: AN OFFICIAL STATEMENT FROM THE AMERICAN ASSOCIATION OF CARDIOVASCULAR AND PULMONARY REHABILITATION. *J Cardiopulm Rehabil Prev* 2016; **36**(2): 75-83 <https://pubmed.ncbi.nlm.nih.gov/26906147>.
754. Stone PW, Hickman K, Steiner MC, Roberts CM, Quint JK, Singh SJ. Predictors of Referral to Pulmonary Rehabilitation from UK Primary Care. *Int J Chron Obstruct Pulmon Dis* 2020; **15**: 2941-52 <https://pubmed.ncbi.nlm.nih.gov/33235443>.
755. Alison JA, McKeough ZJ, Johnston K, et al. Australian and New Zealand Pulmonary Rehabilitation Guidelines. *Respirology* 2017; **22**(4): 800-19 <https://pubmed.ncbi.nlm.nih.gov/28339144>.
756. Manifold J, Chaudhry Y, Singh SJ, Ward TJC, Whelan ME, Orme MW. Changes in physical activity, sedentary behaviour and sleep following pulmonary rehabilitation: a systematic review and network meta-analysis. *Eur Respir Rev* 2024; **33**(172): <https://pubmed.ncbi.nlm.nih.gov/38599676>.
757. Wootton SL, Hill K, Alison JA, et al. Effects of Ongoing Feedback During a 12-Month Maintenance Walking Program on Daily Physical Activity in People with COPD. *Lung* 2019; **197**(3): 315-9 <https://pubmed.ncbi.nlm.nih.gov/30982940>.
758. Singh SJ, Morgan MD, Scott S, Walters D, Hardman AE. Development of a shuttle walking test of disability in patients with chronic airways obstruction. *Thorax* 1992; **47**(12): 1019-24 <https://pubmed.ncbi.nlm.nih.gov/1494764>.
759. Dowson C, Laing R, Barraclough R, et al. The use of the Hospital Anxiety and Depression Scale (HADS) in patients with chronic obstructive pulmonary disease: a pilot study. *N Z Med J* 2001; **114**(1141): 447-9 <https://pubmed.ncbi.nlm.nih.gov/11700772>.
760. Kunik ME, Veazey C, Cully JA, et al. COPD education and cognitive behavioral therapy group treatment for clinically significant symptoms of depression and anxiety in COPD patients: a randomized controlled trial. *Psychol Med* 2008; **38**(3): 385-96 <https://pubmed.ncbi.nlm.nih.gov/17922939>.
761. Blackstock FC, Webster KE, McDonald CF, Hill CJ. Comparable improvements achieved in chronic obstructive pulmonary disease through pulmonary rehabilitation with and without a structured educational intervention: a randomized controlled trial. *Respirology* 2014; **19**(2): 193-202 <https://pubmed.ncbi.nlm.nih.gov/24261584>.
762. Effing TW, Vercoulen JH, Bourbeau J, et al. Definition of a COPD self-management intervention: International Expert Group consensus. *Eur Respir J* 2016; **48**(1): 46-54 <https://pubmed.ncbi.nlm.nih.gov/27076595>.
763. Ashikaga T, Vacek PM, Lewis SO. Evaluation of a community-based education program for individuals with chronic obstructive pulmonary disease. *J Rehabil* 1980; **46**(2): 23-7 <https://pubmed.ncbi.nlm.nih.gov/7392019>.
764. Janelli LM, Scherer YK, Schmieder LE. Can a pulmonary health teaching program alter patients' ability to cope with COPD? *Rehabil Nurs* 1991; **16**(4): 199-202 <https://pubmed.ncbi.nlm.nih.gov/1852971>.
765. Cox NS, Dal Corso S, Hansen H, et al. Telerehabilitation for chronic respiratory disease. *Cochrane Database Syst Rev* 2021; **1**(1): CD013040 <https://pubmed.ncbi.nlm.nih.gov/33511633>.
766. Schrijver J, Lenferink A, Brusse-Keizer M, et al. Self-management interventions for people with chronic obstructive pulmonary disease. *Cochrane Database Syst Rev* 2022; **1**(1): CD002990 <https://pubmed.ncbi.nlm.nih.gov/35001366>.
767. Kermelly SB, Bourbeau J. eHealth in Self-Managing at a Distance Patients with COPD. *Life (Basel)* 2022; **12**(6): <https://pubmed.ncbi.nlm.nih.gov/35743804>.
768. Cranston JM, Crockett AJ, Moss JR, Alpers JH. Domiciliary oxygen for chronic obstructive pulmonary disease. *Cochrane Database Syst Rev* 2005; **2005**(4): CD001744 <https://pubmed.ncbi.nlm.nih.gov/16235285>.
769. Ekström M, Andersson A, Papadopoulos S, et al. Long-Term Oxygen Therapy for 24 or 15 Hours per Day in Severe Hypoxemia. *N Engl J Med* 2024; <https://pubmed.ncbi.nlm.nih.gov/39254466>.
770. Long-term Oxygen Treatment Trial Research Group. A randomized trial of long-term oxygen for COPD with moderate desaturation. *N Engl J Med* 2016; **375**(17): 1617
771. Ekstrom M, Ahmadi Z, Bornefalk-Hermansson A, Abernethy A, Currow D. Oxygen for breathlessness in patients with chronic obstructive pulmonary disease who do not qualify for home oxygen therapy. *Cochrane Database Syst Rev* 2016; **11**(11): CD006429 <https://pubmed.ncbi.nlm.nih.gov/27886372>.
772. Jacobs SS, Krishnan JA, Lederer DJ, et al. Home Oxygen Therapy for Adults with Chronic Lung Disease. An Official American Thoracic Society Clinical Practice Guideline. *Am J Respir Crit Care Med* 2020; **202**(10): e121-e41 <https://pubmed.ncbi.nlm.nih.gov/33185464>.
773. Alison JA, McKeough ZJ, Leung RWM, et al. Oxygen compared to air during exercise training in COPD with exercise-induced desaturation. *Eur Respir J* 2019; **53**(5): 1802429 <https://pubmed.ncbi.nlm.nih.gov/30880289>.

774. Ahmedzai S, Balfour-Lynn IM, Bewick T, et al. Managing passengers with stable respiratory disease planning air travel: British Thoracic Society recommendations. *Thorax* 2011; **66 Suppl 1**: i1-30 <https://pubmed.ncbi.nlm.nih.gov/21856702>.
775. Berg BW, Dillard TA, Rajagopal KR, Mehm WJ. Oxygen supplementation during air travel in patients with chronic obstructive lung disease. *Chest* 1992; **101**(3): 638-41 <https://pubmed.ncbi.nlm.nih.gov/1541125>.
776. Edvardsen A, Akerø A, Christensen CC, Ryg M, Skjonsberg OH. Air travel and chronic obstructive pulmonary disease: a new algorithm for pre-flight evaluation. *Thorax* 2012; **67**(11): 964-9 <https://pubmed.ncbi.nlm.nih.gov/22767877>.
777. Christensen CC, Ryg M, Refvem OK, Skjonsberg OH. Development of severe hypoxaemia in chronic obstructive pulmonary disease patients at 2,438 m (8,000 ft) altitude. *Eur Respir J* 2000; **15**(4): 635-9 <https://pubmed.ncbi.nlm.nih.gov/10780752>.
778. Raveling T, Vonk J, Struik FM, et al. Chronic non-invasive ventilation for chronic obstructive pulmonary disease. *Cochrane Database Syst Rev* 2021; **8**(8): CD002878 <https://pubmed.ncbi.nlm.nih.gov/34368950>.
779. Struik FM, Lacasse Y, Goldstein R, Kerstjens HM, Wijkstra PJ. Nocturnal non-invasive positive pressure ventilation for stable chronic obstructive pulmonary disease. *Cochrane Database Syst Rev* 2013; **2013**(6): CD002878 <https://pubmed.ncbi.nlm.nih.gov/23766138>.
780. Srivali N, Thongprayoon C, Tangpanithandee S, Cheungpasitporn W, Won C. The use of continuous positive airway pressure in COPD-OSA overlap syndrome: A systematic review. *Sleep Med* 2023; **108**: 55-60 <https://pubmed.ncbi.nlm.nih.gov/37336060>.
781. Marin JM, Soriano JB, Carrizo SJ, Boldova A, Celli BR. Outcomes in patients with chronic obstructive pulmonary disease and obstructive sleep apnea: the overlap syndrome. *Am J Respir Crit Care Med* 2010; **182**(3): 325-31 <https://pubmed.ncbi.nlm.nih.gov/20378728>.
782. Elliott MW, Nava S. Noninvasive ventilation for acute exacerbations of chronic obstructive pulmonary disease: "Don't think twice, it's alright!". *Am J Respir Crit Care Med* 2012; **185**(2): 121-3 <https://pubmed.ncbi.nlm.nih.gov/22246701>.
783. Chandra D, Stamm JA, Taylor B, et al. Outcomes of noninvasive ventilation for acute exacerbations of chronic obstructive pulmonary disease in the United States, 1998-2008. *Am J Respir Crit Care Med* 2012; **185**(2): 152-9 <https://pubmed.ncbi.nlm.nih.gov/22016446>.
784. Lindenauer PK, Stefan MS, Shieh MS, Pekow PS, Rothberg MB, Hill NS. Outcomes associated with invasive and noninvasive ventilation among patients hospitalized with exacerbations of chronic obstructive pulmonary disease. *JAMA Intern Med* 2014; **174**(12): 1982-93 <https://pubmed.ncbi.nlm.nih.gov/25347545>.
785. Wilson ME, Dobler CC, Morrow AS, et al. Association of Home Noninvasive Positive Pressure Ventilation With Clinical Outcomes in Chronic Obstructive Pulmonary Disease: A Systematic Review and Meta-analysis. *JAMA* 2020; **323**(5): 455-65 <https://pubmed.ncbi.nlm.nih.gov/32016309>.
786. Murphy PB, Rehal S, Arbane G, et al. Effect of Home Noninvasive Ventilation With Oxygen Therapy vs Oxygen Therapy Alone on Hospital Readmission or Death After an Acute COPD Exacerbation: A Randomized Clinical Trial. *JAMA* 2017; **317**(21): 2177-86 <https://pubmed.ncbi.nlm.nih.gov/28528348>.
787. Galli JA, Krahnke JS, James Mamary A, Shenoy K, Zhao H, Criner GJ. Home non-invasive ventilation use following acute hypercapnic respiratory failure in COPD. *Respir Med* 2014; **108**(5): 722-8 <https://pubmed.ncbi.nlm.nih.gov/24702885>.
788. Coughlin S, Liang WE, Parthasarathy S. Retrospective Assessment of Home Ventilation to Reduce Rehospitalization in Chronic Obstructive Pulmonary Disease. *J Clin Sleep Med* 2015; **11**(6): 663-70 <https://pubmed.ncbi.nlm.nih.gov/25766720>.
789. Clini E, Sturani C, Rossi A, et al. The Italian multicentre study on noninvasive ventilation in chronic obstructive pulmonary disease patients. *Eur Respir J* 2002; **20**(3): 529-38 <https://pubmed.ncbi.nlm.nih.gov/12358325>.
790. Kohnlein T, Windisch W, Kohler D, et al. Non-invasive positive pressure ventilation for the treatment of severe stable chronic obstructive pulmonary disease: a prospective, multicentre, randomised, controlled clinical trial. *Lancet Respir Med* 2014; **2**(9): 698-705 <https://pubmed.ncbi.nlm.nih.gov/25066329>.
791. Struik FM, Sprooten RT, Kerstjens HA, et al. Nocturnal non-invasive ventilation in COPD patients with prolonged hypercapnia after ventilatory support for acute respiratory failure: a randomised, controlled, parallel-group study. *Thorax* 2014; **69**(9): 826-34 <https://pubmed.ncbi.nlm.nih.gov/24781217>.
792. Casanova C, Celli BR, Tost L, et al. Long-term controlled trial of nocturnal nasal positive pressure ventilation in patients with severe COPD. *Chest* 2000; **118**(6): 1582-90 <https://pubmed.ncbi.nlm.nih.gov/11115443>.
793. White DP, Criner GJ, Dreher M, et al. The role of noninvasive ventilation in the management and mitigation of exacerbations and hospital admissions/readmissions for the patient with moderate to severe COPD (multimedia activity). *Chest* 2015; **147**(6): 1704-5 <https://pubmed.ncbi.nlm.nih.gov/26033131>.
794. Lightowler JV, Wedzicha JA, Elliott MW, Ram FS. Non-invasive positive pressure ventilation to treat respiratory failure resulting from exacerbations of chronic obstructive pulmonary disease: Cochrane systematic review and meta-analysis. *BMJ* 2003; **326**(7382): 185 <https://pubmed.ncbi.nlm.nih.gov/12543832>.
795. Kolodziej MA, Jensen L, Rowe B, Sin D. Systematic review of noninvasive positive pressure ventilation in severe stable COPD. *Eur Respir J* 2007; **30**(2): 293-306 <https://pubmed.ncbi.nlm.nih.gov/17459893>.
796. Pitre T, Abbasi S, Kachkovski GV, et al. Home respiratory strategies in COPD patients with chronic hypercapnic respiratory failure: a systematic review and network meta-analysis. *Respir Care* 2024: <https://pubmed.ncbi.nlm.nih.gov/38569922>.

797. Fu C, Liu X, Zhu Q, et al. Efficiency of High-Flow Nasal Cannula on Pulmonary Rehabilitation in COPD Patients: A Meta-Analysis. *Biomed Res Int* 2020; **2020**: 7097243 <https://pubmed.ncbi.nlm.nih.gov/33083481>.
798. Kessler R, Stahl E, Vogelmeier C, et al. Patient understanding, detection, and experience of COPD exacerbations: an observational, interview-based study. *Chest* 2006; **130**(1): 133-42 <https://pubmed.ncbi.nlm.nih.gov/16840393>.
799. Johnson-Warrington V, Mitchell KE, Singh SJ. Is a practice incremental shuttle walk test needed for patients with chronic obstructive pulmonary disease admitted to hospital for an acute exacerbation? *Respiration* 2015; **90**(3): 206-10 <https://pubmed.ncbi.nlm.nih.gov/26406442>.
800. Rochester CL, Vogiatzis I, Holland AE, et al. An Official American Thoracic Society/European Respiratory Society Policy Statement: Enhancing Implementation, Use, and Delivery of Pulmonary Rehabilitation. *Am J Respir Crit Care Med* 2015; **192**(11): 1373-86 <https://pubmed.ncbi.nlm.nih.gov/26623686>.
801. Bourbeau J, Nault D, Sedeno M. Action Plan from the Living Well with COPD series 2005. Available at <https://www.livingwellwithcopd.com/en/copd-treatment.html> [accessed Oct 2024].
802. Janjua S, Pike KC, Carr R, Coles A, Fortescue R, Batavia M. Interventions to improve adherence to pharmacological therapy for chronic obstructive pulmonary disease (COPD). *Cochrane Database Syst Rev* 2021; **9**(9): CD013381 <https://pubmed.ncbi.nlm.nih.gov/34496032>.
803. American Academy of H, Palliative M, Center to Advance Palliative C, et al. National Consensus Project for Quality Palliative Care: Clinical Practice Guidelines for quality palliative care, executive summary. *J Palliat Med* 2004; **7**(5): 611-27 <https://pubmed.ncbi.nlm.nih.gov/15588352>.
804. Au DH, Udris EM, Fihn SD, McDonnell MB, Curtis JR. Differences in health care utilization at the end of life among patients with chronic obstructive pulmonary disease and patients with lung cancer. *Arch Intern Med* 2006; **166**(3): 326-31 <https://pubmed.ncbi.nlm.nih.gov/16476873>.
805. Levy MH, Adolph MD, Back A, et al. Palliative care. *J Natl Compr Canc Netw* 2012; **10**(10): 1284-309 <https://pubmed.ncbi.nlm.nih.gov/23054879>.
806. Morrison RS, Maroney-Galin C, Kralovec PD, Meier DE. The growth of palliative care programs in United States hospitals. *J Palliat Med* 2005; **8**(6): 1127-34 <https://pubmed.ncbi.nlm.nih.gov/16351525>.
807. Han MK, Martinez CH, Au DH, et al. Meeting the challenge of COPD care delivery in the USA: a multiprovider perspective. *Lancet Respir Med* 2016; **4**(6): 473-526 <https://pubmed.ncbi.nlm.nih.gov/27185520>.
808. Ambrosino N, Fracchia C. Strategies to relieve dyspnoea in patients with advanced chronic respiratory diseases. A narrative review. *Pulmonology* 2019; **25**(5): 289-98 <https://pubmed.ncbi.nlm.nih.gov/31129045>.
809. Ekstrom M, Nilsson F, Abernethy AA, Currow DC. Effects of opioids on breathlessness and exercise capacity in chronic obstructive pulmonary disease. A systematic review. *Ann Am Thorac Soc* 2015; **12**(7): 1079-92 <https://pubmed.ncbi.nlm.nih.gov/25803110>.
810. Rocker GM, Simpson AC, Joanne Young B, et al. Opioid therapy for refractory dyspnea in patients with advanced chronic obstructive pulmonary disease: patients' experiences and outcomes. *CMAJ Open* 2013; **1**(1): E27-36 <https://pubmed.ncbi.nlm.nih.gov/25077099>.
811. Marciniuk DD, Goodridge D, Hernandez P, et al. Managing dyspnea in patients with advanced chronic obstructive pulmonary disease: a Canadian Thoracic Society clinical practice guideline. *Can Respir J* 2011; **18**(2): 69-78 <https://pubmed.ncbi.nlm.nih.gov/21499589>.
812. Vieira PJ, Chiappa AM, Cipriano G, Jr., Umpierre D, Arena R, Chiappa GR. Neuromuscular electrical stimulation improves clinical and physiological function in COPD patients. *Respir Med* 2014; **108**(4): 609-20 <https://pubmed.ncbi.nlm.nih.gov/24418570>.
813. Galbraith S, Fagan P, Perkins P, Lynch A, Booth S. Does the use of a handheld fan improve chronic dyspnea? A randomized, controlled, crossover trial. *J Pain Symptom Manage* 2010; **39**(5): 831-8 <https://pubmed.ncbi.nlm.nih.gov/20471544>.
814. Marchetti N, Lammi MR, Travaline JM, Ciccolella D, Civic B, Criner GJ. Air Current Applied to the Face Improves Exercise Performance in Patients with COPD. *Lung* 2015; **193**(5): 725-31 <https://pubmed.ncbi.nlm.nih.gov/26255060>.
815. Aintree TJ, Toson B, Loffler KA, Ekström M, Currow DC, Eckert DJ. Low-Dose Morphine Does Not Cause Sleepiness in COPD: A Secondary Analysis of a Randomized Trial. *Am J Respir Crit Care Med* 2024; <https://pubmed.ncbi.nlm.nih.gov/38477675>.
816. Ekström M, Ferreira D, Chang S, et al. Effect of Regular, Low-Dose, Extended-release Morphine on Chronic Breathlessness in Chronic Obstructive Pulmonary Disease: The BEAMS Randomized Clinical Trial. *Jama* 2022; **328**(20): 2022-32 <https://pubmed.ncbi.nlm.nih.gov/36413230>.
817. Abdallah SJ, Wilkinson-Maitland C, Saad N, et al. Effect of morphine on breathlessness and exercise endurance in advanced COPD: a randomised crossover trial. *Eur Respir J* 2017; **50**(4): 1701235 <https://pubmed.ncbi.nlm.nih.gov/29051274>.
818. Verberkt CA, van den Beuken-Everdingen MHJ, Schols J, Wouters EFM, Janssen DJA. Morphine for chronic breathlessness in COPD: improvement predictors-cross-sectional study. *BMJ Support Palliat Care* 2024; **13**(e3): e829-e32 <https://pubmed.ncbi.nlm.nih.gov/35850961>.
819. Nici L, Mammen MJ, Charbek E, et al. Pharmacologic Management of Chronic Obstructive Pulmonary Disease. An Official American Thoracic Society Clinical Practice Guideline. *Am J Respir Crit Care Med* 2020; **201**(9): e56-e69 <https://pubmed.ncbi.nlm.nih.gov/32283960>.

820. Uronis HE, Ekstrom MP, Currow DC, McCrory DC, Samsa GP, Abernethy AP. Oxygen for relief of dyspnoea in people with chronic obstructive pulmonary disease who would not qualify for home oxygen: a systematic review and meta-analysis. *Thorax* 2015; **70**(5): 492-4 <https://pubmed.ncbi.nlm.nih.gov/25472664>.
821. von Trott P, Oei SL, Ramsenthaler C. Acupuncture for Breathlessness in Advanced Diseases: A Systematic Review and Meta-analysis. *J Pain Symptom Manage* 2020; **59**(2): 327-38 e3 <https://pubmed.ncbi.nlm.nih.gov/31539602>.
822. Higginson IJ, Bausewein C, Reilly CC, et al. An integrated palliative and respiratory care service for patients with advanced disease and refractory breathlessness: a randomised controlled trial. *Lancet Respir Med* 2014; **2**(12): 979-87 <https://pubmed.ncbi.nlm.nih.gov/25465642>.
823. Simon ST, Higginson IJ, Booth S, Harding R, Bausewein C. Benzodiazepines for the relief of breathlessness in advanced malignant and non-malignant diseases in adults. *Cochrane Database Syst Rev* 2010; (1): CD007354 <https://pubmed.ncbi.nlm.nih.gov/20091630>.
824. Bausewein C, Booth S, Gysels M, Higginson I. Non-pharmacological interventions for breathlessness in advanced stages of malignant and non-malignant diseases. *Cochrane Database Syst Rev* 2008; (2): CD005623 <https://pubmed.ncbi.nlm.nih.gov/18425927>.
825. Putcha N, Anzuetto AR, Calverley PMA, et al. Mortality and Exacerbation Risk by Body Mass Index in Patients with COPD in TIOSPIR and UPLIFT. *Ann Am Thorac Soc* 2022; **19**(2): 204-13 <https://pubmed.ncbi.nlm.nih.gov/34406915>.
826. Ferreira IM, Brooks D, White J, Goldstein R. Nutritional supplementation for stable chronic obstructive pulmonary disease. *Cochrane Database Syst Rev* 2012; **12**: CD000998 <https://pubmed.ncbi.nlm.nih.gov/23235577>.
827. Gouzi F, Maury J, Heraud N, et al. Additional Effects of Nutritional Antioxidant Supplementation on Peripheral Muscle during Pulmonary Rehabilitation in COPD Patients: A Randomized Controlled Trial. *Oxid Med Cell Longev* 2019; **2019**: 5496346 <https://pubmed.ncbi.nlm.nih.gov/31178967>.
828. van Beers M, Rutten-van Molken M, van de Bool C, et al. Clinical outcome and cost-effectiveness of a 1-year nutritional intervention programme in COPD patients with low muscle mass: The randomized controlled NUTRAIN trial. *Clin Nutr* 2020; **39**(2): 405-13 <https://pubmed.ncbi.nlm.nih.gov/30954363>.
829. Yohannes AM, Alexopoulos GS. Depression and anxiety in patients with COPD. *Eur Respir Rev* 2014; **23**(133): 345-9 <https://pubmed.ncbi.nlm.nih.gov/25176970>.
830. Farver-Vestergaard I, Jacobsen D, Zachariae R. Efficacy of psychosocial interventions on psychological and physical health outcomes in chronic obstructive pulmonary disease: a systematic review and meta-analysis. *Psychother Psychosom* 2015; **84**(1): 37-50 <https://pubmed.ncbi.nlm.nih.gov/25547641>.
831. Payne C, Wiffen PJ, Martin S. Interventions for fatigue and weight loss in adults with advanced progressive illness. *Cochrane Database Syst Rev* 2012; **1**: CD008427 <https://pubmed.ncbi.nlm.nih.gov/22258985>.
832. Murray SA, Kendall M, Boyd K, Sheikh A. Illness trajectories and palliative care. *BMJ* 2005; **330**(7498): 1007-11 <https://pubmed.ncbi.nlm.nih.gov/15860828>.
833. Eriksen N, Vestbo J. Management and survival of patients admitted with an exacerbation of COPD: comparison of two Danish patient cohorts. *Clin Respir J* 2010; **4**(4): 208-14 <https://pubmed.ncbi.nlm.nih.gov/20887343>.
834. Groenewegen KH, Schols AM, Wouters EF. Mortality and mortality-related factors after hospitalization for acute exacerbation of COPD. *Chest* 2003; **124**(2): 459-67 <https://pubmed.ncbi.nlm.nih.gov/12907529>.
835. Gudmundsson G, Ulrik CS, Gislason T, et al. Long-term survival in patients hospitalized for chronic obstructive pulmonary disease: a prospective observational study in the Nordic countries. *Int J Chron Obstruct Pulmon Dis* 2012; **7**: 571-6 <https://pubmed.ncbi.nlm.nih.gov/23055707>.
836. Disler RT, Green A, Luckett T, et al. Experience of advanced chronic obstructive pulmonary disease: metasynthesis of qualitative research. *J Pain Symptom Manage* 2014; **48**(6): 1182-99 <https://pubmed.ncbi.nlm.nih.gov/24780181>.
837. Halpin DMG, Seamark DA, Seamark CJ. Palliative and end-of-life care for patients with respiratory diseases. *Eur Respir Monograph* 2009; **43**: 327-53
838. Patel K, Janssen DJ, Curtis JR. Advance care planning in COPD. *Respirology* 2012; **17**(1): 72-8 <https://pubmed.ncbi.nlm.nih.gov/22008225>.
839. Pinnock H, Kendall M, Murray SA, et al. Living and dying with severe chronic obstructive pulmonary disease: multi-perspective longitudinal qualitative study. *BMJ* 2011; **342**: d142 <https://pubmed.ncbi.nlm.nih.gov/21262897>.
840. Weber C, Stirnemann J, Herrmann FR, Pautex S, Janssens JP. Can early introduction of specialized palliative care limit intensive care, emergency and hospital admissions in patients with severe and very severe COPD? a randomized study. *BMC Palliat Care* 2014; **13**: 47 <https://pubmed.ncbi.nlm.nih.gov/25927907>.
841. Ek K, Andershed B, Sahlberg-Blom E, Ternstedt BM. "The unpredictable death"-The last year of life for patients with advanced COPD: Relatives' stories. *Palliat Support Care* 2015; **13**(5): 1213-22 <https://pubmed.ncbi.nlm.nih.gov/25315360>.
842. National Hospice and Palliative Care Organization. Web Page. 2019. <http://www.nhpco.org> (accessed Oct 2022).
843. Whittaker H, Rothnie KJ, Quint JK. Cause-specific mortality in COPD subpopulations: a cohort study of 339 647 people in England. *Thorax* 2023; <https://pubmed.ncbi.nlm.nih.gov/37328279>.
844. Calverley PM, Anderson JA, Celli B, et al. Salmeterol and fluticasone propionate and survival in chronic obstructive pulmonary disease. *N Engl J Med* 2007; **356**(8): 775-89 <https://pubmed.ncbi.nlm.nih.gov/17314337>.
845. Vestbo J, Anderson J, Brook RD, et al. The Study to Understand Mortality and Morbidity in COPD (SUMMIT) study protocol. *Eur Respir J* 2013; **41**(5): 1017-22 <https://pubmed.ncbi.nlm.nih.gov/23018908>.

846. Anthonisen NR, Skeans MA, Wise RA, et al. The effects of a smoking cessation intervention on 14.5-year mortality: a randomized clinical trial. *Ann Intern Med* 2005; **142**(4): 233-9 <https://pubmed.ncbi.nlm.nih.gov/15710956>.
847. Lu HY, Chen CF, Lee DL, Tsai YJ, Lin PC. Effects of Early Pulmonary Rehabilitation on Hospitalized Patients with Acute Exacerbation of Chronic Obstructive Pulmonary Disease: A Systematic Review and Meta-Analysis. *Int J Chron Obstruct Pulmon Dis* 2023; **18**: 881-93 <https://pubmed.ncbi.nlm.nih.gov/37215744>.
848. Ryrso CK, Godtfredsen NS, Kofod LM, et al. Lower mortality after early supervised pulmonary rehabilitation following COPD-exacerbations: a systematic review and meta-analysis. *BMC Pulm Med* 2018; **18**(1): 154 <https://pubmed.ncbi.nlm.nih.gov/30219047>.
849. Puhan MA, Gimeno-Santos E, Scharplatz M, Troosters T, Walters EH, Steurer J. Pulmonary rehabilitation following exacerbations of chronic obstructive pulmonary disease. *Cochrane Database Syst Rev* 2011; (10): CD005305 <https://pubmed.ncbi.nlm.nih.gov/21975749>.
850. Puhan MA, Gimeno-Santos E, Cates CJ, Troosters T. Pulmonary rehabilitation following exacerbations of chronic obstructive pulmonary disease. *Cochrane Database Syst Rev* 2016; **12**(12): Cd005305 <https://pubmed.ncbi.nlm.nih.gov/27930803>.
851. Lindenauer PK, Stefan MS, Pekow PS, et al. Association Between Initiation of Pulmonary Rehabilitation After Hospitalization for COPD and 1-Year Survival Among Medicare Beneficiaries. *JAMA* 2020; **323**(18): 1813-23 <https://pubmed.ncbi.nlm.nih.gov/32396181>.
852. NOTT Nocturnal Oxygen Therapy Trial Group. Continuous or nocturnal oxygen therapy in hypoxemic chronic obstructive lung disease: a clinical trial. Nocturnal Oxygen Therapy Trial Group. *Ann Intern Med* 1980; **93**(3): 391-8 <https://pubmed.ncbi.nlm.nih.gov/6776858>.
853. MRC Working Party. Long term domiciliary oxygen therapy in chronic hypoxic cor pulmonale complicating chronic bronchitis and emphysema. Report of the Medical Research Council Working Party. *Lancet* 1981; **1**(8222): 681-6 <https://pubmed.ncbi.nlm.nih.gov/6110912>.
854. Lacasse Y, Casaburi R, Sliwinski P, et al. Home oxygen for moderate hypoxaemia in chronic obstructive pulmonary disease: a systematic review and meta-analysis. *Lancet Respir Med* 2022; **10**(11): 1029-37 <https://pubmed.ncbi.nlm.nih.gov/35817074>.
855. Park SY, Yoo KH, Park YB, et al. The Long-term Efficacy of Domiciliary Noninvasive Positive-Pressure Ventilation in Chronic Obstructive Pulmonary Disease: A Meta-Analysis of Randomized Controlled Trials. *Tuberc Respir Dis (Seoul)* 2022; **85**(1): 47-55 <https://pubmed.ncbi.nlm.nih.gov/34775737>.
856. McEvoy RD, Pierce RJ, Hillman D, et al. Nocturnal non-invasive nasal ventilation in stable hypercapnic COPD: a randomised controlled trial. *Thorax* 2009; **64**(7): 561-6 <https://pubmed.ncbi.nlm.nih.gov/19213769>.
857. Vock DM, Durheim MT, Tsuang WM, et al. Survival Benefit of Lung Transplantation in the Modern Era of Lung Allocation. *Ann Am Thorac Soc* 2017; **14**(2): 172-81 <https://pubmed.ncbi.nlm.nih.gov/27779905>.
858. van der Meer RM, Wagena EJ, Ostelo RW, Jacobs JE, van Schayck CP. Smoking cessation for chronic obstructive pulmonary disease. *Cochrane Database Syst Rev* 2003; **2003**(2): CD002999 <https://pubmed.ncbi.nlm.nih.gov/12804448>.
859. Stead LF, Koilpillai P, Fanshawe TR, Lancaster T. Combined pharmacotherapy and behavioural interventions for smoking cessation. *Cochrane Database Syst Rev* 2016; **3**(3): CD008286 <https://pubmed.ncbi.nlm.nih.gov/27009521>.
860. Okuyemi KS, Nollen NL, Ahluwalia JS. Interventions to facilitate smoking cessation. *Am Fam Physician* 2006; **74**(2): 262-71 <https://pubmed.ncbi.nlm.nih.gov/16883923>.
861. Fiore MC, Bailey WC, Cohen SJ. Smoking Cessation: information for specialists. Rockville, MD; 1996.
862. Lee PN, Fariss MW. A systematic review of possible serious adverse health effects of nicotine replacement therapy. *Arch Toxicol* 2017; **91**(4): 1565-94 <https://pubmed.ncbi.nlm.nih.gov/27699443>.
863. Bullen C, Howe C, Laugesen M, et al. Electronic cigarettes for smoking cessation: a randomised controlled trial. *Lancet* 2013; **382**(9905): 1629-37 <https://pubmed.ncbi.nlm.nih.gov/24029165>.
864. Hajek P, Phillips-Waller A, Przulj D, et al. E-cigarettes compared with nicotine replacement therapy within the UK Stop Smoking Services: the TEC RCT. *Health Technol Assess* 2019; **23**(43): 1-82 <https://pubmed.ncbi.nlm.nih.gov/31434605>.
865. Hanewinkel R, Niederberger K, Pedersen A, Unger JB, Galimov A. E-cigarettes and nicotine abstinence: a meta-analysis of randomised controlled trials. *Eur Respir Rev* 2022; **31**(163): <https://pubmed.ncbi.nlm.nih.gov/35321930>.
866. Morphet K, Fraser D, Borland R, et al. A Pragmatic Randomized Comparative Trial of e-Cigarettes and Other Nicotine Products for Quitting or Long-Term Substitution in Smokers. *Nicotine Tob Res* 2022; **24**(7): 1079-88 <https://pubmed.ncbi.nlm.nih.gov/34929031>.
867. Walker N, Parag V, Verbiest M, Laking G, Laugesen M, Bullen C. Nicotine patches used in combination with e-cigarettes (with and without nicotine) for smoking cessation: a pragmatic, randomised trial. *Lancet Respir Med* 2020; **8**(1): 54-64 <https://pubmed.ncbi.nlm.nih.gov/31515173>.
868. He T, Oks M, Esposito M, Steinberg H, Makaryus M. "Tree-in-Bloom": Severe Acute Lung Injury Induced by Vaping Cannabis Oil. *Ann Am Thorac Soc* 2017; **14**(3): 468-70 <https://pubmed.ncbi.nlm.nih.gov/28248584>.
869. Henry TS, Kanne JP, Kligerman SJ. Imaging of Vaping-Associated Lung Disease. *N Engl J Med* 2019; **381**(15): 1486-7 <https://pubmed.ncbi.nlm.nih.gov/31491070>.
870. Layden JE, Ghinai I, Pray I, et al. Pulmonary Illness Related to E-Cigarette Use in Illinois and Wisconsin - Final Report. *N Engl J Med* 2020; **382**(10): 903-16 <https://pubmed.ncbi.nlm.nih.gov/31491072>.

871. Centers for Disease Control and Prevention; U.S. Department of Health & Human Services. Outbreak of Lung Injury Associated with E-Cigarette Use, or Vaping https://www.cdc.gov/tobacco/basic_information/e-cigarettes/severe-lung-disease.html [accessed Oct 2024].
872. Allbright K, Villandre J, Crotty Alexander LE, et al. The paradox of the safer cigarette: understanding the pulmonary effects of electronic cigarettes. *Eur Respir J* 2024; **63**(6): <https://pubmed.ncbi.nlm.nih.gov/38609098>.
873. Blount BC, Karwowski MP, Shields PG, et al. Vitamin E Acetate in Bronchoalveolar-Lavage Fluid Associated with EVALI. *N Engl J Med* 2020; **382**(8): 697-705 <https://pubmed.ncbi.nlm.nih.gov/31860793>.
874. Garcia-Arcos I, Geraghty P, Baumlín N, et al. Chronic electronic cigarette exposure in mice induces features of COPD in a nicotine-dependent manner. *Thorax* 2016; **71**(12): 1119-29 <https://pubmed.ncbi.nlm.nih.gov/27558745>.
875. Higham A, Bostock D, Booth G, Dungwa JV, Singh D. The effect of electronic cigarette and tobacco smoke exposure on COPD bronchial epithelial cell inflammatory responses. *Int J Chron Obstruct Pulmon Dis* 2018; **13**: 989-1000 <https://pubmed.ncbi.nlm.nih.gov/29615835>.
876. Higham A, Rattray NJ, Dewhurst JA, et al. Electronic cigarette exposure triggers neutrophil inflammatory responses. *Respir Res* 2016; **17**(1): 56 <https://pubmed.ncbi.nlm.nih.gov/27184092>.
877. Lerner CA, Sundar IK, Yao H, et al. Vapors produced by electronic cigarettes and e-juices with flavorings induce toxicity, oxidative stress, and inflammatory response in lung epithelial cells and in mouse lung. *PLoS One* 2015; **10**(2): e0116732 <https://pubmed.ncbi.nlm.nih.gov/25658421>.
878. Reidel B, Radicioni G, Clapp PW, et al. E-Cigarette Use Causes a Unique Innate Immune Response in the Lung, Involving Increased Neutrophilic Activation and Altered Mucin Secretion. *Am J Respir Crit Care Med* 2018; **197**(4): 492-501 <https://pubmed.ncbi.nlm.nih.gov/29053025>.
879. Gotts JE, Jordt SE, McConnell R, Tarran R. What are the respiratory effects of e-cigarettes? *BMJ* 2019; **366**: l5275 <https://pubmed.ncbi.nlm.nih.gov/31570493>.
880. Xie W, Kathuria H, Galiatsatos P, et al. Association of Electronic Cigarette Use With Incident Respiratory Conditions Among US Adults From 2013 to 2018. *JAMA Netw Open* 2020; **3**(11): e2020816 <https://pubmed.ncbi.nlm.nih.gov/33180127>.
881. Bowler RP, Hansel NN, Jacobson S, et al. Electronic Cigarette Use in US Adults at Risk for or with COPD: Analysis from Two Observational Cohorts. *J Gen Intern Med* 2017; **32**(12): 1315-22 <https://pubmed.ncbi.nlm.nih.gov/28884423>.
882. Li J, Hui X, Fu J, Ahmed MM, Yao L, Yang K. Electronic cigarettes versus nicotine-replacement therapy for smoking cessation: A systematic review and meta-analysis of randomized controlled trials. *Tob Induc Dis* 2022; **20**: 90 <https://pubmed.ncbi.nlm.nih.gov/36339933>.
883. Glantz SA, Nguyen N, Oliveira da Silva AL. Population-Based Disease Odds for E-Cigarettes and Dual Use versus Cigarettes. *NEJM Evid* 2024; **3**(3): EVID0a2300229 <https://pubmed.ncbi.nlm.nih.gov/38411454>.
884. Jimenez Ruiz CA, Ramos Pinedo A, Cicero Guerrero A, Mayayo Ulibarri M, Cristobal Fernandez M, Lopez Gonzalez G. Characteristics of COPD smokers and effectiveness and safety of smoking cessation medications. *Nicotine Tob Res* 2012; **14**(9): 1035-9 <https://pubmed.ncbi.nlm.nih.gov/22345320>.
885. Burge PS, Calverley PM, Jones PW, Spencer S, Anderson JA, Maslen TK. Randomised, double blind, placebo controlled study of fluticasone propionate in patients with moderate to severe chronic obstructive pulmonary disease: the ISOLDE trial. *BMJ* 2000; **320**(7245): 1297-303 <https://pubmed.ncbi.nlm.nih.gov/10807619>.
886. Anthonisen NR, Connett JE, Kiley JP, et al. Effects of smoking intervention and the use of an inhaled anticholinergic bronchodilator on the rate of decline of FEV1. The Lung Health Study. *JAMA* 1994; **272**(19): 1497-505 <https://pubmed.ncbi.nlm.nih.gov/7966841>.
887. Pauwels RA, Lofdahl CG, Laitinen LA, et al. Long-term treatment with inhaled budesonide in persons with mild chronic obstructive pulmonary disease who continue smoking. European Respiratory Society Study on Chronic Obstructive Pulmonary Disease. *N Engl J Med* 1999; **340**(25): 1948-53 <https://pubmed.ncbi.nlm.nih.gov/10379018>.
888. Vestbo J, Sorensen T, Lange P, Brix A, Torre P, Viskum K. Long-term effect of inhaled budesonide in mild and moderate chronic obstructive pulmonary disease: a randomised controlled trial. *Lancet* 1999; **353**(9167): 1819-23 <https://pubmed.ncbi.nlm.nih.gov/10359405>.
889. Tashkin DP, Celli B, Senn S, et al. A 4-year trial of tiotropium in chronic obstructive pulmonary disease. *N Engl J Med* 2008; **359**(15): 1543-54 <https://pubmed.ncbi.nlm.nih.gov/18836213>.
890. Celli BR, Anderson JA, Cowans NJ, et al. Pharmacotherapy and Lung Function Decline in Patients with Chronic Obstructive Pulmonary Disease. A Systematic Review. *Am J Respir Crit Care Med* 2021; **203**(6): 689-98 <https://pubmed.ncbi.nlm.nih.gov/32966751>.
891. World Health Organization. WHO package of essential noncommunicable (PEN) disease interventions for primary health care. Geneva. Licence: CC BY-NC-SA 3.0 IGO, online document available here: [https://www.who.int/publications/i/item/who-package-of-essential-noncommunicable-\(pen\)-disease-interventions-for-primary-health-care](https://www.who.int/publications/i/item/who-package-of-essential-noncommunicable-(pen)-disease-interventions-for-primary-health-care) [accessed Oct 2024].
892. O'Donnell DE, Sciruba F, Celli B, et al. Effect of fluticasone propionate/salmeterol on lung hyperinflation and exercise endurance in COPD. *Chest* 2006; **130**(3): 647-56 <https://pubmed.ncbi.nlm.nih.gov/16963658>.
893. Berger R, Smith D. Effect of inhaled metaproterenol on exercise performance in patients with stable "fixed" airway obstruction. *Am Rev Respir Dis* 1988; **138**(3): 624-9 <https://pubmed.ncbi.nlm.nih.gov/3202416>.

894. Hay JG, Stone P, Carter J, et al. Bronchodilator reversibility, exercise performance and breathlessness in stable chronic obstructive pulmonary disease. *Eur Respir J* 1992; **5**(6): 659-64 <https://pubmed.ncbi.nlm.nih.gov/1628722>.
895. Chrystyn H, Mulley BA, Peake MD. Dose response relation to oral theophylline in severe chronic obstructive airways disease. *BMJ* 1988; **297**(6662): 1506-10 <https://pubmed.ncbi.nlm.nih.gov/3147048>.
896. Gross NJ, Petty TL, Friedman M, Skorodin MS, Silvers GW, Donohue JF. Dose response to ipratropium as a nebulized solution in patients with chronic obstructive pulmonary disease. A three-center study. *Am Rev Respir Dis* 1989; **139**(5): 1188-91 <https://pubmed.ncbi.nlm.nih.gov/2523681>.
897. Higgins BG, Powell RM, Cooper S, Tattersfield AE. Effect of salbutamol and ipratropium bromide on airway calibre and bronchial reactivity in asthma and chronic bronchitis. *Eur Respir J* 1991; **4**(4): 415-20 <https://pubmed.ncbi.nlm.nih.gov/1830277>.
898. Vathenen AS, Britton JR, Ebden P, Cookson JB, Wharrad HJ, Tattersfield AE. High-dose inhaled albuterol in severe chronic airflow limitation. *Am Rev Respir Dis* 1988; **138**(4): 850-5 <https://pubmed.ncbi.nlm.nih.gov/2462383>.
899. Donohue JF, Anzueto A, Brooks J, Mehta R, Kalberg C, Crater G. A randomized, double-blind dose-ranging study of the novel LAMA GSK573719 in patients with COPD. *Respir Med* 2012; **106**(7): 970-9 <https://pubmed.ncbi.nlm.nih.gov/22498110>.
900. Donohue JF, Kalberg C, Shah P, et al. Dose response of umeclidinium administered once or twice daily in patients with COPD: a pooled analysis of two randomized, double-blind, placebo-controlled studies. *J Clin Pharmacol* 2014; **54**(11): 1214-20 <https://pubmed.ncbi.nlm.nih.gov/24895108>.
901. Chowdhury BA, Seymour SM, Michele TM, Durmowicz AG, Liu D, Rosebraugh CJ. The risks and benefits of indacaterol--the FDA's review. *N Engl J Med* 2011; **365**(24): 2247-9 <https://pubmed.ncbi.nlm.nih.gov/22168640>.
902. O'Driscoll BR, Kay EA, Taylor RJ, Weatherby H, Chetty MC, Bernstein A. A long-term prospective assessment of home nebulizer treatment. *Respir Med* 1992; **86**(4): 317-25 <https://pubmed.ncbi.nlm.nih.gov/1448587>.
903. Jenkins SC, Heaton RW, Fulton TJ, Moxham J. Comparison of domiciliary nebulized salbutamol and salbutamol from a metered-dose inhaler in stable chronic airflow limitation. *Chest* 1987; **91**(6): 804-7 <https://pubmed.ncbi.nlm.nih.gov/3556051>.
904. Sestini P, Renzoni E, Robinson S, Poole P, Ram FS. Short-acting beta 2 agonists for stable chronic obstructive pulmonary disease. *Cochrane Database Syst Rev* 2002; (4): CD001495 <https://pubmed.ncbi.nlm.nih.gov/12519559>.
905. Cazzola M, Rogliani P, Ruggeri P, et al. Chronic treatment with indacaterol and airway response to salbutamol in stable COPD. *Respir Med* 2013; **107**(6): 848-53 <https://pubmed.ncbi.nlm.nih.gov/23490225>.
906. Kew KM, Mavergames C, Walters JA. Long-acting beta2-agonists for chronic obstructive pulmonary disease. *Cochrane Database Syst Rev* 2013; **10**(10): CD010177 <https://pubmed.ncbi.nlm.nih.gov/24127118>.
907. Han J, Dai L, Zhong N. Indacaterol on dyspnea in chronic obstructive pulmonary disease: a systematic review and meta-analysis of randomized placebo-controlled trials. *BMC Pulm Med* 2013; **13**: 26 <https://pubmed.ncbi.nlm.nih.gov/23617268>.
908. Geake JB, Dabscheck EJ, Wood-Baker R, Cates CJ. Indacaterol, a once-daily beta2-agonist, versus twice-daily beta(2)-agonists or placebo for chronic obstructive pulmonary disease. *Cochrane Database Syst Rev* 2015; **1**(1): CD010139 <https://pubmed.ncbi.nlm.nih.gov/25575340>.
909. Koch A, Pizzichini E, Hamilton A, et al. Lung function efficacy and symptomatic benefit of olodaterol once daily delivered via Respimat(R) versus placebo and formoterol twice daily in patients with GOLD 2-4 COPD: results from two replicate 48-week studies. *Int J Chron Obstruct Pulmon Dis* 2014; **9**: 697-714 <https://pubmed.ncbi.nlm.nih.gov/25045258>.
910. Kempford R, Norris V, Siederer S. Vilanterol trifenate, a novel inhaled long-acting beta2 adrenoceptor agonist, is well tolerated in healthy subjects and demonstrates prolonged bronchodilation in subjects with asthma and COPD. *Pulm Pharmacol Ther* 2013; **26**(2): 256-64 <https://pubmed.ncbi.nlm.nih.gov/23232038>.
911. Lipworth BJ, McDevitt DG, Struthers AD. Hypokalemic and ECG sequelae of combined beta-agonist/diuretic therapy. Protection by conventional doses of spironolactone but not triamterene. *Chest* 1990; **98**(4): 811-5 <https://pubmed.ncbi.nlm.nih.gov/2209135>.
912. Uren NG, Davies SW, Jordan SL, Lipkin DP. Inhaled bronchodilators increase maximum oxygen consumption in chronic left ventricular failure. *Eur Heart J* 1993; **14**(6): 744-50 <https://pubmed.ncbi.nlm.nih.gov/8325299>.
913. Khoukaz G, Gross NJ. Effects of salmeterol on arterial blood gases in patients with stable chronic obstructive pulmonary disease. Comparison with albuterol and ipratropium. *Am J Respir Crit Care Med* 1999; **160**(3): 1028-30 <https://pubmed.ncbi.nlm.nih.gov/10471636>.
914. McGarvey L, Niewoehner D, Magder S, et al. One-Year Safety of Olodaterol Once Daily via Respimat(R) in Patients with GOLD 2-4 Chronic Obstructive Pulmonary Disease: Results of a Pre-Specified Pooled Analysis. *COPD* 2015; **12**(5): 484-93 <https://pubmed.ncbi.nlm.nih.gov/25692310>.
915. Dahl R, Chung KF, Buhl R, et al. Efficacy of a new once-daily long-acting inhaled beta2-agonist indacaterol versus twice-daily formoterol in COPD. *Thorax* 2010; **65**(6): 473-9 <https://pubmed.ncbi.nlm.nih.gov/20522841>.
916. Melani AS. Long-acting muscarinic antagonists. *Expert Rev Clin Pharmacol* 2015; **8**(4): 479-501 <https://pubmed.ncbi.nlm.nih.gov/26109098>.
917. Barnes P. Bronchodilators: basic pharmacology. In: Calverley PMA, Pride NB, eds. *Chronic Obstructive Pulmonary Disease*. London: Chapman and Hall; 1995: 391-417.

918. Appleton S, Jones T, Poole P, et al. Ipratropium bromide versus long-acting beta-2 agonists for stable chronic obstructive pulmonary disease. *Cochrane Database Syst Rev* 2006; **2006**(3): CD006101 <https://pubmed.ncbi.nlm.nih.gov/16856113>.
919. Jones PW, Singh D, Bateman ED, et al. Efficacy and safety of twice-daily aclidinium bromide in COPD patients: the ATTAIN study. *Eur Respir J* 2012; **40**(4): 830-6 <https://pubmed.ncbi.nlm.nih.gov/22441743>.
920. Karner C, Chong J, Poole P. Tiotropium versus placebo for chronic obstructive pulmonary disease. *Cochrane Database Syst Rev* 2014; **2014**(7): CD009285 <https://pubmed.ncbi.nlm.nih.gov/25046211>.
921. Calzetta L, Ritondo BL, Zappa MC, et al. The impact of long-acting muscarinic antagonists on mucus hypersecretion and cough in chronic obstructive pulmonary disease: a systematic review. *Eur Respir Rev* 2022; **31**(164): <https://pubmed.ncbi.nlm.nih.gov/35508331>.
922. Kesten S, Casaburi R, Kukafka D, Cooper CB. Improvement in self-reported exercise participation with the combination of tiotropium and rehabilitative exercise training in COPD patients. *Int J Chron Obstruct Pulmon Dis* 2008; **3**(1): 127-36 <https://pubmed.ncbi.nlm.nih.gov/18488436>.
923. Casaburi R, Kukafka D, Cooper CB, Witek TJ, Jr., Kesten S. Improvement in exercise tolerance with the combination of tiotropium and pulmonary rehabilitation in patients with COPD. *Chest* 2005; **127**(3): 809-17 <https://pubmed.ncbi.nlm.nih.gov/15764761>.
924. Vogelmeier C, Hederer B, Glaab T, et al. Tiotropium versus salmeterol for the prevention of exacerbations of COPD. *N Engl J Med* 2011; **364**(12): 1093-103 <https://pubmed.ncbi.nlm.nih.gov/21428765>.
925. Decramer ML, Chapman KR, Dahl R, et al. Once-daily indacaterol versus tiotropium for patients with severe chronic obstructive pulmonary disease (INVIGORATE): a randomised, blinded, parallel-group study. *Lancet Respir Med* 2013; **1**(7): 524-33 <https://pubmed.ncbi.nlm.nih.gov/24461613>.
926. Tashkin DP. Long-acting anticholinergic use in chronic obstructive pulmonary disease: efficacy and safety. *Curr Opin Pulm Med* 2010; **16**(2): 97-105 <https://pubmed.ncbi.nlm.nih.gov/20019615>.
927. Disse B, Speck GA, Rominger KL, Witek TJ, Jr., Hammer R. Tiotropium (Spiriva): mechanical considerations and clinical profile in obstructive lung disease. *Life Sci* 1999; **64**(6-7): 457-64 <https://pubmed.ncbi.nlm.nih.gov/10069510>.
928. Kesten S, Jara M, Wentworth C, Lanes S. Pooled clinical trial analysis of tiotropium safety. *Chest* 2006; **130**(6): 1695-703 <https://pubmed.ncbi.nlm.nih.gov/17166984>.
929. Anthonisen NR, Connett JE, Enright PL, Manfreda J, Lung Health Study Research G. Hospitalizations and mortality in the Lung Health Study. *Am J Respir Crit Care Med* 2002; **166**(3): 333-9 <https://pubmed.ncbi.nlm.nih.gov/12153966>.
930. Michele TM, Pinheiro S, Iyasu S. The safety of tiotropium--the FDA's conclusions. *N Engl J Med* 2010; **363**(12): 1097-9 <https://pubmed.ncbi.nlm.nih.gov/20843240>.
931. Verhamme KM, Afonso A, Romio S, Stricker BC, Brusselle GG, Sturkenboom MC. Use of tiotropium Respimat Soft Mist Inhaler versus HandiHaler and mortality in patients with COPD. *Eur Respir J* 2013; **42**(3): 606-15 <https://pubmed.ncbi.nlm.nih.gov/23520322>.
932. Wise RA, Anzueto A, Cotton D, et al. Tiotropium Respimat inhaler and the risk of death in COPD. *N Engl J Med* 2013; **369**(16): 1491-501 <https://pubmed.ncbi.nlm.nih.gov/23992515>.
933. Packe GE, Cayton RM, Mashhoudi N. Nebulised ipratropium bromide and salbutamol causing closed-angle glaucoma. *Lancet* 1984; **2**(8404): 691 <https://pubmed.ncbi.nlm.nih.gov/6147708>.
934. Mulpeter KM, Walsh JB, O'Connor M, O'Connell F, Burke C. Ocular hazards of nebulized bronchodilators. *Postgrad Med J* 1992; **68**(796): 132-3 <https://pubmed.ncbi.nlm.nih.gov/1533281>.
935. Hall SK. Acute angle-closure glaucoma as a complication of combined beta-agonist and ipratropium bromide therapy in the emergency department. *Ann Emerg Med* 1994; **23**(4): 884-7 <https://pubmed.ncbi.nlm.nih.gov/8161065>.
936. Aubier M. Pharmacotherapy of respiratory muscles. *Clin Chest Med* 1988; **9**(2): 311-24 <https://pubmed.ncbi.nlm.nih.gov/3292130>.
937. McKay SE, Howie CA, Thomson AH, Whiting B, Addis GJ. Value of theophylline treatment in patients handicapped by chronic obstructive lung disease. *Thorax* 1993; **48**(3): 227-32 <https://pubmed.ncbi.nlm.nih.gov/8497820>.
938. Moxham J. Aminophylline and the respiratory muscles: an alternative view. *Clin Chest Med* 1988; **9**(2): 325-36 <https://pubmed.ncbi.nlm.nih.gov/3292131>.
939. Ram FS, Jones PW, Castro AA, et al. Oral theophylline for chronic obstructive pulmonary disease. *Cochrane Database Syst Rev* 2002; **2002**(4): CD003902 <https://pubmed.ncbi.nlm.nih.gov/12519617>.
940. ZuWallack RL, Mahler DA, Reilly D, et al. Salmeterol plus theophylline combination therapy in the treatment of COPD. *Chest* 2001; **119**(6): 1661-70 <https://pubmed.ncbi.nlm.nih.gov/11399688>.
941. Zacarias EC, Castro AA, Cendon S. Effect of theophylline associated with short-acting or long-acting inhaled beta2-agonists in patients with stable chronic obstructive pulmonary disease: a systematic review. *J Bras Pneumol* 2007; **33**(2): 152-60 <https://pubmed.ncbi.nlm.nih.gov/17724534>.
942. Cosio BG, Shafiek H, Iglesias A, et al. Oral Low-dose Theophylline on Top of Inhaled Fluticasone-Salmeterol Does Not Reduce Exacerbations in Patients With Severe COPD: A Pilot Clinical Trial. *Chest* 2016; **150**(1): 123-30 <https://pubmed.ncbi.nlm.nih.gov/27107490>.
943. Zhou Y, Wang X, Zeng X, et al. Positive benefits of theophylline in a randomized, double-blind, parallel-group, placebo-controlled study of low-dose, slow-release theophylline in the treatment of COPD for 1 year. *Respirology* 2006; **11**(5): 603-10 <https://pubmed.ncbi.nlm.nih.gov/16916334>.

944. Devereux G, Cotton S, Fielding S, et al. Effect of Theophylline as Adjunct to Inhaled Corticosteroids on Exacerbations in Patients With COPD: A Randomized Clinical Trial. *JAMA* 2018; **320**(15): 1548-59 <https://pubmed.ncbi.nlm.nih.gov/30326124>.
945. Jenkins CR, Wen FQ, Martin A, et al. The effect of low-dose corticosteroids and theophylline on the risk of acute exacerbations of COPD: the TASCs randomised controlled trial. *Eur Respir J* 2021; **57**(6): <https://pubmed.ncbi.nlm.nih.gov/33334939>.
946. Cazzola M, Molimard M. The scientific rationale for combining long-acting beta2-agonists and muscarinic antagonists in COPD. *Pulm Pharmacol Ther* 2010; **23**(4): 257-67 <https://pubmed.ncbi.nlm.nih.gov/20381630>.
947. Ray R, Tombs L, Naya I, Compton C, Lipson DA, Boucot I. Efficacy and safety of the dual bronchodilator combination umeclidinium/vilanterol in COPD by age and airflow limitation severity: A pooled post hoc analysis of seven clinical trials. *Pulm Pharmacol Ther* 2019; **57**: 101802 <https://pubmed.ncbi.nlm.nih.gov/31096036>.
948. Gross N, Tashkin D, Miller R, Oren J, Coleman W, Linberg S. Inhalation by nebulization of albuterol-ipratropium combination (Dey combination) is superior to either agent alone in the treatment of chronic obstructive pulmonary disease. Dey Combination Solution Study Group. *Respiration* 1998; **65**(5): 354-62 <https://pubmed.ncbi.nlm.nih.gov/9782217>.
949. Tashkin DP, Pearle J, Iezzoni D, Varghese ST. Formoterol and tiotropium compared with tiotropium alone for treatment of COPD. *COPD* 2009; **6**(1): 17-25 <https://pubmed.ncbi.nlm.nih.gov/19229704>.
950. Farne HA, Cates CJ. Long-acting beta2-agonist in addition to tiotropium versus either tiotropium or long-acting beta2-agonist alone for chronic obstructive pulmonary disease. *Cochrane Database Syst Rev* 2015; **10**(10): CD008989 <https://pubmed.ncbi.nlm.nih.gov/26490945>.
951. Halpin DMG, Rothnie KJ, Banks V, et al. Comparative Adherence and Persistence of Single- and Multiple-Inhaler Triple Therapies Among Patients with Chronic Obstructive Pulmonary Disease in an English Real-World Primary Care Setting. *Int J Chron Obstruct Pulmon Dis* 2022; **17**: 2417-29 <https://pubmed.ncbi.nlm.nih.gov/36185170>.
952. van der Molen T, Cazzola M. Beyond lung function in COPD management: effectiveness of LABA/LAMA combination therapy on patient-centred outcomes. *Prim Care Respir J* 2012; **21**(1): 101-8 <https://pubmed.ncbi.nlm.nih.gov/22222945>.
953. Mahler DA, Decramer M, D'Urzo A, et al. Dual bronchodilation with QVA149 reduces patient-reported dyspnoea in COPD: the BLAZE study. *Eur Respir J* 2014; **43**(6): 1599-609 <https://pubmed.ncbi.nlm.nih.gov/24176997>.
954. Singh D, Ferguson GT, Bolitschek J, et al. Tiotropium + olodaterol shows clinically meaningful improvements in quality of life. *Respir Med* 2015; **109**(10): 1312-9 <https://pubmed.ncbi.nlm.nih.gov/26320402>.
955. Bateman ED, Chapman KR, Singh D, et al. Acclidinium bromide and formoterol fumarate as a fixed-dose combination in COPD: pooled analysis of symptoms and exacerbations from two six-month, multicentre, randomised studies (ACLIFORM and AUGMENT). *Respir Res* 2015; **16**(1): 92 <https://pubmed.ncbi.nlm.nih.gov/26233481>.
956. Martinez FJ, Fabbri LM, Ferguson GT, et al. Baseline Symptom Score Impact on Benefits of Glycopyrrolate/Formoterol Metered Dose Inhaler in COPD. *Chest* 2017; **152**(6): 1169-78 <https://pubmed.ncbi.nlm.nih.gov/28720336>.
957. Vogelmeier CF, Kerwin EM, Bjermer LH, et al. Impact of baseline COPD symptom severity on the benefit from dual versus mono-bronchodilators: an analysis of the EMAX randomised controlled trial. *Thorax* 2020; **75**(14): 1753-466620968500 <https://pubmed.ncbi.nlm.nih.gov/33167780>.
958. Mahler DA, Kerwin E, Ayers T, et al. FLIGHT1 and FLIGHT2: Efficacy and Safety of QVA149 (Indacaterol/Glycopyrrolate) versus Its Monocomponents and Placebo in Patients with Chronic Obstructive Pulmonary Disease. *Am J Respir Crit Care Med* 2015; **192**(9): 1068-79 <https://pubmed.ncbi.nlm.nih.gov/26177074>.
959. Bai C, Ichinose M, Lee SH, et al. Lung function and long-term safety of tiotropium/olodaterol in East Asian patients with chronic obstructive pulmonary disease. *Int J Chron Obstruct Pulmon Dis* 2017; **12**: 3329-39 <https://pubmed.ncbi.nlm.nih.gov/29200840>.
960. Wedzicha JA, Decramer M, Ficker JH, et al. Analysis of chronic obstructive pulmonary disease exacerbations with the dual bronchodilator QVA149 compared with glycopyrronium and tiotropium (SPARK): a randomised, double-blind, parallel-group study. *Lancet Respir Med* 2013; **1**(3): 199-209 <https://pubmed.ncbi.nlm.nih.gov/24429126>.
961. Calverley PMA, Anzueto AR, Carter K, et al. Tiotropium and olodaterol in the prevention of chronic obstructive pulmonary disease exacerbations (DYNAGITO): a double-blind, randomised, parallel-group, active-controlled trial. *Lancet Respir Med* 2018; **6**(5): 337-44 <https://pubmed.ncbi.nlm.nih.gov/29605624>.
962. Wedzicha JA, Banerji D, Chapman KR, et al. Indacaterol-Glycopyrronium versus Salmeterol-Fluticasone for COPD. *N Engl J Med* 2016; **374**(23): 2222-34 <https://pubmed.ncbi.nlm.nih.gov/27181606>.
963. Suissa S, Dell'Aniello S, Ernst P. Comparative Effectiveness and Safety of LABA-LAMA vs LABA-ICS Treatment of COPD in Real-World Clinical Practice. *Chest* 2019; **155**(6): 1158-65 <https://pubmed.ncbi.nlm.nih.gov/30922950>.
964. Barnes PJ. New anti-inflammatory targets for chronic obstructive pulmonary disease. *Nat Rev Drug Discov* 2013; **12**(7): 543-59 <https://pubmed.ncbi.nlm.nih.gov/23977698>.
965. Boardman C, Chachi L, Gavrilu A, et al. Mechanisms of glucocorticoid action and insensitivity in airways disease. *Pulm Pharmacol Ther* 2014; **29**(2): 129-43 <https://pubmed.ncbi.nlm.nih.gov/25218650>.
966. Sonnex K, Alleemudder H, Knaggs R. Impact of smoking status on the efficacy of inhaled corticosteroids in chronic obstructive pulmonary disease: a systematic review. *BMJ Open* 2020; **10**(4): e037509 <https://pubmed.ncbi.nlm.nih.gov/32300001>.

967. Yang IA, Clarke MS, Sim EH, Fong KM. Inhaled corticosteroids for stable chronic obstructive pulmonary disease. *Cochrane Database Syst Rev* 2012; **2012**(7): CD002991 <https://pubmed.ncbi.nlm.nih.gov/22786484>.
968. Vestbo J, Anderson JA, Brook RD, et al. Fluticasone furoate and vilanterol and survival in chronic obstructive pulmonary disease with heightened cardiovascular risk (SUMMIT): a double-blind randomised controlled trial. *Lancet* 2016; **387**(10030): 1817-26 <https://pubmed.ncbi.nlm.nih.gov/27203508>.
969. Calverley PMA, Anderson JA, Brook RD, et al. Fluticasone Furoate, Vilanterol, and Lung Function Decline in Patients with Moderate Chronic Obstructive Pulmonary Disease and Heightened Cardiovascular Risk. *Am J Respir Crit Care Med* 2018; **197**(1): 47-55 <https://pubmed.ncbi.nlm.nih.gov/28737971>.
970. Suissa S, Dell'Aniello S, Gonzalez AV, Ernst P. Inhaled corticosteroid use and the incidence of lung cancer in COPD. *Eur Respir J* 2020; **55**(2): 1901720 <https://pubmed.ncbi.nlm.nih.gov/31744837>.
971. Nannini LJ, Lasserson TJ, Poole P. Combined corticosteroid and long-acting beta(2)-agonist in one inhaler versus long-acting beta(2)-agonists for chronic obstructive pulmonary disease. *Cochrane Database Syst Rev* 2012; **2012**(9): CD006829 <https://pubmed.ncbi.nlm.nih.gov/22972099>.
972. Nannini LJ, Poole P, Milan SJ, Kesterton A. Combined corticosteroid and long-acting beta(2)-agonist in one inhaler versus inhaled corticosteroids alone for chronic obstructive pulmonary disease. *Cochrane Database Syst Rev* 2013; **2013**(8): CD006826 <https://pubmed.ncbi.nlm.nih.gov/23990350>.
973. Beech AS, Lea S, Kolsum U, et al. Bacteria and sputum inflammatory cell counts; a COPD cohort analysis. *Respir Res* 2020; **21**(1): 289 <https://pubmed.ncbi.nlm.nih.gov/33131502>.
974. Martinez-Garcia MA, Faner R, Oscullo G, et al. Inhaled Steroids, Circulating Eosinophils, Chronic Airway Infection, and Pneumonia Risk in Chronic Obstructive Pulmonary Disease. A Network Analysis. *Am J Respir Crit Care Med* 2020; **201**(9): 1078-85 <https://pubmed.ncbi.nlm.nih.gov/31922913>.
975. Roche N, Chapman KR, Vogelmeier CF, et al. Blood Eosinophils and Response to Maintenance Chronic Obstructive Pulmonary Disease Treatment. Data from the FLAME Trial. *Am J Respir Crit Care Med* 2017; **195**(9): 1189-97 <https://pubmed.ncbi.nlm.nih.gov/28278391>.
976. Watz H, Tetzlaff K, Wouters EF, et al. Blood eosinophil count and exacerbations in severe chronic obstructive pulmonary disease after withdrawal of inhaled corticosteroids: a post-hoc analysis of the WISDOM trial. *Lancet Respir Med* 2016; **4**(5): 390-8 <https://pubmed.ncbi.nlm.nih.gov/27066739>.
977. Leitao Filho FS, Takiguchi H, Akata K, et al. Effects of Inhaled Corticosteroid/Long-Acting beta(2)-Agonist Combination on the Airway Microbiome of Patients with Chronic Obstructive Pulmonary Disease: A Randomized Controlled Clinical Trial (DISARM). *Am J Respir Crit Care Med* 2021; **204**(10): 1143-52 <https://pubmed.ncbi.nlm.nih.gov/34464242>.
978. Dransfield MT, Bourbeau J, Jones PW, et al. Once-daily inhaled fluticasone furoate and vilanterol versus vilanterol only for prevention of exacerbations of COPD: two replicate double-blind, parallel-group, randomised controlled trials. *Lancet Respir Med* 2013; **1**(3): 210-23 <https://pubmed.ncbi.nlm.nih.gov/24429127>.
979. Crim C, Dransfield MT, Bourbeau J, et al. Pneumonia risk with inhaled fluticasone furoate and vilanterol compared with vilanterol alone in patients with COPD. *Ann Am Thorac Soc* 2015; **12**(1): 27-34 <https://pubmed.ncbi.nlm.nih.gov/25490706>.
980. Crim C, Calverley PMA, Anderson JA, et al. Pneumonia risk with inhaled fluticasone furoate and vilanterol in COPD patients with moderate airflow limitation: The SUMMIT trial. *Respir Med* 2017; **131**: 27-34 <https://pubmed.ncbi.nlm.nih.gov/28947039>.
981. Pavord ID, Lettis S, Anzueto A, Barnes N. Blood eosinophil count and pneumonia risk in patients with chronic obstructive pulmonary disease: a patient-level meta-analysis. *Lancet Respir Med* 2016; **4**(9): 731-41 <https://pubmed.ncbi.nlm.nih.gov/27460163>.
982. Johnell O, Pauwels R, Lofdahl CG, et al. Bone mineral density in patients with chronic obstructive pulmonary disease treated with budesonide Turbuhaler. *Eur Respir J* 2002; **19**(6): 1058-63 <https://pubmed.ncbi.nlm.nih.gov/12108857>.
983. Ferguson GT, Calverley PMA, Anderson JA, et al. Prevalence and progression of osteoporosis in patients with COPD: results from the TOWARDS a Revolution in COPD Health study. *Chest* 2009; **136**(6): 1456-65 <https://pubmed.ncbi.nlm.nih.gov/19581353>.
984. Loke YK, Cavallazzi R, Singh S. Risk of fractures with inhaled corticosteroids in COPD: systematic review and meta-analysis of randomised controlled trials and observational studies. *Thorax* 2011; **66**(8): 699-708 <https://pubmed.ncbi.nlm.nih.gov/21602540>.
985. Suissa S, Kezouh A, Ernst P. Inhaled corticosteroids and the risks of diabetes onset and progression. *Am J Med* 2010; **123**(11): 1001-6 <https://pubmed.ncbi.nlm.nih.gov/20870201>.
986. Wang JJ, Rochtchina E, Tan AG, Cumming RG, Leeder SR, Mitchell P. Use of inhaled and oral corticosteroids and the long-term risk of cataract. *Ophthalmology* 2009; **116**(4): 652-7 <https://pubmed.ncbi.nlm.nih.gov/19243828>.
987. Andrejak C, Nielsen R, Thomsen VO, Duhaut P, Sorensen HT, Thomsen RW. Chronic respiratory disease, inhaled corticosteroids and risk of non-tuberculous mycobacteriosis. *Thorax* 2013; **68**(3): 256-62 <https://pubmed.ncbi.nlm.nih.gov/22781123>.
988. Dong YH, Chang CH, Wu FL, et al. Use of inhaled corticosteroids in patients with COPD and the risk of TB and influenza: A systematic review and meta-analysis of randomized controlled trials. a systematic review and meta-analysis of randomized controlled trials. *Chest* 2014; **145**(6): 1286-97 <https://pubmed.ncbi.nlm.nih.gov/24504044>.

989. Lee CH, Kim K, Hyun MK, Jang EJ, Lee NR, Yim JJ. Use of inhaled corticosteroids and the risk of tuberculosis. *Thorax* 2013; **68**(12): 1105-13 <https://pubmed.ncbi.nlm.nih.gov/23749841>.
990. Castellana G, Castellana M, Castellana C, et al. Inhaled Corticosteroids And Risk Of Tuberculosis In Patients With Obstructive Lung Diseases: A Systematic Review And Meta-Analysis Of Non-randomized Studies. *Int J Chron Obstruct Pulmon Dis* 2019; **14**: 2219-27 <https://pubmed.ncbi.nlm.nih.gov/31576118>.
991. Price D, Yawn B, Brusselle G, Rossi A. Risk-to-benefit ratio of inhaled corticosteroids in patients with COPD. *Prim Care Respir J* 2013; **22**(1): 92-100 <https://pubmed.ncbi.nlm.nih.gov/23135217>.
992. Nadeem NJ, Taylor SJ, Eldridge SM. Withdrawal of inhaled corticosteroids in individuals with COPD--a systematic review and comment on trial methodology. *Respir Res* 2011; **12**(1): 107 <https://pubmed.ncbi.nlm.nih.gov/21838890>.
993. van der Valk P, Monninkhof E, van der Palen J, Zielhuis G, van Herwaarden C. Effect of discontinuation of inhaled corticosteroids in patients with chronic obstructive pulmonary disease: the COPE study. *Am J Respir Crit Care Med* 2002; **166**(10): 1358-63 <https://pubmed.ncbi.nlm.nih.gov/12406823>.
994. Wouters EF, Postma DS, Fokkens B, et al. Withdrawal of fluticasone propionate from combined salmeterol/fluticasone treatment in patients with COPD causes immediate and sustained disease deterioration: a randomised controlled trial. *Thorax* 2005; **60**(6): 480-7 <https://pubmed.ncbi.nlm.nih.gov/15923248>.
995. Kunz LIZ, Postma DS, Klooster K, et al. Relapse in FEV1 Decline After Steroid Withdrawal in COPD. *Chest* 2015; **148**(2): 389-96 <https://pubmed.ncbi.nlm.nih.gov/25836351>.
996. Magnussen H, Disse B, Rodriguez-Roisin R, et al. Withdrawal of inhaled glucocorticoids and exacerbations of COPD. *N Engl J Med* 2014; **371**(14): 1285-94 <https://pubmed.ncbi.nlm.nih.gov/25196117>.
997. Chalmers JD, Laska IF, Franssen FME, et al. Withdrawal of inhaled corticosteroids in COPD: a European Respiratory Society guideline. *Eur Respir J* 2020; **55**(6): <https://pubmed.ncbi.nlm.nih.gov/32366483>.
998. Oshagbemi OA, Franssen FME, van Kraaij S, et al. Blood Eosinophil Counts, Withdrawal of Inhaled Corticosteroids and Risk of COPD Exacerbations and Mortality in the Clinical Practice Research Datalink (CPRD). *Copd* 2019; **16**(2): 152-9 <https://pubmed.ncbi.nlm.nih.gov/31117850>.
999. Suissa S, Dell'Aniello S, Ernst P. Discontinuation of Inhaled Corticosteroids from Triple Therapy in COPD: Effects on Major Outcomes in Real World Clinical Practice. *Copd* 2022; **19**(1): 133-41 <https://pubmed.ncbi.nlm.nih.gov/35392746>.
1000. Vogelmeier CF, Worth H, Buhl R, Criée CP, Gückel E, Kardos P. Impact of switching from triple therapy to dual bronchodilation in COPD: the DACCORD 'real world' study. *Respir Res* 2022; **23**(1): 109 <https://pubmed.ncbi.nlm.nih.gov/35501806>.
1001. Neches García V, Vallejo-Aparicio LA, Ismaila AS, et al. Clinical and Economic Impact of Long-Term Inhaled Corticosteroid Withdrawal in Patients with Chronic Obstructive Pulmonary Disease Treated with Triple Therapy in Spain. *Int J Chron Obstruct Pulmon Dis* 2022; **17**: 2161-74 <https://pubmed.ncbi.nlm.nih.gov/36101793>.
1002. Brusselle G, Price D, Gruffydd-Jones K, et al. The inevitable drift to triple therapy in COPD: an analysis of prescribing pathways in the UK. *Int J Chron Obstruct Pulmon Dis* 2015; **10**: 2207-17 <https://pubmed.ncbi.nlm.nih.gov/26527869>.
1003. Welte T, Miravittles M, Hernandez P, et al. Efficacy and tolerability of budesonide/formoterol added to tiotropium in patients with chronic obstructive pulmonary disease. *Am J Respir Crit Care Med* 2009; **180**(8): 741-50 <https://pubmed.ncbi.nlm.nih.gov/19644045>.
1004. Singh D, Brooks J, Hagan G, Cahn A, O'Connor BJ. Superiority of "triple" therapy with salmeterol/fluticasone propionate and tiotropium bromide versus individual components in moderate to severe COPD. *Thorax* 2008; **63**(7): 592-8 <https://pubmed.ncbi.nlm.nih.gov/18245142>.
1005. Jung KS, Park HY, Park SY, et al. Comparison of tiotropium plus fluticasone propionate/salmeterol with tiotropium in COPD: a randomized controlled study. *Respir Med* 2012; **106**(3): 382-9 <https://pubmed.ncbi.nlm.nih.gov/21975275>.
1006. Hanania NA, Crater GD, Morris AN, Emmett AH, O'Dell DM, Niewoehner DE. Benefits of adding fluticasone propionate/salmeterol to tiotropium in moderate to severe COPD. *Respir Med* 2012; **106**(1): 91-101 <https://pubmed.ncbi.nlm.nih.gov/22040533>.
1007. Frith PA, Thompson PJ, Ratnavadivel R, et al. Glycopyrronium once-daily significantly improves lung function and health status when combined with salmeterol/fluticasone in patients with COPD: the GLISTEN study, a randomised controlled trial. *Thorax* 2015; **70**(6): 519-27 <https://pubmed.ncbi.nlm.nih.gov/25841237>.
1008. Lipson DA, Barnacle H, Birk R, et al. FULFIL Trial: Once-Daily Triple Therapy for Patients with Chronic Obstructive Pulmonary Disease. *Am J Respir Crit Care Med* 2017; **196**(4): 438-46 <https://pubmed.ncbi.nlm.nih.gov/28375647>.
1009. Siler TM, Kerwin E, Singletary K, Brooks J, Church A. Efficacy and Safety of Umeclidinium Added to Fluticasone Propionate/Salmeterol in Patients with COPD: Results of Two Randomized, Double-Blind Studies. *COPD* 2016; **13**(1): 1-10 <https://pubmed.ncbi.nlm.nih.gov/26451734>.
1010. Singh D, Papi A, Corradi M, et al. Single inhaler triple therapy versus inhaled corticosteroid plus long-acting beta2-agonist therapy for chronic obstructive pulmonary disease (TRILOGY): a double-blind, parallel group, randomised controlled trial. *Lancet* 2016; **388**(10048): 963-73 <https://pubmed.ncbi.nlm.nih.gov/27598678>.
1011. Bardsley S, Criner GJ, Halpin DMG, et al. Single-inhaler triple therapy fluticasone furoate/umeclidinium/vilanterol versus dual therapy in current and former smokers with COPD: IMPACT trial post hoc analysis. *Respir Med* 2022; **205**: 107040 <https://pubmed.ncbi.nlm.nih.gov/36470149>.
1012. Vestbo J, Fabbri L, Papi A, et al. Inhaled corticosteroid containing combinations and mortality in COPD. *Eur Respir J* 2018; **52**(6): 1801230 <https://pubmed.ncbi.nlm.nih.gov/30209195>.

1013. Lipson DA, Crim C, Criner GJ, et al. Reduction in All-Cause Mortality with Fluticasone Furoate/Umeclidinium/Vilanterol in Patients with Chronic Obstructive Pulmonary Disease. *Am J Respir Crit Care Med* 2020; **201**(12): 1508-16 <https://pubmed.ncbi.nlm.nih.gov/32162970>.
1014. Manson SC, Brown RE, Cerulli A, Vidaurre CF. The cumulative burden of oral corticosteroid side effects and the economic implications of steroid use. *Respir Med* 2009; **103**(7): 975-94 <https://pubmed.ncbi.nlm.nih.gov/19372037>.
1015. Walters JA, Tan DJ, White CJ, Gibson PG, Wood-Baker R, Walters EH. Systemic corticosteroids for acute exacerbations of chronic obstructive pulmonary disease. *Cochrane Database Syst Rev* 2014; (9): CD001288 <https://pubmed.ncbi.nlm.nih.gov/25178099>.
1016. Renkema TE, Schouten JP, Koeter GH, Postma DS. Effects of long-term treatment with corticosteroids in COPD. *Chest* 1996; **109**(5): 1156-62 <https://pubmed.ncbi.nlm.nih.gov/8625660>.
1017. Rice KL, Rubins JB, Lebahn F, et al. Withdrawal of chronic systemic corticosteroids in patients with COPD: a randomized trial. *Am J Respir Crit Care Med* 2000; **162**(1): 174-8 <https://pubmed.ncbi.nlm.nih.gov/10903238>.
1018. Rabe KF. Update on roflumilast, a phosphodiesterase 4 inhibitor for the treatment of chronic obstructive pulmonary disease. *Br J Pharmacol* 2011; **163**(1): 53-67 <https://pubmed.ncbi.nlm.nih.gov/21232047>.
1019. Calverley PM, Rabe KF, Goehring UM, et al. Roflumilast in symptomatic chronic obstructive pulmonary disease: two randomised clinical trials. *Lancet* 2009; **374**(9691): 685-94 <https://pubmed.ncbi.nlm.nih.gov/19716960>.
1020. Fabbri LM, Calverley PM, Izquierdo-Alonso JL, et al. Roflumilast in moderate-to-severe chronic obstructive pulmonary disease treated with longacting bronchodilators: two randomised clinical trials. *Lancet* 2009; **374**(9691): 695-703 <https://pubmed.ncbi.nlm.nih.gov/19716961>.
1021. Chong J, Leung B, Poole P. Phosphodiesterase 4 inhibitors for chronic obstructive pulmonary disease. *Cochrane Database Syst Rev* 2013; **11**(11): CD002309 <https://pubmed.ncbi.nlm.nih.gov/24190161>.
1022. Francis RS, May JR, Spicer CC. Chemotherapy of bronchitis. Influence of penicillin and tetracycline administered daily, or intermittently for exacerbations. A report to the Research Committee of the British Tuberculosis Association by its Bronchitis Subcommittee. *Br Med J* 1961; **2**(5258): 979-85 <https://pubmed.ncbi.nlm.nih.gov/13894512>.
1023. Francis RS, Spicer CC. Chemotherapy in chronic bronchitis. Influence of daily penicillin and tetracycline on exacerbations and their cost. *Br Med J* 1960; **1**(5169): 297-303 <https://pubmed.ncbi.nlm.nih.gov/13824401>.
1024. Johnston RN, McNeill RS, Smith DH, et al. Five-year winter chemoprophylaxis for chronic bronchitis. *Br Med J* 1969; **4**(5678): 265-9 <https://pubmed.ncbi.nlm.nih.gov/4899454>.
1025. Herath SC, Poole P. Prophylactic antibiotic therapy for chronic obstructive pulmonary disease (COPD). *Cochrane Database of Systematic Reviews* 2013; (11): CD009764 <https://pubmed.ncbi.nlm.nih.gov/24288145>.
1026. Ni W, Shao X, Cai X, et al. Prophylactic use of macrolide antibiotics for the prevention of chronic obstructive pulmonary disease exacerbation: a meta-analysis. *PLoS One* 2015; **10**(3): e0121257 <https://pubmed.ncbi.nlm.nih.gov/25812085>.
1027. Seemungal TA, Wilkinson TM, Hurst JR, Perera WR, Sapsford RJ, Wedzicha JA. Long-term erythromycin therapy is associated with decreased chronic obstructive pulmonary disease exacerbations. *Am J Respir Crit Care Med* 2008; **178**(11): 1139-47 <https://pubmed.ncbi.nlm.nih.gov/18723437>.
1028. Uzun S, Djamin RS, Kluymans JA, et al. Azithromycin maintenance treatment in patients with frequent exacerbations of chronic obstructive pulmonary disease (COLUMBUS): a randomised, double-blind, placebo-controlled trial. *Lancet Respir Med* 2014; **2**(5): 361-8 <https://pubmed.ncbi.nlm.nih.gov/24746000>.
1029. Sethi S, Jones PW, Theron MS, et al. Pulsed moxifloxacin for the prevention of exacerbations of chronic obstructive pulmonary disease: a randomized controlled trial. *Respir Res* 2010; **11**(1): 10 <https://pubmed.ncbi.nlm.nih.gov/20109213>.
1030. Allinson JP, Vlies BH, Brill SE, et al. A Double-Blind, Randomized, Placebo-controlled Trial of Long-Term Doxycycline Therapy on Exacerbation Rate in Patients with Stable Chronic Obstructive Pulmonary Disease. *Am J Respir Crit Care Med* 2023; **208**(5): 549-58 <https://pubmed.ncbi.nlm.nih.gov/37450935>.
1031. Cazzola M, Calzetta L, Page C, et al. Influence of N-acetylcysteine on chronic bronchitis or COPD exacerbations: a meta-analysis. *Eur Respir Rev* 2015; **24**(137): 451-61 <https://pubmed.ncbi.nlm.nih.gov/26324807>.
1032. Poole P, Chong J, Cates CJ. Mucolytic agents versus placebo for chronic bronchitis or chronic obstructive pulmonary disease. *Cochrane Database Syst Rev* 2015; (7): CD001287 <https://pubmed.ncbi.nlm.nih.gov/26222376>.
1033. Dal Negro RW, Wedzicha JA, Iversen M, et al. Effect of erdosteine on the rate and duration of COPD exacerbations: the RESTORE study. *Eur Respir J* 2017; **50**(4): PA675 <https://pubmed.ncbi.nlm.nih.gov/29025888>.
1034. Rogliani P, Matera MG, Page C, Puxeddu E, Cazzola M, Calzetta L. Efficacy and safety profile of mucolytic/antioxidant agents in chronic obstructive pulmonary disease: a comparative analysis across erdosteine, carbocysteine, and N-acetylcysteine. *Respir Res* 2019; **20**(1): 104 <https://pubmed.ncbi.nlm.nih.gov/31133026>.
1035. Poole P, Sathananthan K, Fortescue R. Mucolytic agents versus placebo for chronic bronchitis or chronic obstructive pulmonary disease. *Cochrane Database Syst Rev* 2019; **5**(5): CD001287 <https://pubmed.ncbi.nlm.nih.gov/31107966>.
1036. Anzueto A, Barjaktarevic IZ, Siler TM, et al. Ensifentrine, a Novel Phosphodiesterase 3 and 4 Inhibitor for the Treatment of Chronic Obstructive Pulmonary Disease: Randomized, Double-Blind, Placebo-controlled, Multicenter Phase III Trials (the ENHANCE Trials). *Am J Respir Crit Care Med* 2023; **208**(4): 406-16 <https://pubmed.ncbi.nlm.nih.gov/37364283>.
1037. Singh D, Lea S, Mathioudakis AG. Inhaled Phosphodiesterase Inhibitors for the Treatment of Chronic Obstructive Pulmonary Disease. *Drugs* 2021; **81**(16): 1821-30 <https://pubmed.ncbi.nlm.nih.gov/34731461>.

1038. Pavord ID, Chanez P, Criner GJ, et al. Mepolizumab for Eosinophilic Chronic Obstructive Pulmonary Disease. *N Engl J Med* 2017; **377**(17): 1613-29 <https://pubmed.ncbi.nlm.nih.gov/28893134>.
1039. Criner GJ, Celli BR, Brightling CE, et al. Benralizumab for the Prevention of COPD Exacerbations. *N Engl J Med* 2019; **381**(11): 1023-34 <https://pubmed.ncbi.nlm.nih.gov/31112385>.
1040. Lee JH, Kim HJ, Kim YH. The Effectiveness of Anti-leukotriene Agents in Patients with COPD: A Systemic Review and Meta-analysis. *Lung* 2015; **193**(4): 477-86 <https://pubmed.ncbi.nlm.nih.gov/25972156>.
1041. Liu L, Wang JL, Xu XY, Feng M, Hou Y, Chen L. Leukotriene receptor antagonists do not improve lung function decline in COPD: a meta-analysis. *Eur Rev Med Pharmacol Sci* 2018; **22**(3): 829-34 <https://pubmed.ncbi.nlm.nih.gov/29461616>.
1042. Rennard SI, Fogarty C, Kelsen S, et al. The safety and efficacy of infliximab in moderate to severe chronic obstructive pulmonary disease. *Am J Respir Crit Care Med* 2007; **175**(9): 926-34 <https://pubmed.ncbi.nlm.nih.gov/17290043>.
1043. Fraser A, Poole P. Immunostimulants versus placebo for preventing exacerbations in adults with chronic bronchitis or chronic obstructive pulmonary disease. *Cochrane Database Syst Rev* 2022; **11**(11): Cd013343 <https://pubmed.ncbi.nlm.nih.gov/36373977>.
1044. Dransfield MT, Voelker H, Bhatt SP, et al. Metoprolol for the Prevention of Acute Exacerbations of COPD. *N Engl J Med* 2019; **381**(24): 2304-14 <https://pubmed.ncbi.nlm.nih.gov/31633896>.
1045. Devereux G, Cotton S, Nath M, et al. Bisoprolol in Patients With Chronic Obstructive Pulmonary Disease at High Risk of Exacerbation: The BICS Randomized Clinical Trial. *Jama* 2024: <https://pubmed.ncbi.nlm.nih.gov/38762800>.
1046. Criner GJ, Connett JE, Aaron SD, et al. Simvastatin for the prevention of exacerbations in moderate-to-severe COPD. *N Engl J Med* 2014; **370**(23): 2201-10 <https://pubmed.ncbi.nlm.nih.gov/24836125>.
1047. Ingebrigtsen TS, Marott JL, Nordestgaard BG, Lange P, Hallas J, Vestbo J. Statin use and exacerbations in individuals with chronic obstructive pulmonary disease. *Thorax* 2015; **70**(1): 33-40 <https://pubmed.ncbi.nlm.nih.gov/25349333>.
1048. Lehouck A, Mathieu C, Carremans C, et al. High doses of vitamin D to reduce exacerbations in chronic obstructive pulmonary disease: a randomized trial. *Ann Intern Med* 2012; **156**(2): 105-14 <https://pubmed.ncbi.nlm.nih.gov/22250141>.
1049. Jolliffe DA, Greenberg L, Hooper RL, et al. Vitamin D to prevent exacerbations of COPD: systematic review and meta-analysis of individual participant data from randomised controlled trials. *Thorax* 2019; **74**(4): 337-45 <https://pubmed.ncbi.nlm.nih.gov/30630893>.
1050. Rafiq R, Aleva FE, Schrupf JA, et al. Vitamin D supplementation in chronic obstructive pulmonary disease patients with low serum vitamin D: a randomized controlled trial. *Am J Clin Nutr* 2022; **116**(2): 491-9 <https://pubmed.ncbi.nlm.nih.gov/35383823>.
1051. World Health Organization. Adherence to long-term therapies : evidence for action (2003) [edited by Eduardo Sabaté]. Online document available at <https://apps.who.int/iris/handle/10665/42682> [accessed Oct 2024].
1052. Chen R, Gao Y, Wang H, Shang H, Xuan J. Association Between Adherence to Maintenance Medication in Patients with COPD and Acute Exacerbation Occurrence and Cost in China: A Retrospective Cohort Database Study. *Int J Chron Obstruct Pulmon Dis* 2020; **15**: 963-71 <https://pubmed.ncbi.nlm.nih.gov/32440108>.
1053. Chrystyn H, Small M, Milligan G, Higgins V, Gil EG, Estruch J. Impact of patients' satisfaction with their inhalers on treatment compliance and health status in COPD. *Respir Med* 2014; **108**(2): 358-65 <https://pubmed.ncbi.nlm.nih.gov/24209768>.
1054. Ierodiakonou D, Sifaki-Pistolla D, Kampouraki M, et al. Adherence to inhalers and comorbidities in COPD patients. A cross-sectional primary care study from Greece. *BMC Pulm Med* 2020; **20**(1): 253 <https://pubmed.ncbi.nlm.nih.gov/32977779>.
1055. Ingebrigtsen TS, Marott JL, Nordestgaard BG, et al. Low use and adherence to maintenance medication in chronic obstructive pulmonary disease in the general population. *J Gen Intern Med* 2015; **30**(1): 51-9 <https://pubmed.ncbi.nlm.nih.gov/25245885>.
1056. Moreira ATA, Pinto CR, Lemos ACM, Assuncao-Costa L, Souza GS, Martins Netto E. Evidence of the association between adherence to treatment and mortality among patients with COPD monitored at a public disease management program in Brazil. *J Bras Pneumol* 2021; **48**(1): e20210120 <https://pubmed.ncbi.nlm.nih.gov/34909924>.
1057. van Boven JF, Chavannes NH, van der Molen T, Rutten-van Molken MP, Postma MJ, Vegter S. Clinical and economic impact of non-adherence in COPD: a systematic review. *Respir Med* 2014; **108**(1): 103-13 <https://pubmed.ncbi.nlm.nih.gov/24070566>.
1058. van Boven JF, Tommelein E, Boussey K, et al. Improving inhaler adherence in patients with chronic obstructive pulmonary disease: a cost-effectiveness analysis. *Respir Res* 2014; **15**(1): 66 <https://pubmed.ncbi.nlm.nih.gov/24929799>.
1059. Vestbo J, Anderson JA, Calverley PM, et al. Adherence to inhaled therapy, mortality and hospital admission in COPD. *Thorax* 2009; **64**(11): 939-43 <https://pubmed.ncbi.nlm.nih.gov/19703830>.
1060. Wisniewski D, Porzezinska M, Gruchala-Niedoszytko M, Niedoszytko M, Slominski JM, Jassem E. Factors influencing adherence to treatment in COPD patients and its relationship with disease exacerbations. *Pneumonol Alergol Pol* 2014; **82**(2): 96-104 <https://pubmed.ncbi.nlm.nih.gov/24615193>.
1061. Kim JA, Lim MK, Kim K, Park J, Rhee CK. Adherence to Inhaled Medications and its Effect on Healthcare Utilization and Costs Among High-Grade Chronic Obstructive Pulmonary Disease Patients. *Clin Drug Investig* 2018; **38**(4): 333-40 <https://pubmed.ncbi.nlm.nih.gov/29209982>.

1062. Moradkhani B, Mollazadeh S, Niloofar P, Bashiri A, Oghazian MB. Association between medication adherence and health-related quality of life in patients with chronic obstructive pulmonary disease. *J Pharm Health Care Sci* 2021; **7**(1): 40 <https://pubmed.ncbi.nlm.nih.gov/34775992>.
1063. Bhattarai B, Walpola R, Mey A, Anoopkumar-Dukie S, Khan S. Barriers and Strategies for Improving Medication Adherence Among People Living With COPD: A Systematic Review. *Respir Care* 2020; **65**(11): 1738-50 <https://pubmed.ncbi.nlm.nih.gov/32576706>.
1064. Unni EJ, Gupta S, Sternbach N. Using the Medication Adherence Reasons Scale (MAR-Scale) in asthma and chronic obstructive pulmonary disease to determine the extent and identify the reasons for non-adherence. *Respir Med* 2021; **179**: 106337 <https://pubmed.ncbi.nlm.nih.gov/33639405>.
1065. Jarab AS, Mukattash TL. Exploring variables associated with medication non-adherence in patients with COPD. *Int J Clin Pharm* 2019; **41**(5): 1202-9 <https://pubmed.ncbi.nlm.nih.gov/31468254>.
1066. Montes de Oca M, Menezes A, Wehrmeister FC, et al. Adherence to inhaled therapies of COPD patients from seven Latin American countries: The LASSYC study. *PLoS One* 2017; **12**(11): e0186777 <https://pubmed.ncbi.nlm.nih.gov/29140978>.
1067. Ngo CQ, Phan DM, Vu GV, et al. Inhaler Technique and Adherence to Inhaled Medications among Patients with Acute Exacerbation of Chronic Obstructive Pulmonary Disease in Vietnam. *Int J Environ Res Public Health* 2019; **16**(2): <https://pubmed.ncbi.nlm.nih.gov/30634631>.
1068. Shrestha R, Pant A, Shakya Shrestha S, Shrestha B, Gurung RB, Karmacharya BM. A Cross-Sectional Study of Medication Adherence Pattern and Factors Affecting the Adherence in Chronic Obstructive Pulmonary Disease. *Kathmandu Univ Med J (KUMJ)* 2015; **13**(49): 64-70 <https://pubmed.ncbi.nlm.nih.gov/26620752>.
1069. Rand CS. I took the medicine like you told me, doctor: Self-report of adherence with medical regimens. In: Stone A, ed. The science of self-report: implications for research and practice. Mahway, NJ: Lawrence Erlbaum Associates; 2000: 257-76.
1070. DiMatteo MR. Variations in patients' adherence to medical recommendations: a quantitative review of 50 years of research. *Med Care* 2004; **42**(3): 200-9 <https://pubmed.ncbi.nlm.nih.gov/15076819>.
1071. Bourbeau J, Bartlett SJ. Patient adherence in COPD. *Thorax* 2008; **63**(9): 831-8 <https://pubmed.ncbi.nlm.nih.gov/18728206>.
1072. Swiatoniewska N, Chabowski M, Polanski J, Mazur G, Jankowska-Polanska B. Adherence to Therapy in Chronic Obstructive Pulmonary Disease: A Systematic Review. *Adv Exp Med Biol* 2020; **1271**: 37-47 <https://pubmed.ncbi.nlm.nih.gov/32016912>.
1073. Le TT, Bjarnadottir M, Qato DM, Magder L, Zafari Z, Simoni-Wastila L. Prediction of treatment nonadherence among older adults with chronic obstructive pulmonary disease using Medicare real-world data. *J Manag Care Spec Pharm* 2022; **28**(6): 631-44 <https://pubmed.ncbi.nlm.nih.gov/35621722>.
1074. Tottenborg SS, Lange P, Johnsen SP, Nielsen H, Ingebrigtsen TS, Thomsen RW. Socioeconomic inequalities in adherence to inhaled maintenance medications and clinical prognosis of COPD. *Respir Med* 2016; **119**: 160-7 <https://pubmed.ncbi.nlm.nih.gov/27692139>.
1075. Tabyshova A, Sooronbaev T, Akylbekov A, et al. Medication availability and economic barriers to adherence in asthma and COPD patients in low-resource settings. *NPJ Prim Care Respir Med* 2022; **32**(1): 20 <https://pubmed.ncbi.nlm.nih.gov/35637220>.
1076. Bosnic-Anticevich S, Chrystyn H, Costello RW, et al. The use of multiple respiratory inhalers requiring different inhalation techniques has an adverse effect on COPD outcomes. *Int J Chron Obstruct Pulmon Dis* 2017; **12**: 59-71 <https://pubmed.ncbi.nlm.nih.gov/28053517>.
1077. Gallefoss F, Bakke PS. Impact of patient education and self-management on morbidity in asthmatics and patients with chronic obstructive pulmonary disease. *Respir Med* 2000; **94**(3): 279-87 <https://pubmed.ncbi.nlm.nih.gov/10783940>.
1078. Chapman KR, Stockley RA, Dawkins C, Wilkes MM, Navickis RJ. Augmentation therapy for alpha1 antitrypsin deficiency: a meta-analysis. *COPD* 2009; **6**(3): 177-84 <https://pubmed.ncbi.nlm.nih.gov/19811373>.
1079. The Alpha-1-Antitrypsin Deficiency Registry Study Group. Survival and FEV1 decline in individuals with severe deficiency of alpha1-antitrypsin. The Alpha-1-Antitrypsin Deficiency Registry Study Group. *Am J Respir Crit Care Med* 1998; **158**(1): 49-59 <https://pubmed.ncbi.nlm.nih.gov/9655706>.
1080. Dirksen A, Dijkman JH, Madsen F, et al. A randomized clinical trial of alpha(1)-antitrypsin augmentation therapy. *Am J Respir Crit Care Med* 1999; **160**(5 Pt 1): 1468-72 <https://pubmed.ncbi.nlm.nih.gov/10556107>.
1081. Dirksen A, Piitulainen E, Parr DG, et al. Exploring the role of CT densitometry: a randomised study of augmentation therapy in alpha1-antitrypsin deficiency. *Eur Respir J* 2009; **33**(6): 1345-53 <https://pubmed.ncbi.nlm.nih.gov/19196813>.
1082. McElvaney NG, Burdon J, Holmes M, et al. Long-term efficacy and safety of alpha1 proteinase inhibitor treatment for emphysema caused by severe alpha1 antitrypsin deficiency: an open-label extension trial (RAPID-OLE). *Lancet Respir Med* 2017; **5**(1): 51-60 <https://pubmed.ncbi.nlm.nih.gov/27916480>.
1083. Stockley RA, Edgar RG, Pillai A, Turner AM. Individualized lung function trends in alpha-1-antitrypsin deficiency: a need for patience in order to provide patient centered management? *Int J Chron Obstruct Pulmon Dis* 2016; **11**: 1745-56 <https://pubmed.ncbi.nlm.nih.gov/27536086>.
1084. Stoller JK, Aboussouan LS. A review of alpha1-antitrypsin deficiency. *Am J Respir Crit Care Med* 2012; **185**(3): 246-59 <https://pubmed.ncbi.nlm.nih.gov/21960536>.

1085. Sandhaus RA, Turino G, Brantly ML, et al. The Diagnosis and Management of Alpha-1 Antitrypsin Deficiency in the Adult. *Chronic Obstr Pulm Dis* 2016; **3**(3): 668-82 <https://pubmed.ncbi.nlm.nih.gov/28848891>.
1086. Fraughen DD, Ghosh AJ, Hobbs BD, et al. Augmentation Therapy for Severe Alpha-1 Antitrypsin Deficiency Improves Survival and Is Decoupled from Spirometric Decline-A Multinational Registry Analysis. *Am J Respir Crit Care Med* 2023; **208**(9): 964-74 <https://pubmed.ncbi.nlm.nih.gov/37624745>.
1087. Schildmann EK, Remi C, Bausewein C. Levodropropizine in the management of cough associated with cancer or nonmalignant chronic disease--a systematic review. *J Pain Palliat Care Pharmacother* 2011; **25**(3): 209-18 <https://pubmed.ncbi.nlm.nih.gov/21806417>.
1088. Barbera JA, Roger N, Roca J, Rovira I, Higenbottam TW, Rodriguez-Roisin R. Worsening of pulmonary gas exchange with nitric oxide inhalation in chronic obstructive pulmonary disease. *Lancet* 1996; **347**(8999): 436-40 <https://pubmed.ncbi.nlm.nih.gov/8618485>.
1089. Blanco I, Santos S, Gea J, et al. Sildenafil to improve respiratory rehabilitation outcomes in COPD: a controlled trial. *Eur Respir J* 2013; **42**(4): 982-92 <https://pubmed.ncbi.nlm.nih.gov/23429918>.
1090. Goudie AR, Lipworth BJ, Hopkinson PJ, Wei L, Struthers AD. Tadalafil in patients with chronic obstructive pulmonary disease: a randomised, double-blind, parallel-group, placebo-controlled trial. *Lancet Respir Med* 2014; **2**(4): 293-300 <https://pubmed.ncbi.nlm.nih.gov/24717626>.
1091. Mullen JB, Wright JL, Wiggs BR, Pare PD, Hogg JC. Structure of central airways in current smokers and ex-smokers with and without mucus hypersecretion: relationship to lung function. *Thorax* 1987; **42**(11): 843-8 <https://pubmed.ncbi.nlm.nih.gov/3424265>.
1092. Burgel PR, Nadel JA. Roles of epidermal growth factor receptor activation in epithelial cell repair and mucin production in airway epithelium. *Thorax* 2004; **59**(11): 992-6 <https://pubmed.ncbi.nlm.nih.gov/15516478>.
1093. Alghamdi SM, Alsulayyim AS, Alasmari AM, et al. Oscillatory positive expiratory pressure therapy in COPD (O-COPD): a randomised controlled trial. *Thorax* 2023; **78**(2): 136-43 <https://pubmed.ncbi.nlm.nih.gov/35948418>.
1094. Coppolo DP, Schloss J, Suggett JA, Mitchell JP. Non-Pharmaceutical Techniques for Obstructive Airway Clearance Focusing on the Role of Oscillating Positive Expiratory Pressure (OPEP): A Narrative Review. *Pulm Ther* 2022; **8**(1): 1-41 <https://pubmed.ncbi.nlm.nih.gov/34860355>.
1095. Kellett F, Redfern J, Niven RM. Evaluation of nebulised hypertonic saline (7%) as an adjunct to physiotherapy in patients with stable bronchiectasis. *Respir Med* 2005; **99**(1): 27-31 <https://pubmed.ncbi.nlm.nih.gov/15672845>.
1096. Kellett F, Robert NM. Nebulised 7% hypertonic saline improves lung function and quality of life in bronchiectasis. *Respir Med* 2011; **105**(12): 1831-5 <https://pubmed.ncbi.nlm.nih.gov/22018993>.
1097. Clarke SW, Lopez-Vidriero MT, Pavia D, Thomson ML. The effect of sodium 2-mercapto-ethane sulphonate and hypertonic saline aerosols on bronchial clearance in chronic bronchitis. *Br J Clin Pharmacol* 1979; **7**(1): 39-44 <https://pubmed.ncbi.nlm.nih.gov/104724>.
1098. Valderramas SR, Atallah AN. Effectiveness and safety of hypertonic saline inhalation combined with exercise training in patients with chronic obstructive pulmonary disease: a randomized trial. *Respir Care* 2009; **54**(3): 327-33 <https://pubmed.ncbi.nlm.nih.gov/19245725>.
1099. Zhang Y, Song A, Liu J, Dai J, Lin J. Therapeutic effect of nebulized hypertonic saline for muco-obstructive lung diseases: a systematic review and meta-analysis with trial sequential analysis. *J Investig Med* 2021; **69**(3): 742-8 <https://pubmed.ncbi.nlm.nih.gov/33272932>.
1100. Calzetta L, Rogliani P, Matera MG, Cazzola M. A Systematic Review With Meta-Analysis of Dual Bronchodilation With LAMA/LABA for the Treatment of Stable COPD. *Chest* 2016; **149**(5): 1181-96 <https://pubmed.ncbi.nlm.nih.gov/26923629>.
1101. McGarvey L, Morice AH, Smith JA, et al. Effect of acclidinium bromide on cough and sputum symptoms in moderate-to-severe COPD in three phase III trials. *BMJ Open Respir Res* 2016; **3**(1): e000148 <https://pubmed.ncbi.nlm.nih.gov/28074135>.
1102. Hasani A, Toms N, Agnew JE, Sarno M, Harrison AJ, Dilworth P. The effect of inhaled tiotropium bromide on lung mucociliary clearance in patients with COPD. *Chest* 2004; **125**(5): 1726-34 <https://pubmed.ncbi.nlm.nih.gov/15136383>.
1103. Powrie DJ, Wilkinson TM, Donaldson GC, et al. Effect of tiotropium on sputum and serum inflammatory markers and exacerbations in COPD. *Eur Respir J* 2007; **30**(3): 472-8 <https://pubmed.ncbi.nlm.nih.gov/17504798>.
1104. O'Donnell AE, Barker AF, Ilowite JS, Fick RB. Treatment of idiopathic bronchiectasis with aerosolized recombinant human DNase I. rhDNase Study Group. *Chest* 1998; **113**(5): 1329-34 <https://pubmed.ncbi.nlm.nih.gov/9596315>.
1105. Wilkinson M, Sugumar K, Milan SJ, Hart A, Crockett A, Crossingham I. Mucolytics for bronchiectasis. *Cochrane Database Syst Rev* 2014; **2014**(5): CD001289 <https://pubmed.ncbi.nlm.nih.gov/24789119>.
1106. Ehre C, Rushton ZL, Wang B, et al. An Improved Inhaled Mucolytic to Treat Airway Muco-obstructive Diseases. *Am J Respir Crit Care Med* 2019; **199**(2): 171-80 <https://pubmed.ncbi.nlm.nih.gov/30212240>.
1107. Rowe SM, Jones I, Dransfield MT, et al. Efficacy and Safety of the CFTR Potentiator Icatinofor (QBW251) in COPD: Results from a Phase 2 Randomized Trial. *Int J Chron Obstruct Pulmon Dis* 2020; **15**: 2399-409 <https://pubmed.ncbi.nlm.nih.gov/33116455>.
1108. Garner JL, Shaipanich T, Hartman JE, et al. A prospective safety and feasibility study of metered cryospray for patients with chronic bronchitis in COPD. *Eur Respir J* 2020; **56**(6): <https://pubmed.ncbi.nlm.nih.gov/32586881>.

1109. Slebos DJ, Breen D, Coad J, et al. Safety and Histological Effect of Liquid Nitrogen Metered Spray Cryotherapy in the Lung. *Am J Respir Crit Care Med* 2017; **196**(10): 1351-2 <https://pubmed.ncbi.nlm.nih.gov/28358989>.
1110. Slebos DJ, Klooster K, Koegelenberg CF, et al. Targeted lung denervation for moderate to severe COPD: a pilot study. *Thorax* 2015; **70**(5): 411-9 <https://pubmed.ncbi.nlm.nih.gov/25739911>.
1111. Valipour A, Shah PL, Herth FJ, et al. Two-Year Outcomes for the Double-Blind, Randomized, Sham-Controlled Study of Targeted Lung Denervation in Patients with Moderate to Severe COPD: AIRFLOW-2. *Int J Chron Obstruct Pulmon Dis* 2020; **15**: 2807-16 <https://pubmed.ncbi.nlm.nih.gov/33177818>.
1112. Fan VS, Gaziano JM, Lew R, et al. A comprehensive care management program to prevent chronic obstructive pulmonary disease hospitalizations: a randomized, controlled trial. *Ann Intern Med* 2012; **156**(10): 673-83 <https://pubmed.ncbi.nlm.nih.gov/22586006>.
1113. Peytremann-Bridevaux I, Taffe P, Burnand B, Bridevaux PO, Puhan MA. Mortality of patients with COPD participating in chronic disease management programmes: a happy end? *Thorax* 2014; **69**(9): 865-6 <https://pubmed.ncbi.nlm.nih.gov/24718640>.
1114. Kessler R, Casan-Clara P, Koehler D, et al. COMET: a multicomponent home-based disease-management programme versus routine care in severe COPD. *Eur Respir J* 2018; **51**(1): 1701612 <https://pubmed.ncbi.nlm.nih.gov/29326333>.
1115. Rose L, Istamboulian L, Carriere L, et al. Program of Integrated Care for Patients with Chronic Obstructive Pulmonary Disease and Multiple Comorbidities (PIC COPD(+)): a randomised controlled trial. *Eur Respir J* 2018; **51**(1): <https://pubmed.ncbi.nlm.nih.gov/29326330>.
1116. Aboumatar H, Naqibuddin M, Chung S, et al. Effect of a Hospital-Initiated Program Combining Transitional Care and Long-term Self-management Support on Outcomes of Patients Hospitalized With Chronic Obstructive Pulmonary Disease: A Randomized Clinical Trial. *JAMA* 2019; **322**(14): 1371-80 <https://pubmed.ncbi.nlm.nih.gov/31593271>.
1117. Benzo R, Vickers K, Novotny PJ, et al. Health Coaching and Chronic Obstructive Pulmonary Disease Rehospitalization. A Randomized Study. *Am J Respir Crit Care Med* 2016; **194**(6): 672-80 <https://pubmed.ncbi.nlm.nih.gov/26953637>.
1118. Benzo R, McEvoy C. Effect of Health Coaching Delivered by a Respiratory Therapist or Nurse on Self-Management Abilities in Severe COPD: Analysis of a Large Randomized Study. *Respir Care* 2019; **64**(9): 1065-72 <https://pubmed.ncbi.nlm.nih.gov/30914491>.
1119. Poot CC, Meijer E, Kruis AL, Smidt N, Chavannes NH, Honkoop PJ. Integrated disease management interventions for patients with chronic obstructive pulmonary disease. *Cochrane Database Syst Rev* 2021; **9**(9): CD009437 <https://pubmed.ncbi.nlm.nih.gov/34495549>.
1120. Kruis AL, Boland MR, Assendelft WJ, et al. Effectiveness of integrated disease management for primary care chronic obstructive pulmonary disease patients: results of cluster randomised trial. *BMJ* 2014; **349**: g5392 <https://pubmed.ncbi.nlm.nih.gov/25209620>.
1121. Licskai C, Hussey A, Rowley V, et al. Quantifying sustained health system benefits of primary care-based integrated disease management for COPD: a 6-year interrupted time series study. *Thorax* 2024; <https://pubmed.ncbi.nlm.nih.gov/38889973>.
1122. Gregersen TL, Green A, Frausing E, Ringbaek T, Brondum E, Suppli Ulrik C. Do telemedical interventions improve quality of life in patients with COPD? A systematic review. *Int J Chron Obstruct Pulmon Dis* 2016; **11**: 809-22 <https://pubmed.ncbi.nlm.nih.gov/27143872>.
1123. Cartwright M, Hirani SP, Rixon L, et al. Effect of telehealth on quality of life and psychological outcomes over 12 months (Whole Systems Demonstrator telehealth questionnaire study): nested study of patient reported outcomes in a pragmatic, cluster randomised controlled trial. *BMJ* 2013; **346**: f653 <https://pubmed.ncbi.nlm.nih.gov/23444424>.
1124. Pitta F, Troosters T, Spruit MA, Probst VS, Decramer M, Gosselink R. Characteristics of physical activities in daily life in chronic obstructive pulmonary disease. *Am J Respir Crit Care Med* 2005; **171**(9): 972-7 <https://pubmed.ncbi.nlm.nih.gov/15665324>.
1125. Watz H, Pitta F, Rochester CL, et al. An official European Respiratory Society statement on physical activity in COPD. *Eur Respir J* 2014; **44**(6): 1521-37 <https://pubmed.ncbi.nlm.nih.gov/25359358>.
1126. Garcia-Aymerich J, Lange P, Benet M, Schnohr P, Anto JM. Regular physical activity reduces hospital admission and mortality in chronic obstructive pulmonary disease: a population based cohort study. *Thorax* 2006; **61**(9): 772-8 <https://pubmed.ncbi.nlm.nih.gov/16738033>.
1127. Yohannes AM, Baldwin RC, Connolly M. Mortality predictors in disabling chronic obstructive pulmonary disease in old age. *Age Ageing* 2002; **31**(2): 137-40 <https://pubmed.ncbi.nlm.nih.gov/11937477>.
1128. Mantoani LC, Rubio N, McKinstry B, MacNee W, Rabinovich RA. Interventions to modify physical activity in patients with COPD: a systematic review. *Eur Respir J* 2016; **48**(1): 69-81 <https://pubmed.ncbi.nlm.nih.gov/27103381>.
1129. Spielmanns M, Gloeckl R, Jarosch I, et al. Using a smartphone application maintains physical activity following pulmonary rehabilitation in patients with COPD: a randomised controlled trial. *Thorax* 2023; **78**(5): 442-50 <https://pubmed.ncbi.nlm.nih.gov/35450945>.
1130. Robinson SA, Shimada SL, Quigley KS, Moy ML. A web-based physical activity intervention benefits persons with low self-efficacy in COPD: results from a randomized controlled trial. *J Behav Med* 2019; **42**(6): 1082-90 <https://pubmed.ncbi.nlm.nih.gov/30980223>.

1131. Nguyen HQ, Moy ML, Liu IA, et al. Effect of Physical Activity Coaching on Acute Care and Survival Among Patients With Chronic Obstructive Pulmonary Disease: A Pragmatic Randomized Clinical Trial. *JAMA Netw Open* 2019; **2**(8): e199657 <https://pubmed.ncbi.nlm.nih.gov/31418811>.
1132. Wan ES, Kantorowski A, Polak M, et al. Long-term effects of web-based pedometer-mediated intervention on COPD exacerbations. *Respir Med* 2020; **162**: 105878 <https://pubmed.ncbi.nlm.nih.gov/32056676>.
1133. Yang Y, Wei L, Wang S, et al. The effects of pursed lip breathing combined with diaphragmatic breathing on pulmonary function and exercise capacity in patients with COPD: a systematic review and meta-analysis. *Physiother Theory Pract* 2022; **38**(7): 847-57 <https://pubmed.ncbi.nlm.nih.gov/32808571>.
1134. Lahham A, McDonald CF, Holland AE. Exercise training alone or with the addition of activity counseling improves physical activity levels in COPD: a systematic review and meta-analysis of randomized controlled trials. *Int J Chron Obstruct Pulmon Dis* 2016; **11**: 3121-36 <https://pubmed.ncbi.nlm.nih.gov/27994451>.
1135. Ortega F, Toral J, Cejudo P, et al. Comparison of effects of strength and endurance training in patients with chronic obstructive pulmonary disease. *Am J Respir Crit Care Med* 2002; **166**(5): 669-74 <https://pubmed.ncbi.nlm.nih.gov/12204863>.
1136. Garber CE, Blissmer B, Deschenes MR, et al. American College of Sports Medicine position stand. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: guidance for prescribing exercise. *Med Sci Sports Exerc* 2011; **43**(7): 1334-59 <https://pubmed.ncbi.nlm.nih.gov/21694556>.
1137. Horowitz MB, Littenberg B, Mahler DA. Dyspnea ratings for prescribing exercise intensity in patients with COPD. *Chest* 1996; **109**(5): 1169-75 <https://pubmed.ncbi.nlm.nih.gov/8625662>.
1138. Puhan MA, Busching G, Schunemann HJ, VanOort E, Zaugg C, Frey M. Interval versus continuous high-intensity exercise in chronic obstructive pulmonary disease: a randomized trial. *Ann Intern Med* 2006; **145**(11): 816-25 <https://pubmed.ncbi.nlm.nih.gov/17146066>.
1139. Vogiatzis I, Nanas S, Roussos C. Interval training as an alternative modality to continuous exercise in patients with COPD. *Eur Respir J* 2002; **20**(1): 12-9 <https://pubmed.ncbi.nlm.nih.gov/12166558>.
1140. Liu X, Fu C, Hu W, et al. The effect of Tai Chi on the pulmonary rehabilitation of chronic obstructive pulmonary disease: a systematic review and meta-analysis. *Ann Palliat Med* 2021; **10**(4): 3763-82 <https://pubmed.ncbi.nlm.nih.gov/33894710>.
1141. Ramirez-Venegas A, Ward J, Lentine T, Mahler DA. Salmeterol reduces dyspnea and improves lung function in patients with COPD. *Chest* 1997; **112**(2): 336-40 <https://pubmed.ncbi.nlm.nih.gov/9266866>.
1142. Bernard S, Whittom F, Leblanc P, et al. Aerobic and strength training in patients with chronic obstructive pulmonary disease. *Am J Respir Crit Care Med* 1999; **159**(3): 896-901 <https://pubmed.ncbi.nlm.nih.gov/10051269>.
1143. Velloso M, do Nascimento NH, Gazzotti MR, Jardim JR. Evaluation of effects of shoulder girdle training on strength and performance of activities of daily living in patients with chronic obstructive pulmonary disease. *Int J Chron Obstruct Pulmon Dis* 2013; **8**: 187-92 <https://pubmed.ncbi.nlm.nih.gov/23589685>.
1144. Cardim AB, Marinho PE, Nascimento JF, Jr., Fuzari HK, Dornelas de Andrade A. Does Whole-Body Vibration Improve the Functional Exercise Capacity of Subjects With COPD? A Meta-Analysis. *Respir Care* 2016; **61**(11): 1552-9 <https://pubmed.ncbi.nlm.nih.gov/27651524>.
1145. Beaumont M, Forget P, Couturaud F, Reyckler G. Effects of inspiratory muscle training in COPD patients: A systematic review and meta-analysis. *Clin Respir J* 2018; **12**(7): 2178-88 <https://pubmed.ncbi.nlm.nih.gov/29665262>.
1146. Charususin N, Gosselink R, Decramer M, et al. Randomised controlled trial of adjunctive inspiratory muscle training for patients with COPD. *Thorax* 2018; **73**(10): 942-50 <https://pubmed.ncbi.nlm.nih.gov/29914940>.
1147. Chuang HY, Chang HY, Fang YY, Guo SE. The effects of threshold inspiratory muscle training in patients with chronic obstructive pulmonary disease: A randomised experimental study. *J Clin Nurs* 2017; **26**(23-24): 4830-8 <https://pubmed.ncbi.nlm.nih.gov/28382660>.
1148. Beaumont M, Mialon P, Le Ber C, et al. Effects of inspiratory muscle training on dyspnoea in severe COPD patients during pulmonary rehabilitation: controlled randomised trial. *Eur Respir J* 2018; **51**(1): 1701107 <https://pubmed.ncbi.nlm.nih.gov/29371379>.
1149. McCarthy B, Casey D, Devane D, Murphy K, Murphy E, Lacasse Y. Pulmonary rehabilitation for chronic obstructive pulmonary disease. *Cochrane Database Syst Rev* 2015; **2015**(2): CD003793 <https://pubmed.ncbi.nlm.nih.gov/25705944>.
1150. Moecke DP, Zhu K, Gill J, et al. Safety and Efficacy of Inpatient Pulmonary Rehabilitation for Patients Hospitalized with an Acute Exacerbation of Chronic Obstructive Pulmonary Disease: Systematic Review and Meta-analyses. *Ann Am Thorac Soc* 2023; **20**(2): 307-19 <https://pubmed.ncbi.nlm.nih.gov/36191273>.
1151. Sahin H, Naz I, Varol Y, Aksel N, Tuksavul F, Ozsoz A. Is a pulmonary rehabilitation program effective in COPD patients with chronic hypercapnic failure? *Expert Rev Respir Med* 2016; **10**(5): 593-8 <https://pubmed.ncbi.nlm.nih.gov/26954769>.
1152. Stolz D, Boersma W, Blasi F, et al. Exertional hypoxemia in stable COPD is common and predicted by circulating proadrenomedullin. *Chest* 2014; **146**(2): 328-38 <https://pubmed.ncbi.nlm.nih.gov/24722847>.
1153. Long-Term Oxygen Treatment Trial Research G, Albert RK, Au DH, et al. A Randomized Trial of Long-Term Oxygen for COPD with Moderate Desaturation. *N Engl J Med* 2016; **375**(17): 1617-27 <https://pubmed.ncbi.nlm.nih.gov/27783918>.

1154. Nonoyama ML, Brooks D, Lacasse Y, Guyatt GH, Goldstein RS. Oxygen therapy during exercise training in chronic obstructive pulmonary disease. *Cochrane Database Syst Rev* 2007; **2007**(2): CD005372 <https://pubmed.ncbi.nlm.nih.gov/17443585>.
1155. Pisani L, Fasano L, Corcione N, et al. Change in pulmonary mechanics and the effect on breathing pattern of high flow oxygen therapy in stable hypercapnic COPD. *Thorax* 2017; **72**(4): 373-5 <https://pubmed.ncbi.nlm.nih.gov/28104830>.
1156. Vitacca M, Paneroni M, Zampogna E, et al. High-Flow Oxygen Therapy During Exercise Training in Patients With Chronic Obstructive Pulmonary Disease and Chronic Hypoxemia: A Multicenter Randomized Controlled Trial. *Phys Ther* 2020; **100**(8): 1249-59 <https://pubmed.ncbi.nlm.nih.gov/32329780>.
1157. Carlucci A, Rossi V, Cirio S, et al. Portable High-Flow Nasal Oxygen during Walking in Patients with Severe Chronic Obstructive Pulmonary Disease: A Randomized Controlled Trial. *Respiration* 2021; **100**(12): 1158-64 <https://pubmed.ncbi.nlm.nih.gov/34261072>.
1158. Stefan MS, Pekow PS, Priya A, et al. Association between Initiation of Pulmonary Rehabilitation and Rehospitalizations in Patients Hospitalized with Chronic Obstructive Pulmonary Disease. *Am J Respir Crit Care Med* 2021; **204**(9): 1015-23 <https://pubmed.ncbi.nlm.nih.gov/34283694>.
1159. Greening NJ, Williams JE, Hussain SF, et al. An early rehabilitation intervention to enhance recovery during hospital admission for an exacerbation of chronic respiratory disease: randomised controlled trial. *BMJ* 2014; **349**: g4315 <https://pubmed.ncbi.nlm.nih.gov/25004917>.
1160. Rutkowski S, Rutkowska A, Kiper P, et al. Virtual Reality Rehabilitation in Patients with Chronic Obstructive Pulmonary Disease: A Randomized Controlled Trial. *Int J Chron Obstruct Pulmon Dis* 2020; **15**: 117-24 <https://pubmed.ncbi.nlm.nih.gov/32021150>.
1161. Coultas DB, Jackson BE, Russo R, et al. Home-based Physical Activity Coaching, Physical Activity, and Health Care Utilization in Chronic Obstructive Pulmonary Disease. Chronic Obstructive Pulmonary Disease Self-Management Activation Research Trial Secondary Outcomes. *Ann Am Thorac Soc* 2018; **15**(4): 470-8 <https://pubmed.ncbi.nlm.nih.gov/29283670>.
1162. Stone PW, Hickman K, Steiner MC, Roberts CM, Quint JK, Singh SJ. Predictors of pulmonary rehabilitation completion in the UK. *ERJ Open Res* 2021; **7**(1): <https://pubmed.ncbi.nlm.nih.gov/33585658>.
1163. Holland AE, Mahal A, Hill CJ, et al. Home-based rehabilitation for COPD using minimal resources: a randomised, controlled equivalence trial. *Thorax* 2017; **72**(1): 57-65 <https://pubmed.ncbi.nlm.nih.gov/27672116>.
1164. Maltais F, Bourbeau J, Shapiro S, et al. Effects of home-based pulmonary rehabilitation in patients with chronic obstructive pulmonary disease: a randomized trial. *Ann Intern Med* 2008; **149**(12): 869-78 <https://pubmed.ncbi.nlm.nih.gov/19075206>.
1165. Bourne S, DeVos R, North M, et al. Online versus face-to-face pulmonary rehabilitation for patients with chronic obstructive pulmonary disease: randomised controlled trial. *BMJ Open* 2017; **7**(7): e014580 <https://pubmed.ncbi.nlm.nih.gov/28716786>.
1166. Horton EJ, Mitchell KE, Johnson-Warrington V, et al. Comparison of a structured home-based rehabilitation programme with conventional supervised pulmonary rehabilitation: a randomised non-inferiority trial. *Thorax* 2018; **73**(1): 29-36 <https://pubmed.ncbi.nlm.nih.gov/28756402>.
1167. Nolan CM, Kaliaraju D, Jones SE, et al. Home versus outpatient pulmonary rehabilitation in COPD: a propensity-matched cohort study. *Thorax* 2019; **74**(10): 996-8 <https://pubmed.ncbi.nlm.nih.gov/31278173>.
1168. Guell MR, Cejudo P, Ortega F, et al. Benefits of Long-Term Pulmonary Rehabilitation Maintenance Program in Patients with Severe Chronic Obstructive Pulmonary Disease. Three-Year Follow-up. *Am J Respir Crit Care Med* 2017; **195**(5): 622-9 <https://pubmed.ncbi.nlm.nih.gov/27611807>.
1169. Gordon CS, Waller JW, Cook RM, Cavalera SL, Lim WT, Osadnik CR. Effect of Pulmonary Rehabilitation on Symptoms of Anxiety and Depression in COPD: A Systematic Review and Meta-Analysis. *Chest* 2019; **156**(1): 80-91 <https://pubmed.ncbi.nlm.nih.gov/31034818>.
1170. Lacasse Y, Cates CJ, McCarthy B, Welsh EJ. This Cochrane Review is closed: deciding what constitutes enough research and where next for pulmonary rehabilitation in COPD. *Cochrane Database Syst Rev* 2015; (11): ED000107 <https://pubmed.ncbi.nlm.nih.gov/26593129>.
1171. Baltzan MA, Kamel H, Alter A, Rotaple M, Wolkove N. Pulmonary rehabilitation improves functional capacity in patients 80 years of age or older. *Can Respir J* 2004; **11**(6): 407-13 <https://pubmed.ncbi.nlm.nih.gov/15510248>.
1172. Berry MJ, Rejeski WJ, Adair NE, Zaccaro D. Exercise rehabilitation and chronic obstructive pulmonary disease stage. *Am J Respir Crit Care Med* 1999; **160**(4): 1248-53 <https://pubmed.ncbi.nlm.nih.gov/10508815>.
1173. Verrill D, Barton C, Beasley W, Lippard WM. The effects of short-term and long-term pulmonary rehabilitation on functional capacity, perceived dyspnea, and quality of life. *Chest* 2005; **128**(2): 673-83 <https://pubmed.ncbi.nlm.nih.gov/16100153>.
1174. Houchen-Wolloff L, Steiner MC. Pulmonary rehabilitation at a time of social distancing: prime time for tele-rehabilitation? *Thorax* 2020; **75**(6): 446-7 <https://pubmed.ncbi.nlm.nih.gov/32398319>.
1175. Holland AE, Malaguti C, Hoffman M, et al. Home-based or remote exercise testing in chronic respiratory disease, during the COVID-19 pandemic and beyond: A rapid review. *Chron Respir Dis* 2020; **17**: 1479973120952418 <https://pubmed.ncbi.nlm.nih.gov/32840385>.

1176. Silva J, Hipólito N, Machado P, Flora S, Cruz J. Technological features of smartphone apps for physical activity promotion in patients with COPD: A systematic review. *Pulmonology* 2023; <https://pubmed.ncbi.nlm.nih.gov/37394341>.
1177. Collins PF, Elia M, Kurukulaaratchy RJ, Stratton RJ. The influence of deprivation on malnutrition risk in outpatients with chronic obstructive pulmonary disease (COPD). *Clin Nutr* 2018; **37**(1): 144-8 <https://pubmed.ncbi.nlm.nih.gov/27866758>.
1178. Collins PF, Stratton RJ, Kurukulaaratchy RJ, Elia M. Influence of deprivation on health care use, health care costs, and mortality in COPD. *Int J Chron Obstruct Pulmon Dis* 2018; **13**: 1289-96 <https://pubmed.ncbi.nlm.nih.gov/29719384>.
1179. Gunay E, Kaymaz D, Selcuk NT, Ergun P, Sengul F, Demir N. Effect of nutritional status in individuals with chronic obstructive pulmonary disease undergoing pulmonary rehabilitation. *Respirology* 2013; **18**(8): 1217-22 <https://pubmed.ncbi.nlm.nih.gov/23714353>.
1180. Hoong JM, Ferguson M, Hukins C, Collins PF. Economic and operational burden associated with malnutrition in chronic obstructive pulmonary disease. *Clin Nutr* 2017; **36**(4): 1105-9 <https://pubmed.ncbi.nlm.nih.gov/27496063>.
1181. Nguyen HT, Collins PF, Pavey TG, Nguyen NV, Pham TD, Gallegos DL. Nutritional status, dietary intake, and health-related quality of life in outpatients with COPD. *Int J Chron Obstruct Pulmon Dis* 2019; **14**: 215-26 <https://pubmed.ncbi.nlm.nih.gov/30666102>.
1182. Collins PF, Elia M, Stratton RJ. Nutritional support and functional capacity in chronic obstructive pulmonary disease: a systematic review and meta-analysis. *Respirology* 2013; **18**(4): 616-29 <https://pubmed.ncbi.nlm.nih.gov/23432923>.
1183. King DA, Cordova F, Scharf SM. Nutritional aspects of chronic obstructive pulmonary disease. *Proc Am Thorac Soc* 2008; **5**(4): 519-23 <https://pubmed.ncbi.nlm.nih.gov/18453365>.
1184. Creutzberg EC, Wouters EF, Vanderhoven-Augustin IM, Dentener MA, Schols AM. Disturbances in leptin metabolism are related to energy imbalance during acute exacerbations of chronic obstructive pulmonary disease. *Am J Respir Crit Care Med* 2000; **162**(4 Pt 1): 1239-45 <https://pubmed.ncbi.nlm.nih.gov/11029324>.
1185. Schols A. Nutrition as a metabolic modulator in COPD. *Chest* 2013; **144**(4): 1340-5 <https://pubmed.ncbi.nlm.nih.gov/24081345>.
1186. Wilson DO, Rogers RM, Wright EC, Anthonisen NR. Body weight in chronic obstructive pulmonary disease. The National Institutes of Health Intermittent Positive-Pressure Breathing Trial. *Am Rev Respir Dis* 1989; **139**(6): 1435-8 <https://pubmed.ncbi.nlm.nih.gov/2658702>.
1187. Kim V, Kretschman DM, Sternberg AL, DeCamp MM, Jr., Criner GJ, National Emphysema Treatment Trial Research G. Weight gain after lung reduction surgery is related to improved lung function and ventilatory efficiency. *Am J Respir Crit Care Med* 2012; **186**(11): 1109-16 <https://pubmed.ncbi.nlm.nih.gov/22878279>.
1188. Casaburi R. Skeletal muscle dysfunction in chronic obstructive pulmonary disease. *Med Sci Sports Exerc* 2001; **33**(7 Suppl): S662-70 <https://pubmed.ncbi.nlm.nih.gov/11462075>.
1189. Engelen MP, Schols AM, Baken WC, Wesseling GJ, Wouters EF. Nutritional depletion in relation to respiratory and peripheral skeletal muscle function in out-patients with COPD. *Eur Respir J* 1994; **7**(10): 1793-7 <https://pubmed.ncbi.nlm.nih.gov/7828687>.
1190. Franssen FM, Wouters EF, Schols AM. The contribution of starvation, deconditioning and ageing to the observed alterations in peripheral skeletal muscle in chronic organ diseases. *Clin Nutr* 2002; **21**(1): 1-14 <https://pubmed.ncbi.nlm.nih.gov/11884007>.
1191. Schols AM, Soeters PB, Mostert R, Pluymers RJ, Wouters EF. Physiologic effects of nutritional support and anabolic steroids in patients with chronic obstructive pulmonary disease. A placebo-controlled randomized trial. *Am J Respir Crit Care Med* 1995; **152**(4 Pt 1): 1268-74 <https://pubmed.ncbi.nlm.nih.gov/7551381>.
1192. Steiner MC, Barton RL, Singh SJ, Morgan MD. Nutritional enhancement of exercise performance in chronic obstructive pulmonary disease: a randomised controlled trial. *Thorax* 2003; **58**(9): 745-51 <https://pubmed.ncbi.nlm.nih.gov/12947128>.
1193. Vermeeren MA, Wouters EF, Geraerts-Keeris AJ, Schols AM. Nutritional support in patients with chronic obstructive pulmonary disease during hospitalization for an acute exacerbation; a randomized controlled feasibility trial. *Clin Nutr* 2004; **23**(5): 1184-92 <https://pubmed.ncbi.nlm.nih.gov/15380912>.
1194. van Wetering CR, Hoogendoorn M, Broekhuizen R, et al. Efficacy and costs of nutritional rehabilitation in muscle-wasted patients with chronic obstructive pulmonary disease in a community-based setting: a prespecified subgroup analysis of the INTERCOM trial. *J Am Med Dir Assoc* 2010; **11**(3): 179-87 <https://pubmed.ncbi.nlm.nih.gov/20188315>.
1195. Deutz NE, Ziegler TR, Matheson EM, et al. Reduced mortality risk in malnourished hospitalized older adult patients with COPD treated with a specialized oral nutritional supplement: Sub-group analysis of the NOURISH study. *Clin Nutr* 2021; **40**(3): 1388-95 <https://pubmed.ncbi.nlm.nih.gov/32921503>.
1196. Marchetti N, Criner GJ. Surgical Approaches to Treating Emphysema: Lung Volume Reduction Surgery, Bullectomy, and Lung Transplantation. *Semin Respir Crit Care Med* 2015; **36**(4): 592-608 <https://pubmed.ncbi.nlm.nih.gov/26238644>.
1197. Travaline JM, Addonizio VP, Criner GJ. Effect of bullectomy on diaphragm strength. *Am J Respir Crit Care Med* 1995; **152**(5 Pt 1): 1697-701 <https://pubmed.ncbi.nlm.nih.gov/7582315>.
1198. Marchetti N, Criner KT, Keresztury MF, Furukawa S, Criner GJ. The acute and chronic effects of bullectomy on cardiovascular function at rest and during exercise. *J Thorac Cardiovasc Surg* 2008; **135**(1): 205-6, 6 e1 <https://pubmed.ncbi.nlm.nih.gov/18179944>.

1199. Kanoh S, Kobayashi H, Motoyoshi K. Intrabullous blood injection for lung volume reduction. *Thorax* 2008; **63**(6): 564-5 <https://pubmed.ncbi.nlm.nih.gov/18511641>.
1200. Kemp SV, Zoumot Z, Shah PL. Three-Year Follow-Up of a Patient with a Giant Bulla Treated by Bronchoscopic Intrabullous Autologous Blood Instillation. *Respiration* 2016; **92**(4): 283-4 <https://pubmed.ncbi.nlm.nih.gov/27606975>.
1201. Zoumot Z, Kemp SV, Caneja C, Singh S, Shah PL. Bronchoscopic intrabullous autologous blood instillation: a novel approach for the treatment of giant bullae. *Ann Thorac Surg* 2013; **96**(4): 1488-91 <https://pubmed.ncbi.nlm.nih.gov/24088475>.
1202. Cooper JD, Trulock EP, Triantafillou AN, et al. Bilateral pneumectomy (volume reduction) for chronic obstructive pulmonary disease. *J Thorac Cardiovasc Surg* 1995; **109**(1): 106-16; discussion 16-9 <https://pubmed.ncbi.nlm.nih.gov/7815786>.
1203. Stolk J, Versteegh MI, Montenijs LJ, et al. Densitometry for assessment of effect of lung volume reduction surgery for emphysema. *Eur Respir J* 2007; **29**(6): 1138-43 <https://pubmed.ncbi.nlm.nih.gov/17331971>.
1204. Criner G, Cordova FC, Leyenson V, et al. Effect of lung volume reduction surgery on diaphragm strength. *Am J Respir Crit Care Med* 1998; **157**(5 Pt 1): 1578-85 <https://pubmed.ncbi.nlm.nih.gov/9603141>.
1205. Martinez FJ, de Oca MM, Whyte RI, Stetz J, Gay SE, Celli BR. Lung-volume reduction improves dyspnea, dynamic hyperinflation, and respiratory muscle function. *Am J Respir Crit Care Med* 1997; **155**(6): 1984-90 <https://pubmed.ncbi.nlm.nih.gov/9196106>.
1206. Fessler HE, Permutt S. Lung volume reduction surgery and airflow limitation. *Am J Respir Crit Care Med* 1998; **157**(3 Pt 1): 715-22 <https://pubmed.ncbi.nlm.nih.gov/9517581>.
1207. Washko GR, Fan VS, Ramsey SD, et al. The effect of lung volume reduction surgery on chronic obstructive pulmonary disease exacerbations. *Am J Respir Crit Care Med* 2008; **177**(2): 164-9 <https://pubmed.ncbi.nlm.nih.gov/17962632>.
1208. Geddes D, Davies M, Koyama H, et al. Effect of lung-volume-reduction surgery in patients with severe emphysema. *N Engl J Med* 2000; **343**(4): 239-45 <https://pubmed.ncbi.nlm.nih.gov/10911005>.
1209. van Geffen WH, Slebos DJ, Herth FJ, Kemp SV, Weder W, Shah PL. Surgical and endoscopic interventions that reduce lung volume for emphysema: a systemic review and meta-analysis. *Lancet Respir Med* 2019; **7**(4): 313-24 <https://pubmed.ncbi.nlm.nih.gov/30744937>.
1210. Lim E, Sousa I, Shah PL, Diggle P, Goldstraw P. Lung Volume Reduction Surgery: Reinterpreted With Longitudinal Data Analyses Methodology. *Ann Thorac Surg* 2020; **109**(5): 1496-501 <https://pubmed.ncbi.nlm.nih.gov/31891694>.
1211. National Emphysema Treatment Trial Research Group, Fishman A, Fessler H, et al. Patients at high risk of death after lung-volume-reduction surgery. *N Engl J Med* 2001; **345**(15): 1075-83 <https://pubmed.ncbi.nlm.nih.gov/11596586>.
1212. Greening NJ, Vaughan P, Oey I, et al. Individualised risk in patients undergoing lung volume reduction surgery: the Glenfield BFG score. *Eur Respir J* 2017; **49**(6): <https://pubmed.ncbi.nlm.nih.gov/28572121>.
1213. Imfeld S, Bloch KE, Weder W, Russi EW. The BODE index after lung volume reduction surgery correlates with survival. *Chest* 2006; **129**(4): 873-8 <https://pubmed.ncbi.nlm.nih.gov/16608932>.
1214. Caviezel C, Schaffter N, Schneiter D, et al. Outcome After Lung Volume Reduction Surgery in Patients With Severely Impaired Diffusion Capacity. *Ann Thorac Surg* 2018; **105**(2): 379-85 <https://pubmed.ncbi.nlm.nih.gov/29223424>.
1215. Caviezel C, Froehlich T, Schneiter D, et al. Identification of target zones for lung volume reduction surgery using three-dimensional computed tomography rendering. *ERJ Open Res* 2020; **6**(3): <https://pubmed.ncbi.nlm.nih.gov/32963992>.
1216. Ramsey SD, Berry K, Etzioni R, et al. Cost effectiveness of lung-volume-reduction surgery for patients with severe emphysema. *N Engl J Med* 2003; **348**(21): 2092-102 <https://pubmed.ncbi.nlm.nih.gov/12759480>.
1217. Ginsburg ME, Thomashow BM, Bulman WA, et al. The safety, efficacy, and durability of lung-volume reduction surgery: A 10-year experience. *J Thorac Cardiovasc Surg* 2016; **151**(3): 717-24 e1 <https://pubmed.ncbi.nlm.nih.gov/26670190>.
1218. Abdelsattar ZM, Allen M, Blackmon S, et al. Contemporary Practice Patterns of Lung Volume Reduction Surgery in the United States. *Ann Thorac Surg* 2021; **112**(3): 952-60 <https://pubmed.ncbi.nlm.nih.gov/33161015>.
1219. Stanifer BP, Ginsburg ME. Lung volume reduction surgery in the post-National Emphysema Treatment Trial era. *J Thorac Dis* 2018; **10**(Suppl 23): S2744-S7 <https://pubmed.ncbi.nlm.nih.gov/30210827>.
1220. Buttery S, Lewis A, Oey I, et al. Patient experience of lung volume reduction procedures for emphysema: a qualitative service improvement project. *ERJ Open Res* 2017; **3**(3): <https://pubmed.ncbi.nlm.nih.gov/28835891>.
1221. McNulty W, Jordan S, Hopkinson NS. Attitudes and access to lung volume reduction surgery for COPD: a survey by the British Thoracic Society. *BMJ Open Respir Res* 2014; **1**(1): e000023 <https://pubmed.ncbi.nlm.nih.gov/25478175>.
1222. Rathinam S, Oey I, Steiner M, Spyt T, Morgan MD, Waller DA. The role of the emphysema multidisciplinary team in a successful lung volume reduction surgery programmedagger. *Eur J Cardiothorac Surg* 2014; **46**(6): 1021-6; discussion 6 <https://pubmed.ncbi.nlm.nih.gov/24771753>.
1223. Chambers DC, Cherkh WS, Goldfarb SB, et al. The International Thoracic Organ Transplant Registry of the International Society for Heart and Lung Transplantation: Thirty-fifth adult lung and heart-lung transplant report-2018; Focus theme: Multiorgan Transplantation. *J Heart Lung Transplant* 2018; **37**(10): 1169-83 <https://pubmed.ncbi.nlm.nih.gov/30293613>.
1224. Weill D, Benden C, Corris PA, et al. A consensus document for the selection of lung transplant candidates: 2014--an update from the Pulmonary Transplantation Council of the International Society for Heart and Lung Transplantation. *J Heart Lung Transplant* 2015; **34**(1): 1-15 <https://pubmed.ncbi.nlm.nih.gov/25085497>.

1225. Arjuna A, Olson MT, Walia R. Current trends in candidate selection, contraindications, and indications for lung transplantation. *J Thorac Dis* 2021; **13**(11): 6514-27 <https://pubmed.ncbi.nlm.nih.gov/34992831>.
1226. Christie JD, Edwards LB, Kucheryavaya AY, et al. The Registry of the International Society for Heart and Lung Transplantation: 29th adult lung and heart-lung transplant report-2012. *J Heart Lung Transplant* 2012; **31**(10): 1073-86 <https://pubmed.ncbi.nlm.nih.gov/22975097>.
1227. Stavem K, Bjortuft O, Borgan O, Geiran O, Boe J. Lung transplantation in patients with chronic obstructive pulmonary disease in a national cohort is without obvious survival benefit. *J Heart Lung Transplant* 2006; **25**(1): 75-84 <https://pubmed.ncbi.nlm.nih.gov/16399534>.
1228. Tanash HA, Riise GC, Hansson L, Nilsson PM, Piitulainen E. Survival benefit of lung transplantation in individuals with severe alpha1-anti-trypsin deficiency (PiZZ) and emphysema. *J Heart Lung Transplant* 2011; **30**(12): 1342-7 <https://pubmed.ncbi.nlm.nih.gov/21821433>.
1229. Tanash HA, Riise GC, Ekstrom MP, Hansson L, Piitulainen E. Survival benefit of lung transplantation for chronic obstructive pulmonary disease in Sweden. *Ann Thorac Surg* 2014; **98**(6): 1930-5 <https://pubmed.ncbi.nlm.nih.gov/25443001>.
1230. Eskander A, Waddell TK, Faughnan ME, Chowdhury N, Singer LG. BODE index and quality of life in advanced chronic obstructive pulmonary disease before and after lung transplantation. *J Heart Lung Transplant* 2011; **30**(12): 1334-41 <https://pubmed.ncbi.nlm.nih.gov/21782467>.
1231. Lahzami S, Bridevaux PO, Soccacal PM, et al. Survival impact of lung transplantation for COPD. *Eur Respir J* 2010; **36**(1): 74-80 <https://pubmed.ncbi.nlm.nih.gov/19996194>.
1232. Thabut G, Ravaud P, Christie JD, et al. Determinants of the survival benefit of lung transplantation in patients with chronic obstructive pulmonary disease. *Am J Respir Crit Care Med* 2008; **177**(10): 1156-63 <https://pubmed.ncbi.nlm.nih.gov/18310481>.
1233. ISHLT: The International Society for Heart & Lung Transplantation [Internet]. Slide Sets - Overall Lung Transplantation Statistics. Available from: <https://ishltregistries.org/registries/slides.asp> (accessed Oct 2022).
1234. Thabut G, Christie JD, Ravaud P, et al. Survival after bilateral versus single lung transplantation for patients with chronic obstructive pulmonary disease: a retrospective analysis of registry data. *Lancet* 2008; **371**(9614): 744-51 <https://pubmed.ncbi.nlm.nih.gov/18313503>.
1235. Pochettino A, Kotloff RM, Rosengard BR, et al. Bilateral versus single lung transplantation for chronic obstructive pulmonary disease: intermediate-term results. *Ann Thorac Surg* 2000; **70**(6): 1813-8; discussion 8-9 <https://pubmed.ncbi.nlm.nih.gov/11156077>.
1236. Gonzalez FJ, Alvarez E, Moreno P, et al. The influence of the native lung on early outcomes and survival after single lung transplantation. *PLoS One* 2021; **16**(4): e0249758 <https://pubmed.ncbi.nlm.nih.gov/33826650>.
1237. Fang YC, Cheng WH, Lu HI, et al. Double lung transplantation is better than single lung transplantation for end-stage chronic obstructive pulmonary disease: a meta-analysis. *J Cardiothorac Surg* 2024; **19**(1): 162 <https://pubmed.ncbi.nlm.nih.gov/38555450>.
1238. Minai OA, Shah S, Mazzone P, et al. Bronchogenic carcinoma after lung transplantation: characteristics and outcomes. *J Thorac Oncol* 2008; **3**(12): 1404-9 <https://pubmed.ncbi.nlm.nih.gov/19057264>.
1239. Weill D, Torres F, Hodges TN, Olmos JJ, Zamora MR. Acute native lung hyperinflation is not associated with poor outcomes after single lung transplant for emphysema. *J Heart Lung Transplant* 1999; **18**(11): 1080-7 <https://pubmed.ncbi.nlm.nih.gov/10598731>.
1240. Yonan NA, el-Gamel A, Egan J, Kakadellis J, Rahman A, Deiraniya AK. Single lung transplantation for emphysema: predictors for native lung hyperinflation. *J Heart Lung Transplant* 1998; **17**(2): 192-201 <https://pubmed.ncbi.nlm.nih.gov/9513858>.
1241. Benvenuto LJ, Costa J, Piloni D, et al. Right single lung transplantation or double lung transplantation compared with left single lung transplantation in chronic obstructive pulmonary disease. *J Heart Lung Transplant* 2020; **39**(9): 870-7 <https://pubmed.ncbi.nlm.nih.gov/32693937>.
1242. Mal H, Brugiere O, Sleiman C, et al. Morbidity and mortality related to the native lung in single lung transplantation for emphysema. *J Heart Lung Transplant* 2000; **19**(2): 220-3 <https://pubmed.ncbi.nlm.nih.gov/10703700>.
1243. Ramos KJ, Harhay MO, Mulligan MS. Which Shall I Choose? Lung Transplantation Listing Preference for Individuals with Interstitial Lung Disease and Chronic Obstructive Pulmonary Disease. *Ann Am Thorac Soc* 2019; **16**(2): 193-5 <https://pubmed.ncbi.nlm.nih.gov/30707065>.
1244. Theodore J, Lewiston N. Lung transplantation comes of age. *N Engl J Med* 1990; **322**(11): 772-4 <https://pubmed.ncbi.nlm.nih.gov/2308605>.
1245. Tiong LU, Davies R, Gibson PG, et al. Lung volume reduction surgery for diffuse emphysema. *Cochrane Database Syst Rev* 2006; (4): CD001001 <https://pubmed.ncbi.nlm.nih.gov/17054132>.
1246. Criner GJ, Cordova F, Sternberg AL, Martinez FJ. The National Emphysema Treatment Trial (NETT) Part II: Lessons learned about lung volume reduction surgery. *Am J Respir Crit Care Med* 2011; **184**(8): 881-93 <https://pubmed.ncbi.nlm.nih.gov/21719757>.
1247. Herth FJ, Valipour A, Shah PL, et al. Segmental volume reduction using thermal vapour ablation in patients with severe emphysema: 6-month results of the multicentre, parallel-group, open-label, randomised controlled STEP-UP trial. *Lancet Respir Med* 2016; **4**(3): 185-93 <https://pubmed.ncbi.nlm.nih.gov/26899390>.

1248. Kemp SV, Slebos DJ, Kirk A, et al. A Multicenter Randomized Controlled Trial of Zephyr Endobronchial Valve Treatment in Heterogeneous Emphysema (TRANSFORM). *Am J Respir Crit Care Med* 2017; **196**(12): 1535-43 <https://pubmed.ncbi.nlm.nih.gov/28885054>.
1249. Valipour A, Slebos DJ, Herth F, et al. Endobronchial Valve Therapy in Patients with Homogeneous Emphysema. Results from the IMPACT Study. *Am J Respir Crit Care Med* 2016; **194**(9): 1073-82 <https://pubmed.ncbi.nlm.nih.gov/27580428>.
1250. van Geffen WH, Klooster K, Hartman JE, et al. Pleural Adhesion Assessment as a Predictor for Pneumothorax after Endobronchial Valve Treatment. *Respiration* 2017; **94**(2): 224-31 <https://pubmed.ncbi.nlm.nih.gov/28637047>.
1251. Hopkinson NS, Kemp SV, Toma TP, et al. Atelectasis and survival after bronchoscopic lung volume reduction for COPD. *Eur Respir J* 2011; **37**(6): 1346-51 <https://pubmed.ncbi.nlm.nih.gov/20947683>.
1252. Garner J, Kemp SV, Toma TP, et al. Survival after Endobronchial Valve Placement for Emphysema: A 10-Year Follow-up Study. *Am J Respir Crit Care Med* 2016; **194**(4): 519-21 <https://pubmed.ncbi.nlm.nih.gov/27525462>.
1253. Gompelmann D, Benjamin N, Bischoff E, et al. Survival after Endoscopic Valve Therapy in Patients with Severe Emphysema. *Respiration* 2019; **97**(2): 145-52 <https://pubmed.ncbi.nlm.nih.gov/30227420>.
1254. Hartman JE, Welling JBA, Klooster K, Carpaij OA, Augustijn SWS, Slebos DJ. Survival in COPD patients treated with bronchoscopic lung volume reduction. *Respir Med* 2022; **196**: 106825 <https://pubmed.ncbi.nlm.nih.gov/35325741>.
1255. Mansfield C, Sutphin J, Shriner K, Criner GJ, Celli BR. Patient Preferences for Endobronchial Valve Treatment of Severe Emphysema. *Chronic Obstr Pulm Dis* 2018; **6**(1): 51-63 <https://pubmed.ncbi.nlm.nih.gov/30775424>.
1256. Naunheim KS, Wood DE, Mohsenifar Z, et al. Long-term follow-up of patients receiving lung-volume-reduction surgery versus medical therapy for severe emphysema by the National Emphysema Treatment Trial Research Group. *Ann Thorac Surg* 2006; **82**(2): 431-43 <https://pubmed.ncbi.nlm.nih.gov/16888872>.
1257. DeCamp MM, Blackstone EH, Naunheim KS, et al. Patient and surgical factors influencing air leak after lung volume reduction surgery: lessons learned from the National Emphysema Treatment Trial. *Ann Thorac Surg* 2006; **82**(1): 197-206; discussion -7 <https://pubmed.ncbi.nlm.nih.gov/16798215>.
1258. Shah PL, Slebos DJ, Cardoso PF, et al. Bronchoscopic lung-volume reduction with Exhale airway stents for emphysema (EASE trial): randomised, sham-controlled, multicentre trial. *Lancet* 2011; **378**(9795): 997-1005 <https://pubmed.ncbi.nlm.nih.gov/21907863>.
1259. Come CE, Kramer MR, Dransfield MT, et al. A randomised trial of lung sealant versus medical therapy for advanced emphysema. *Eur Respir J* 2015; **46**(3): 651-62 <https://pubmed.ncbi.nlm.nih.gov/25837041>.
1260. Shah PL, Gompelmann D, Valipour A, et al. Thermal vapour ablation to reduce segmental volume in patients with severe emphysema: STEP-UP 12 month results. *Lancet Respir Med* 2016; **4**(9): e44-e5 <https://pubmed.ncbi.nlm.nih.gov/27451345>.
1261. Deslee G, Mal H, Dutau H, et al. Lung Volume Reduction Coil Treatment vs Usual Care in Patients With Severe Emphysema: The REVOLENS Randomized Clinical Trial. *JAMA* 2016; **315**(2): 175-84 <https://pubmed.ncbi.nlm.nih.gov/26757466>.
1262. Sciruba FC, Criner GJ, Strange C, et al. Effect of Endobronchial Coils vs Usual Care on Exercise Tolerance in Patients With Severe Emphysema: The RENEW Randomized Clinical Trial. *JAMA* 2016; **315**(20): 2178-89 <https://pubmed.ncbi.nlm.nih.gov/27179849>.
1263. Shah PL, Zoumot Z, Singh S, et al. Endobronchial coils for the treatment of severe emphysema with hyperinflation (RESET): a randomised controlled trial. *Lancet Respir Med* 2013; **1**(3): 233-40 <https://pubmed.ncbi.nlm.nih.gov/24429129>.
1264. Slebos DJ, Cicens J, Sciruba FC, et al. Predictors of Response to Endobronchial Coil Therapy in Patients With Advanced Emphysema. *Chest* 2019; **155**(5): 928-37 <https://pubmed.ncbi.nlm.nih.gov/30797746>.
1265. Bavaria JE, Pochettino A, Kotloff RM, et al. Effect of volume reduction on lung transplant timing and selection for chronic obstructive pulmonary disease. *J Thorac Cardiovasc Surg* 1998; **115**(1): 9-17; discussion -8 <https://pubmed.ncbi.nlm.nih.gov/9451040>.
1266. Senbaklavaci O, Wisser W, Ozpaker C, et al. Successful lung volume reduction surgery brings patients into better condition for later lung transplantation. *Eur J Cardiothorac Surg* 2002; **22**(3): 363-7 <https://pubmed.ncbi.nlm.nih.gov/12204724>.
1267. Slama A, Taube C, Kamler M, Aigner C. Lung volume reduction followed by lung transplantation-considerations on selection criteria and outcome. *J Thorac Dis* 2018; **10**(Suppl 27): S3366-S75 <https://pubmed.ncbi.nlm.nih.gov/30450243>.
1268. Reece TB, Mitchell JD, Zamora MR, et al. Native lung volume reduction surgery relieves functional graft compression after single-lung transplantation for chronic obstructive pulmonary disease. *J Thorac Cardiovasc Surg* 2008; **135**(4): 931-7 <https://pubmed.ncbi.nlm.nih.gov/18374782>.
1269. Anderson MB, Kriett JM, Kapelanski DP, Perricone A, Smith CM, Jamieson SW. Volume reduction surgery in the native lung after single lung transplantation for emphysema. *J Heart Lung Transplant* 1997; **16**(7): 752-7 <https://pubmed.ncbi.nlm.nih.gov/9257257>.
1270. Crespo MM, Johnson BA, McCurry KR, Landreneau RJ, Sciruba FC. Use of endobronchial valves for native lung hyperinflation associated with respiratory failure in a single-lung transplant recipient for emphysema. *Chest* 2007; **131**(1): 214-6 <https://pubmed.ncbi.nlm.nih.gov/17218578>.

1271. Venuta F, De Giacomo T, Rendina EA, et al. Thoracoscopic volume reduction of the native lung after single lung transplantation for emphysema. *Am J Respir Crit Care Med* 1998; **157**(1): 292-3
<https://pubmed.ncbi.nlm.nih.gov/9445313>.
1272. Kemp SV, Carby M, Cetti EJ, Herth FJ, Shah PL. A potential role for endobronchial valves in patients with lung transplant. *J Heart Lung Transplant* 2010; **29**(11): 1310-2 <https://pubmed.ncbi.nlm.nih.gov/20708411>.
1273. Perch M, Riise GC, Hogarth K, et al. Endoscopic treatment of native lung hyperinflation using endobronchial valves in single-lung transplant patients: a multinational experience. *Clin Respir J* 2015; **9**(1): 104-10
<https://pubmed.ncbi.nlm.nih.gov/24506317>.
1274. Shigemura N, Gilbert S, Bhama JK, et al. Lung transplantation after lung volume reduction surgery. *Transplantation* 2013; **96**(4): 421-5 <https://pubmed.ncbi.nlm.nih.gov/23736352>.
1275. Slama A, Ceulemans LJ, Hedderich C, et al. Lung Volume Reduction Followed by Lung Transplantation in Emphysema-A Multicenter Matched Analysis. *Transpl Int* 2022; **35**: 10048 <https://pubmed.ncbi.nlm.nih.gov/35497884>.
1276. Fuehner T, Clajus C, Fuge J, et al. Lung transplantation after endoscopic lung volume reduction. *Respiration* 2015; **90**(3): 243-50 <https://pubmed.ncbi.nlm.nih.gov/26138023>.
1277. Bhatt SP, Terry NL, Nath H, et al. Association Between Expiratory Central Airway Collapse and Respiratory Outcomes Among Smokers. *JAMA* 2016; **315**(5): 498-505 <https://pubmed.ncbi.nlm.nih.gov/26836732>.
1278. Ernst A, Majid A, Feller-Kopman D, et al. Airway stabilization with silicone stents for treating adult tracheobronchomalacia: a prospective observational study. *Chest* 2007; **132**(2): 609-16
<https://pubmed.ncbi.nlm.nih.gov/17699133>.
1279. Wright CD, Mathisen DJ. Tracheobronchoplasty for tracheomalacia. *Ann Cardiothorac Surg* 2018; **7**(2): 261-5
<https://pubmed.ncbi.nlm.nih.gov/29707504>.
1280. Hartman JE, Garner JL, Shah PL, Slebos DJ. New bronchoscopic treatment modalities for patients with chronic bronchitis. *Eur Respir Rev* 2021; **30**(159): <https://pubmed.ncbi.nlm.nih.gov/33472961>.
1281. Valipour A, Fernandez-Bussy S, Ing AJ, et al. Bronchial Rheoplasty for Treatment of Chronic Bronchitis. Twelve-Month Results from a Multicenter Clinical Trial. *Am J Respir Crit Care Med* 2020; **202**(5): 681-9
<https://pubmed.ncbi.nlm.nih.gov/32407638>.
1282. U.S. National Library of Medicine ClinicalTrials.gov. RejuvenAir® System Trial for COPD With Chronic Bronchitis (SPRAY-CB) [accessed Oct 2024]. <https://clinicaltrials.gov/ct2/show/NCT03893370>.
1283. U.S. National Library of Medicine ClinicalTrials.gov. Clinical Study of the RheOx Bronchial Rheoplasty System in Treating the Symptoms of Chronic Bronchitis [accessed Oct 2024]. <https://www.clinicaltrials.gov/ct2/show/NCT04677465>.
1284. Valipour A, Asadi S, Pison C, et al. Long-term safety of bilateral targeted lung denervation in patients with COPD. *Int J Chron Obstruct Pulmon Dis* 2018; **13**: 2163-72 <https://pubmed.ncbi.nlm.nih.gov/30038492>.
1285. Valipour A, Shah PL, Pison C, et al. Safety and Dose Study of Targeted Lung Denervation in Moderate/Severe COPD Patients. *Respiration* 2019; **98**(4): 329-39 <https://pubmed.ncbi.nlm.nih.gov/31220851>.
1286. Slebos DJ, Shah PL, Herth FJF, et al. Safety and Adverse Events after Targeted Lung Denervation for Symptomatic Moderate to Severe Chronic Obstructive Pulmonary Disease (AIRFLOW). A Multicenter Randomized Controlled Clinical Trial. *Am J Respir Crit Care Med* 2019; **200**(12): 1477-86 <https://pubmed.ncbi.nlm.nih.gov/31404499>.
1287. Mazzone PJ. Preoperative evaluation of the lung cancer resection candidate. *Expert Rev Respir Med* 2010; **4**(1): 97-113
<https://pubmed.ncbi.nlm.nih.gov/20387296>.
1288. Celli BR, MacNee W, Force AET. Standards for the diagnosis and treatment of patients with COPD: a summary of the ATS/ERS position paper. *Eur Respir J* 2004; **23**(6): 932-46 <https://pubmed.ncbi.nlm.nih.gov/15219010>.
1289. Schuurmans MM, Diacon AH, Bolliger CT. Functional evaluation before lung resection. *Clin Chest Med* 2002; **23**(1): 159-72 <https://pubmed.ncbi.nlm.nih.gov/11901909>.
1290. Smetana GW. Preoperative pulmonary evaluation. *N Engl J Med* 1999; **340**(12): 937-44
<https://pubmed.ncbi.nlm.nih.gov/10089188>.
1291. Brunelli A, Charloux A, Bolliger CT, et al. ERS/ESTS clinical guidelines on fitness for radical therapy in lung cancer patients (surgery and chemo-radiotherapy). *Eur Respir J* 2009; **34**(1): 17-41
<https://pubmed.ncbi.nlm.nih.gov/19567600>.
1292. Colice GL, Shafazand S, Griffin JP, Keenan R, Bolliger CT, American College of Chest P. Physiologic evaluation of the patient with lung cancer being considered for resectional surgery: ACCP evidenced-based clinical practice guidelines (2nd edition). *Chest* 2007; **132**(3 Suppl): 161S-77S <https://pubmed.ncbi.nlm.nih.gov/17873167>.
1293. Spies R, Potter M, Hollamby R, et al. Sputum Color as a Marker for Bacteria in Acute Exacerbations of Chronic Obstructive Pulmonary Disease: A Systematic Review and Meta-analysis. *Ann Am Thorac Soc* 2023; **20**(5): 738-48
<https://pubmed.ncbi.nlm.nih.gov/36724375>.
1294. Anthonisen NR, Manfreda J, Warren CP, Hershfield ES, Harding GK, Nelson NA. Antibiotic therapy in exacerbations of chronic obstructive pulmonary disease. *Ann Intern Med* 1987; **106**(2): 196-204
<https://pubmed.ncbi.nlm.nih.gov/3492164>.
1295. Beghe B, Verduri A, Roca M, Fabbri LM. Exacerbation of respiratory symptoms in COPD patients may not be exacerbations of COPD. *Eur Respir J* 2013; **41**(4): 993-5 <https://pubmed.ncbi.nlm.nih.gov/23543648>.
1296. Stolz D, Bredthardt T, Christ-Crain M, et al. Use of B-type natriuretic peptide in the risk stratification of acute exacerbations of COPD. *Chest* 2008; **133**(5): 1088-94 <https://pubmed.ncbi.nlm.nih.gov/18339792>.

1297. Crisafulli E, Manco A, Ferrer M, et al. Pneumonic versus Nonpneumonic Exacerbations of Chronic Obstructive Pulmonary Disease. *Semin Respir Crit Care Med* 2020; **41**(6): 817-29 <https://pubmed.ncbi.nlm.nih.gov/32726837>.
1298. Torres A, Blasi F, Dartois N, Akova M. Which individuals are at increased risk of pneumococcal disease and why? Impact of COPD, asthma, smoking, diabetes, and/or chronic heart disease on community-acquired pneumonia and invasive pneumococcal disease. *Thorax* 2015; **70**(10): 984-9 <https://pubmed.ncbi.nlm.nih.gov/26219979>.
1299. Couturaud F, Bertoletti L, Pastre J, et al. Prevalence of Pulmonary Embolism Among Patients With COPD Hospitalized With Acutely Worsening Respiratory Symptoms. *JAMA* 2021; **325**(1): 59-68 <https://pubmed.ncbi.nlm.nih.gov/33399840>.
1300. Jimenez D, Agusti A, Taberero E, et al. Effect of a Pulmonary Embolism Diagnostic Strategy on Clinical Outcomes in Patients Hospitalized for COPD Exacerbation: A Randomized Clinical Trial. *JAMA* 2021; **326**(13): 1277-85 <https://pubmed.ncbi.nlm.nih.gov/34609451>.
1301. Calverley PMA, Martinez FJ, Vestbo J, et al. International Differences in the Frequency of Chronic Obstructive Pulmonary Disease Exacerbations Reported in Three Clinical Trials. *Am J Respir Crit Care Med* 2022; **206**(1): 25-33 <https://pubmed.ncbi.nlm.nih.gov/35363593>.
1302. Althobiani MA, Shah AJ, Khan B, Hurst JR. Clinicians' and Researchers' Perspectives on a New Chronic Obstructive Pulmonary Disease Exacerbation Definition: Rome Wasn't Built in a Day. *Am J Respir Crit Care Med* 2023; **207**(8): 1095-7 <https://pubmed.ncbi.nlm.nih.gov/36656550>.
1303. Reumkens C, Endres A, Simons SO, Savelkoul PHM, Sprooten RTM, Franssen FME. Application of the Rome severity classification of COPD exacerbations in a real-world cohort of hospitalised patients. *ERJ Open Res* 2023; **9**(3): <https://pubmed.ncbi.nlm.nih.gov/37228266>.
1304. Wilkinson TM, Donaldson GC, Hurst JR, Seemungal TA, Wedzicha JA. Early therapy improves outcomes of exacerbations of chronic obstructive pulmonary disease. *Am J Respir Crit Care Med* 2004; **169**(12): 1298-303 <https://pubmed.ncbi.nlm.nih.gov/14990395>.
1305. Vijayaratha K, Stockley RA. Reported and unreported exacerbations of COPD: analysis by diary cards. *Chest* 2008; **133**(1): 34-41 <https://pubmed.ncbi.nlm.nih.gov/17989153>.
1306. Konstantinoudis G, Minelli C, Vicedo-Cabrera AM, Ballester J, Gasparrini A, Blangiardo M. Ambient heat exposure and COPD hospitalisations in England: a nationwide case-crossover study during 2007-2018. *Thorax* 2022; **77**(11): 1098-104 <https://pubmed.ncbi.nlm.nih.gov/35459745>.
1307. Li N, Ma J, Ji K, Wang L. Association of PM_{2.5} and PM₁₀ with Acute Exacerbation of Chronic Obstructive Pulmonary Disease at lag0 to lag7: A Systematic Review and Meta-Analysis. *COPD* 2022; **19**(1): 243-54 <https://pubmed.ncbi.nlm.nih.gov/35616887>.
1308. Liu S, Zhou Y, Liu S, et al. Association between exposure to ambient particulate matter and chronic obstructive pulmonary disease: results from a cross-sectional study in China. *Thorax* 2017; **72**(9): 788-95 <https://pubmed.ncbi.nlm.nih.gov/27941160>.
1309. Liang L, Cai Y, Barratt B, et al. Associations between daily air quality and hospitalisations for acute exacerbation of chronic obstructive pulmonary disease in Beijing, 2013-17: an ecological analysis. *Lancet Planet Health* 2019; **3**(6): e270-e9 <https://pubmed.ncbi.nlm.nih.gov/31229002>.
1310. White AJ, Gompertz S, Stockley RA. Chronic obstructive pulmonary disease . 6: The aetiology of exacerbations of chronic obstructive pulmonary disease. *Thorax* 2003; **58**(1): 73-80 <https://pubmed.ncbi.nlm.nih.gov/12511727>.
1311. Woodhead M, Blasi F, Ewig S, et al. Guidelines for the management of adult lower respiratory tract infections. *Eur Respir J* 2005; **26**(6): 1138-80 <https://pubmed.ncbi.nlm.nih.gov/16319346>.
1312. Bafadhel M, McKenna S, Agbetile J, et al. *Aspergillus fumigatus* during stable state and exacerbations of COPD. *Eur Respir J* 2014; **43**(1): 64-71 <https://pubmed.ncbi.nlm.nih.gov/23598955>.
1313. Huerta A, Soler N, Esperatti M, et al. Importance of *Aspergillus* spp. isolation in Acute exacerbations of severe COPD: prevalence, factors and follow-up: the FUNGI-COPD study. *Respir Res* 2014; **15**(1): 17 <https://pubmed.ncbi.nlm.nih.gov/24517318>.
1314. Mir T, Uddin M, Khalil A, et al. Mortality outcomes associated with invasive aspergillosis among acute exacerbation of chronic obstructive pulmonary disease patient population. *Respir Med* 2022; **191**: 106720 <https://pubmed.ncbi.nlm.nih.gov/34959147>.
1315. Hammond EE, McDonald CS, Vestbo J, Denning DW. The global impact of *Aspergillus* infection on COPD. *BMC Pulm Med* 2020; **20**(1): 241 <https://pubmed.ncbi.nlm.nih.gov/32912168>.
1316. Gu Y, Ye X, Liu Y, et al. A risk-predictive model for invasive pulmonary aspergillosis in patients with acute exacerbation of chronic obstructive pulmonary disease. *Respir Res* 2021; **22**(1): 176 <https://pubmed.ncbi.nlm.nih.gov/34107968>.
1317. Tiew PY, Narayana JK, Quek MSL, et al. Sensitisation to recombinant *Aspergillus fumigatus* allergens and clinical outcomes in COPD. *Eur Respir J* 2023; **61**(1): <https://pubmed.ncbi.nlm.nih.gov/35926878>.
1318. Bulpa P, Duplaquet F, Dimopoulos G, Vogelaers D, Blot S. Invasive Pulmonary Aspergillosis in Chronic Obstructive Pulmonary Disease Exacerbations. *Semin Respir Crit Care Med* 2020; **41**(6): 851-61 <https://pubmed.ncbi.nlm.nih.gov/32599634>.
1319. Papi A, Bellettato CM, Braccioni F, et al. Infections and airway inflammation in chronic obstructive pulmonary disease severe exacerbations. *Am J Respir Crit Care Med* 2006; **173**(10): 1114-21 <https://pubmed.ncbi.nlm.nih.gov/16484677>.

1320. Bafadhel M, McKenna S, Terry S, et al. Acute exacerbations of chronic obstructive pulmonary disease: identification of biologic clusters and their biomarkers. *Am J Respir Crit Care Med* 2011; **184**(6): 662-71 <https://pubmed.ncbi.nlm.nih.gov/21680942>.
1321. Baines KJ, Pavord ID, Gibson PG. The role of biomarkers in the management of airways disease. *Int J Tuberc Lung Dis* 2014; **18**(11): 1264-8 <https://pubmed.ncbi.nlm.nih.gov/25299856>.
1322. Groenke L, Disse B. Blood eosinophil counts as markers of response to inhaled corticosteroids in COPD? *Lancet Respir Med* 2015; **3**(8): e26 <https://pubmed.ncbi.nlm.nih.gov/26282478>.
1323. Bafadhel M, McKenna S, Terry S, et al. Blood eosinophils to direct corticosteroid treatment of exacerbations of chronic obstructive pulmonary disease: a randomized placebo-controlled trial. *Am J Respir Crit Care Med* 2012; **186**(1): 48-55 <https://pubmed.ncbi.nlm.nih.gov/22447964>.
1324. Seemungal TA, Donaldson GC, Bhowmik A, Jeffries DJ, Wedzicha JA. Time course and recovery of exacerbations in patients with chronic obstructive pulmonary disease. *Am J Respir Crit Care Med* 2000; **161**(5): 1608-13 <https://pubmed.ncbi.nlm.nih.gov/10806163>.
1325. Halpin DMG, Birk R, Brealey N, et al. Single-inhaler triple therapy in symptomatic COPD patients: FULFIL subgroup analyses. *ERJ Open Res* 2018; **4**(2): 00119-2017 <https://pubmed.ncbi.nlm.nih.gov/29750142>.
1326. Donaldson GC, Law M, Kowlessar B, et al. Impact of Prolonged Exacerbation Recovery in Chronic Obstructive Pulmonary Disease. *Am J Respir Crit Care Med* 2015; **192**(8): 943-50 <https://pubmed.ncbi.nlm.nih.gov/26151174>.
1327. Hurst JR, Donaldson GC, Quint JK, Goldring JJ, Baghai-Ravary R, Wedzicha JA. Temporal clustering of exacerbations in chronic obstructive pulmonary disease. *Am J Respir Crit Care Med* 2009; **179**(5): 369-74 <https://pubmed.ncbi.nlm.nih.gov/19074596>.
1328. Donaldson GC, Mullerova H, Locantore N, et al. Factors associated with change in exacerbation frequency in COPD. *Respir Res* 2013; **14**(1): 79 <https://pubmed.ncbi.nlm.nih.gov/23899210>.
1329. Burgel PR, Nesme-Meyer P, Chanez P, et al. Cough and sputum production are associated with frequent exacerbations and hospitalizations in COPD subjects. *Chest* 2009; **135**(4): 975-82 <https://pubmed.ncbi.nlm.nih.gov/19017866>.
1330. Rafiq R, Aleva FE, Schrupf JA, et al. Vitamin D supplementation in chronic obstructive pulmonary disease patients with low serum vitamin D: a randomized controlled trial. *Am J Clin Nutr* 2022; **116**(2): 491-9 <https://pubmed.ncbi.nlm.nih.gov/35383823>.
1331. Martinez FJ, Han MK, Flaherty K, Curtis J. Role of infection and antimicrobial therapy in acute exacerbations of chronic obstructive pulmonary disease. *Expert Rev Anti Infect Ther* 2006; **4**(1): 101-24 <https://pubmed.ncbi.nlm.nih.gov/16441213>.
1332. Celli BR, Thomas NE, Anderson JA, et al. Effect of pharmacotherapy on rate of decline of lung function in chronic obstructive pulmonary disease: results from the TORCH study. *Am J Respir Crit Care Med* 2008; **178**(4): 332-8 <https://pubmed.ncbi.nlm.nih.gov/18511702>.
1333. Celli BR, Barnes PJ. Exacerbations of chronic obstructive pulmonary disease. *Eur Respir J* 2007; **29**(6): 1224-38 <https://pubmed.ncbi.nlm.nih.gov/17540785>.
1334. Hoogendoorn M, Hoogenveen RT, Rutten-van Molken MP, Vestbo J, Feenstra TL. Case fatality of COPD exacerbations: a meta-analysis and statistical modelling approach. *Eur Respir J* 2011; **37**(3): 508-15 <https://pubmed.ncbi.nlm.nih.gov/20595157>.
1335. Piquet J, Chavaillon JM, David P, et al. High-risk patients following hospitalisation for an acute exacerbation of COPD. *Eur Respir J* 2013; **42**(4): 946-55 <https://pubmed.ncbi.nlm.nih.gov/23349446>.
1336. Singanayagam A, Schembri S, Chalmers JD. Predictors of mortality in hospitalized adults with acute exacerbation of chronic obstructive pulmonary disease. *Ann Am Thorac Soc* 2013; **10**(2): 81-9 <https://pubmed.ncbi.nlm.nih.gov/23607835>.
1337. Guo Y, Zhang T, Wang Z, et al. Body mass index and mortality in chronic obstructive pulmonary disease: A dose-response meta-analysis. *Medicine (Baltimore)* 2016; **95**(28): e4225 <https://pubmed.ncbi.nlm.nih.gov/27428228>.
1338. Garcia-Aymerich J, Serra Pons I, Mannino DM, Maas AK, Miller DP, Davis KJ. Lung function impairment, COPD hospitalisations and subsequent mortality. *Thorax* 2011; **66**(7): 585-90 <https://pubmed.ncbi.nlm.nih.gov/21515553>.
1339. Daniels K, Lanes S, Tave A, et al. Risk of Death and Cardiovascular Events Following an Exacerbation of COPD: The EXACOS-CV US Study. *Int J Chron Obstruct Pulmon Dis* 2024; **19**: 225-41 <https://pubmed.ncbi.nlm.nih.gov/38259591>.
1340. Chen J, Yang J, Zhou M, et al. Cold spell and mortality in 31 Chinese capital cities: Definitions, vulnerability and implications. *Environ Int* 2019; **128**: 271-8 <https://pubmed.ncbi.nlm.nih.gov/31071590>.
1341. Howcroft M, Walters EH, Wood-Baker R, Walters JA. Action plans with brief patient education for exacerbations in chronic obstructive pulmonary disease. *Cochrane Database Syst Rev* 2016; **12**(12): CD005074 <https://pubmed.ncbi.nlm.nih.gov/27990628>.
1342. National Institute for Health and Care Excellence. Chronic obstructive pulmonary disease in over 16s: diagnosis and management. 2018. <https://www.nice.org.uk/guidance/NG115>.
1343. van Geffen WH, Douma WR, Slebos DJ, Kerstjens HA. Bronchodilators delivered by nebuliser versus pMDI with spacer or DPI for exacerbations of COPD. *Cochrane Database Syst Rev* 2016; **2016**(8): CD011826 <https://pubmed.ncbi.nlm.nih.gov/27569680>.
1344. Barr RG, Rowe BH, Camargo CA, Jr. Methylxanthines for exacerbations of chronic obstructive pulmonary disease: meta-analysis of randomised trials. *BMJ* 2003; **327**(7416): 643 <https://pubmed.ncbi.nlm.nih.gov/14500434>.

1345. Duffy N, Walker P, Diamantea F, Calverley PM, Davies L. Intravenous aminophylline in patients admitted to hospital with non-acidotic exacerbations of chronic obstructive pulmonary disease: a prospective randomised controlled trial. *Thorax* 2005; **60**(9): 713-7 <https://pubmed.ncbi.nlm.nih.gov/15939732>.
1346. Bardsley G, Pilcher J, McKinstry S, et al. Oxygen versus air-driven nebulisers for exacerbations of chronic obstructive pulmonary disease: a randomised controlled trial. *BMC Pulm Med* 2018; **18**(1): 157 <https://pubmed.ncbi.nlm.nih.gov/30285695>.
1347. Davies L, Angus RM, Calverley PM. Oral corticosteroids in patients admitted to hospital with exacerbations of chronic obstructive pulmonary disease: a prospective randomised controlled trial. *Lancet* 1999; **354**(9177): 456-60 <https://pubmed.ncbi.nlm.nih.gov/10465169>.
1348. Maltais F, Ostinelli J, Bourbeau J, et al. Comparison of nebulized budesonide and oral prednisolone with placebo in the treatment of acute exacerbations of chronic obstructive pulmonary disease: a randomized controlled trial. *Am J Respir Crit Care Med* 2002; **165**(5): 698-703 <https://pubmed.ncbi.nlm.nih.gov/11874817>.
1349. Niewoehner DE, Erbland ML, Deupree RH, et al. Effect of systemic glucocorticoids on exacerbations of chronic obstructive pulmonary disease. Department of Veterans Affairs Cooperative Study Group. *N Engl J Med* 1999; **340**(25): 1941-7 <https://pubmed.ncbi.nlm.nih.gov/10379017>.
1350. Thompson WH, Nielson CP, Carvalho P, Charan NB, Crowley JJ. Controlled trial of oral prednisone in outpatients with acute COPD exacerbation. *Am J Respir Crit Care Med* 1996; **154**(2 Pt 1): 407-12 <https://pubmed.ncbi.nlm.nih.gov/8756814>.
1351. Alia I, de la Cal MA, Esteban A, et al. Efficacy of corticosteroid therapy in patients with an acute exacerbation of chronic obstructive pulmonary disease receiving ventilatory support. *Arch Intern Med* 2011; **171**(21): 1939-46 <https://pubmed.ncbi.nlm.nih.gov/22123804>.
1352. Aaron SD, Vandemheen KL, Hebert P, et al. Outpatient oral prednisone after emergency treatment of chronic obstructive pulmonary disease. *N Engl J Med* 2003; **348**(26): 2618-25 <https://pubmed.ncbi.nlm.nih.gov/12826636>.
1353. Leuppi JD, Schuetz P, Bingisser R, et al. Short-term vs conventional glucocorticoid therapy in acute exacerbations of chronic obstructive pulmonary disease: the REDUCE randomized clinical trial. *JAMA* 2013; **309**(21): 2223-31 <https://pubmed.ncbi.nlm.nih.gov/23695200>.
1354. Sivapalan P, Ingebrigtsen TS, Rasmussen DB, et al. COPD exacerbations: the impact of long versus short courses of oral corticosteroids on mortality and pneumonia: nationwide data on 67 000 patients with COPD followed for 12 months. *BMJ Open Respir Res* 2019; **6**(1): e000407 <https://pubmed.ncbi.nlm.nih.gov/31179005>.
1355. de Jong YP, Uil SM, Grotjohan HP, Postma DS, Kerstjens HA, van den Berg JW. Oral or IV prednisolone in the treatment of COPD exacerbations: a randomized, controlled, double-blind study. *Chest* 2007; **132**(6): 1741-7 <https://pubmed.ncbi.nlm.nih.gov/17646228>.
1356. Gunen H, Hacievliyagil SS, Yetkin O, Gulbas G, Mutlu LC, In E. The role of nebulised budesonide in the treatment of exacerbations of COPD. *Eur Respir J* 2007; **29**(4): 660-7 <https://pubmed.ncbi.nlm.nih.gov/17251232>.
1357. Stallberg B, Selroos O, Vogelmeier C, Andersson E, Ekstrom T, Larsson K. Budesonide/formoterol as effective as prednisolone plus formoterol in acute exacerbations of COPD. A double-blind, randomised, non-inferiority, parallel-group, multicentre study. *Respir Res* 2009; **10**(1): 11 <https://pubmed.ncbi.nlm.nih.gov/19228428>.
1358. Ding Z, Li X, Lu Y, et al. A randomized, controlled multicentric study of inhaled budesonide and intravenous methylprednisolone in the treatment on acute exacerbation of chronic obstructive pulmonary disease. *Respir Med* 2016; **121**: 39-47 <https://pubmed.ncbi.nlm.nih.gov/27888990>.
1359. Stolz D, Hirsch HH, Schilter D, et al. Intensified Therapy with Inhaled Corticosteroids and Long-Acting beta(2)-Agonists at the Onset of Upper Respiratory Tract Infection to Prevent Chronic Obstructive Pulmonary Disease Exacerbations. A Multicenter, Randomized, Double-Blind, Placebo-controlled Trial. *Am J Respir Crit Care Med* 2018; **197**(9): 1136-46 <https://pubmed.ncbi.nlm.nih.gov/29266965>.
1360. Waljee AK, Rogers MA, Lin P, et al. Short term use of oral corticosteroids and related harms among adults in the United States: population based cohort study. *BMJ* 2017; **357**: j1415 <https://pubmed.ncbi.nlm.nih.gov/28404617>.
1361. Sivapalan P, Lapperre TS, Janner J, et al. Eosinophil-guided corticosteroid therapy in patients admitted to hospital with COPD exacerbation (CORTICO-COP): a multicentre, randomised, controlled, open-label, non-inferiority trial. *Lancet Respir Med* 2019; **7**(8): 699-709 <https://pubmed.ncbi.nlm.nih.gov/31122894>.
1362. Ramakrishnan S, Jeffers H, Langford-Wiley B, et al. Blood eosinophil-guided oral prednisolone for COPD exacerbations in primary care in the UK (STARR2): a non-inferiority, multicentre, double-blind, placebo-controlled, randomised controlled trial. *Lancet Respir Med* 2024; **12**(1): 67-77 <https://pubmed.ncbi.nlm.nih.gov/37924830>.
1363. Seemungal T, Harper-Owen R, Bhowmik A, et al. Respiratory viruses, symptoms, and inflammatory markers in acute exacerbations and stable chronic obstructive pulmonary disease. *Am J Respir Crit Care Med* 2001; **164**(9): 1618-23 <https://pubmed.ncbi.nlm.nih.gov/11719299>.
1364. Vollenweider DJ, Jarrett H, Steurer-Stey CA, Garcia-Aymerich J, Puhan MA. Antibiotics for exacerbations of chronic obstructive pulmonary disease. *Cochrane Database Syst Rev* 2012; **12**: CD010257 <https://pubmed.ncbi.nlm.nih.gov/23235687>.
1365. Miravittles M, Kruesmann F, Haverstock D, Perroncel R, Choudhri SH, Arvis P. Sputum colour and bacteria in chronic bronchitis exacerbations: a pooled analysis. *Eur Respir J* 2012; **39**(6): 1354-60 <https://pubmed.ncbi.nlm.nih.gov/22034649>.

1366. Ram FS, Rodriguez-Roisin R, Granados-Navarrete A, Garcia-Aymerich J, Barnes NC. Antibiotics for exacerbations of chronic obstructive pulmonary disease. *Cochrane Database Syst Rev* 2006; (2): CD004403 <https://pubmed.ncbi.nlm.nih.gov/16625602>.
1367. Quon BS, Gan WQ, Sin DD. Contemporary management of acute exacerbations of COPD: a systematic review and metaanalysis. *Chest* 2008; **133**(3): 756-66 <https://pubmed.ncbi.nlm.nih.gov/18321904>.
1368. Wilson R, Anzueto A, Miravittles M, et al. Moxifloxacin versus amoxicillin/clavulanic acid in outpatient acute exacerbations of COPD: MAESTRAL results. *Eur Respir J* 2012; **40**(1): 17-27 <https://pubmed.ncbi.nlm.nih.gov/22135277>.
1369. van Velzen P, Ter Riet G, Bresser P, et al. Doxycycline for outpatient-treated acute exacerbations of COPD: a randomised double-blind placebo-controlled trial. *Lancet Respir Med* 2017; **5**(6): 492-9 <https://pubmed.ncbi.nlm.nih.gov/28483402>.
1370. Clark TW, Medina MJ, Batham S, Curran MD, Parmar S, Nicholson KG. C-reactive protein level and microbial aetiology in patients hospitalised with acute exacerbation of COPD. *Eur Respir J* 2015; **45**(1): 76-86 <https://pubmed.ncbi.nlm.nih.gov/25186260>.
1371. Peng C, Tian C, Zhang Y, Yang X, Feng Y, Fan H. C-reactive protein levels predict bacterial exacerbation in patients with chronic obstructive pulmonary disease. *Am J Med Sci* 2013; **345**(3): 190-4 <https://pubmed.ncbi.nlm.nih.gov/23221507>.
1372. Prins HJ, Duijkers R, van der Valk P, et al. CRP-guided antibiotic treatment in acute exacerbations of COPD in hospital admissions. *Eur Respir J* 2019; **53**(5): <https://pubmed.ncbi.nlm.nih.gov/30880285>.
1373. Butler CC, Gillespie D, White P, et al. C-Reactive Protein Testing to Guide Antibiotic Prescribing for COPD Exacerbations. *N Engl J Med* 2019; **381**(2): 111-20 <https://pubmed.ncbi.nlm.nih.gov/31291514>.
1374. Christ-Crain M, Jaccard-Stolz D, Bingisser R, et al. Effect of procalcitonin-guided treatment on antibiotic use and outcome in lower respiratory tract infections: cluster-randomised, single-blinded intervention trial. *Lancet* 2004; **363**(9409): 600-7 <https://pubmed.ncbi.nlm.nih.gov/14987884>.
1375. Schuetz P, Christ-Crain M, Thomann R, et al. Effect of procalcitonin-based guidelines vs standard guidelines on antibiotic use in lower respiratory tract infections: the ProHOSP randomized controlled trial. *JAMA* 2009; **302**(10): 1059-66 <https://pubmed.ncbi.nlm.nih.gov/19738090>.
1376. Schuetz P, Muller B, Christ-Crain M, et al. Procalcitonin to initiate or discontinue antibiotics in acute respiratory tract infections. *Cochrane Database Syst Rev* 2012; **2012**(9): CD007498 <https://pubmed.ncbi.nlm.nih.gov/22972110>.
1377. Wang JX, Zhang SM, Li XH, Zhang Y, Xu ZY, Cao B. Acute exacerbations of chronic obstructive pulmonary disease with low serum procalcitonin values do not benefit from antibiotic treatment: a prospective randomized controlled trial. *Int J Infect Dis* 2016; **48**: 40-5 <https://pubmed.ncbi.nlm.nih.gov/27155210>.
1378. Chen K, Pleasants KA, Pleasants RA, et al. Procalcitonin for Antibiotic Prescription in Chronic Obstructive Pulmonary Disease Exacerbations: Systematic Review, Meta-Analysis, and Clinical Perspective. *Pulm Ther* 2020; **6**(2): 201-14 <https://pubmed.ncbi.nlm.nih.gov/32676981>.
1379. Daubin C, Valette X, Thiolliere F, et al. Procalcitonin algorithm to guide initial antibiotic therapy in acute exacerbations of COPD admitted to the ICU: a randomized multicenter study. *Intensive Care Med* 2018; **44**(4): 428-37 <https://pubmed.ncbi.nlm.nih.gov/29663044>.
1380. Masterton RG, Burley CJ. Randomized, double-blind study comparing 5- and 7-day regimens of oral levofloxacin in patients with acute exacerbation of chronic bronchitis. *Int J Antimicrob Agents* 2001; **18**(6): 503-12 <https://pubmed.ncbi.nlm.nih.gov/11738336>.
1381. Llor C, Moragas A, Miravittles M, Mesquita P, Cordoba G. Are short courses of antibiotic therapy as effective as standard courses for COPD exacerbations? A systematic review and meta-analysis. *Pulm Pharmacol Ther* 2022; **72**: 102111 <https://pubmed.ncbi.nlm.nih.gov/35032637>.
1382. Adams S, J. M, Luther M. Antibiotics are associated with lower relapse rates in outpatients with acute exacerbations of chronic obstructive pulmonary disease. *Chest* 2000; **117**: 1345-52
1383. Miravittles M, Espinosa C, Fernandez-Laso E, Martos JA, Maldonado JA, Gallego M. Relationship between bacterial flora in sputum and functional impairment in patients with acute exacerbations of COPD. Study Group of Bacterial Infection in COPD. *Chest* 1999; **116**(1): 40-6 <https://pubmed.ncbi.nlm.nih.gov/10424501>.
1384. Soler N, Torres A, Ewig S, et al. Bronchial microbial patterns in severe exacerbations of chronic obstructive pulmonary disease (COPD) requiring mechanical ventilation. *Am J Respir Crit Care Med* 1998; **157**(5 Pt 1): 1498-505 <https://pubmed.ncbi.nlm.nih.gov/9603129>.
1385. Rizkallah J, Man SFP, Sin DD. Prevalence of pulmonary embolism in acute exacerbations of COPD: a systematic review and metaanalysis. *Chest* 2009; **135**(3): 786-93 <https://pubmed.ncbi.nlm.nih.gov/18812453>.
1386. Gunen H, Gulbas G, In E, Yetkin O, Hacievliyagil SS. Venous thromboemboli and exacerbations of COPD. *Eur Respir J* 2010; **35**(6): 1243-8 <https://pubmed.ncbi.nlm.nih.gov/19926740>.
1387. Bertoletti L, Quenet S, Laporte S, et al. Pulmonary embolism and 3-month outcomes in 4036 patients with venous thromboembolism and chronic obstructive pulmonary disease: data from the RIETE registry. *Respir Res* 2013; **14**(1): 75 <https://pubmed.ncbi.nlm.nih.gov/23865769>.
1388. Kahn S, Lim W, Dunn A, et al. American College of Chest Physicians. Prevention of VTE in nonsurgical patients: Antithrombotic Therapy and Prevention of Thrombosis, 9th ed: American College of Chest Physicians Evidence-Based Practice Guidelines. *Chest* 2012; **141**((2 Suppl)): e195S-226S

1389. Austin MA, Wills KE, Blizzard L, Walters EH, Wood-Baker R. Effect of high flow oxygen on mortality in chronic obstructive pulmonary disease patients in prehospital setting: randomised controlled trial. *BMJ* 2010; **341**: c5462 <https://pubmed.ncbi.nlm.nih.gov/20959284>.
1390. Sjoding MW, Dickson RP, Iwashyna TJ, Gay SE, Valley TS. Racial Bias in Pulse Oximetry Measurement. *N Engl J Med* 2020; **383**(25): 2477-8 <https://pubmed.ncbi.nlm.nih.gov/33326721>.
1391. McKeever TM, Hearson G, Housley G, et al. Using venous blood gas analysis in the assessment of COPD exacerbations: a prospective cohort study. *Thorax* 2016; **71**(3): 210-5 <https://pubmed.ncbi.nlm.nih.gov/26628461>.
1392. Roca O, Hernandez G, Diaz-Lobato S, et al. Current evidence for the effectiveness of heated and humidified high flow nasal cannula supportive therapy in adult patients with respiratory failure. *Crit Care* 2016; **20**(1): 109 <https://pubmed.ncbi.nlm.nih.gov/27121707>.
1393. Fraser JF, Spooner AJ, Dunster KR, Anstey CM, Corley A. Nasal high flow oxygen therapy in patients with COPD reduces respiratory rate and tissue carbon dioxide while increasing tidal and end-expiratory lung volumes: a randomised crossover trial. *Thorax* 2016; **71**(8): 759-61 <https://pubmed.ncbi.nlm.nih.gov/27015801>.
1394. Mauri T, Turrini C, Eronia N, et al. Physiologic Effects of High-Flow Nasal Cannula in Acute Hypoxemic Respiratory Failure. *Am J Respir Crit Care Med* 2017; **195**(9): 1207-15 <https://pubmed.ncbi.nlm.nih.gov/27997805>.
1395. Frat JP, Coudroy R, Marjanovic N, Thille AW. High-flow nasal oxygen therapy and noninvasive ventilation in the management of acute hypoxemic respiratory failure. *Ann Transl Med* 2017; **5**(14): 297 <https://pubmed.ncbi.nlm.nih.gov/28828372>.
1396. Lin SM, Liu KX, Lin ZH, Lin PH. Does high-flow nasal cannula oxygen improve outcome in acute hypoxemic respiratory failure? A systematic review and meta-analysis. *Respir Med* 2017; **131**: 58-64 <https://pubmed.ncbi.nlm.nih.gov/28947043>.
1397. Nagata K, Kikuchi T, Horie T, et al. Domiciliary High-Flow Nasal Cannula Oxygen Therapy for Patients with Stable Hypercapnic Chronic Obstructive Pulmonary Disease. A Multicenter Randomized Crossover Trial. *Ann Am Thorac Soc* 2018; **15**(4): 432-9 <https://pubmed.ncbi.nlm.nih.gov/29283682>.
1398. Braunlich J, Dellweg D, Bastian A, et al. Nasal high-flow versus noninvasive ventilation in patients with chronic hypercapnic COPD. *Int J Chron Obstruct Pulmon Dis* 2019; **14**: 1411-21 <https://pubmed.ncbi.nlm.nih.gov/31308647>.
1399. Bruni A, Garofalo E, Cammarota G, et al. High Flow Through Nasal Cannula in Stable and Exacerbated Chronic Obstructive Pulmonary Disease Patients. *Rev Recent Clin Trials* 2019; **14**(4): 247-60 <https://pubmed.ncbi.nlm.nih.gov/31291880>.
1400. Bonnevie T, Elkins M, Paumier C, et al. Nasal High Flow for Stable Patients with Chronic Obstructive Pulmonary Disease: A Systematic Review and Meta-Analysis. *COPD* 2019; **16**(5-6): 368-77 <https://pubmed.ncbi.nlm.nih.gov/31656111>.
1401. Nagata K, Horie T, Chohnabayashi N, et al. Home High-Flow Nasal Cannula Oxygen Therapy for Stable Hypercapnic COPD: A Randomized Clinical Trial. *Am J Respir Crit Care Med* 2022; **206**(11): 1326-35 <https://pubmed.ncbi.nlm.nih.gov/35771533>.
1402. Xia J, Gu S, Lei W, et al. High-flow nasal cannula versus conventional oxygen therapy in acute COPD exacerbation with mild hypercapnia: a multicenter randomized controlled trial. *Crit Care* 2022; **26**(1): 109 <https://pubmed.ncbi.nlm.nih.gov/35428349>.
1403. Oczkowski S, Ergan B, Bos L, et al. ERS clinical practice guidelines: high-flow nasal cannula in acute respiratory failure. *Eur Respir J* 2022; **59**(4): <https://pubmed.ncbi.nlm.nih.gov/34649974>.
1404. Osadnik CR, Tee VS, Carson-Chahhoud KV, Picot J, Wedzicha JA, Smith BJ. Non-invasive ventilation for the management of acute hypercapnic respiratory failure due to exacerbation of chronic obstructive pulmonary disease. *Cochrane Database Syst Rev* 2017; **7**(7): CD004104 <https://pubmed.ncbi.nlm.nih.gov/28702957>.
1405. Brochard L, Mancebo J, Wysocki M, et al. Noninvasive ventilation for acute exacerbations of chronic obstructive pulmonary disease. *N Engl J Med* 1995; **333**(13): 817-22 <https://pubmed.ncbi.nlm.nih.gov/7651472>.
1406. Meyer TJ, Hill NS. Noninvasive positive pressure ventilation to treat respiratory failure. *Ann Intern Med* 1994; **120**(9): 760-70 <https://pubmed.ncbi.nlm.nih.gov/8147550>.
1407. Consensus development conference committee. Clinical indications for noninvasive positive pressure ventilation in chronic respiratory failure due to restrictive lung disease, COPD, and nocturnal hypoventilation--a consensus conference report. *Chest* 1999; **116**(2): 521-34 <https://pubmed.ncbi.nlm.nih.gov/10453883>.
1408. Bott J, Carroll MP, Conway JH, et al. Randomised controlled trial of nasal ventilation in acute ventilatory failure due to chronic obstructive airways disease. *Lancet* 1993; **341**(8860): 1555-7 <https://pubmed.ncbi.nlm.nih.gov/8099639>.
1409. Kramer N, Meyer TJ, Meharg J, Cece RD, Hill NS. Randomized, prospective trial of noninvasive positive pressure ventilation in acute respiratory failure. *Am J Respir Crit Care Med* 1995; **151**(6): 1799-806 <https://pubmed.ncbi.nlm.nih.gov/7767523>.
1410. Plant PK, Owen JL, Elliott MW. Early use of non-invasive ventilation for acute exacerbations of chronic obstructive pulmonary disease on general respiratory wards: a multicentre randomised controlled trial. *Lancet* 2000; **355**(9219): 1931-5 <https://pubmed.ncbi.nlm.nih.gov/10859037>.
1411. Sellares J, Ferrer M, Anton A, et al. Discontinuing noninvasive ventilation in severe chronic obstructive pulmonary disease exacerbations: a randomised controlled trial. *Eur Respir J* 2017; **50**(1): <https://pubmed.ncbi.nlm.nih.gov/28679605>.

1412. Conti G, Antonelli M, Navalesi P, et al. Noninvasive vs. conventional mechanical ventilation in patients with chronic obstructive pulmonary disease after failure of medical treatment in the ward: a randomized trial. *Intensive Care Med* 2002; **28**(12): 1701-7 <https://pubmed.ncbi.nlm.nih.gov/12447511>.
1413. Esteban A, Anzueto A, Frutos F, et al. Characteristics and outcomes in adult patients receiving mechanical ventilation: a 28-day international study. *JAMA* 2002; **287**(3): 345-55 <https://pubmed.ncbi.nlm.nih.gov/11790214>.
1414. Wildman MJ, Sanderson C, Groves J, et al. Implications of prognostic pessimism in patients with chronic obstructive pulmonary disease (COPD) or asthma admitted to intensive care in the UK within the COPD and asthma outcome study (CAOS): multicentre observational cohort study. *BMJ* 2007; **335**(7630): 1132 <https://pubmed.ncbi.nlm.nih.gov/17975254>.
1415. Gunen H, Hacievliyagil SS, Kosar F, et al. Factors affecting survival of hospitalised patients with COPD. *Eur Respir J* 2005; **26**(2): 234-41 <https://pubmed.ncbi.nlm.nih.gov/16055870>.
1416. Kong CW, Wilkinson TMA. Predicting and preventing hospital readmission for exacerbations of COPD. *ERJ Open Res* 2020; **6**(2): 00325-2019 <https://pubmed.ncbi.nlm.nih.gov/32420313>.
1417. Jennings JH, Thavarajah K, Mendez MP, Eichenhorn M, Kvale P, Yessayan L. Predischarge bundle for patients with acute exacerbations of COPD to reduce readmissions and ED visits: a randomized controlled trial. *Chest* 2015; **147**(5): 1227-34 <https://pubmed.ncbi.nlm.nih.gov/25940250>.
1418. Alqahtani JS, Njoku CM, Bereznicki B, et al. Risk factors for all-cause hospital readmission following exacerbation of COPD: a systematic review and meta-analysis. *Eur Respir Rev* 2020; **29**(156): epub 30 Jun <https://pubmed.ncbi.nlm.nih.gov/32499306>.
1419. Singh G, Zhang W, Kuo YF, Sharma G. Association of Psychological Disorders With 30-Day Readmission Rates in Patients With COPD. *Chest* 2016; **149**(4): 905-15 <https://pubmed.ncbi.nlm.nih.gov/26204260>.
1420. Ringbaek T, Green A, Laursen LC, Frausing E, Brondum E, Ulrik CS. Effect of tele health care on exacerbations and hospital admissions in patients with chronic obstructive pulmonary disease: a randomized clinical trial. *Int J Chron Obstruct Pulmon Dis* 2015; **10**: 1801-8 <https://pubmed.ncbi.nlm.nih.gov/26366072>.
1421. Hartl S, Lopez-Campos JL, Pozo-Rodriguez F, et al. Risk of death and readmission of hospital-admitted COPD exacerbations: European COPD Audit. *Eur Respir J* 2016; **47**(1): 113-21 <https://pubmed.ncbi.nlm.nih.gov/26493806>.
1422. Jordan RE, Majothi S, Heneghan NR, et al. Supported self-management for patients with moderate to severe chronic obstructive pulmonary disease (COPD): an evidence synthesis and economic analysis. *Health Technol Assess* 2015; **19**(36): 1-516 <https://pubmed.ncbi.nlm.nih.gov/25980984>.
1423. Walker PP, Pompilio PP, Zanaboni P, et al. Telemonitoring in Chronic Obstructive Pulmonary Disease (CHROMED). A Randomized Clinical Trial. *Am J Respir Crit Care Med* 2018; **198**(5): 620-8 <https://pubmed.ncbi.nlm.nih.gov/29557669>.
1424. Gavish R, Levy A, Dekel OK, Karp E, Maimon N. The Association Between Hospital Readmission and Pulmonologist Follow-up Visits in Patients With COPD. *Chest* 2015; **148**(2): 375-81 <https://pubmed.ncbi.nlm.nih.gov/25611698>.
1425. Oga T, Tsukino M, Hajiro T, Ikeda A, Nishimura K. Predictive properties of different multidimensional staging systems in patients with chronic obstructive pulmonary disease. *Int J Chron Obstruct Pulmon Dis* 2011; **6**: 521-6 <https://pubmed.ncbi.nlm.nih.gov/22069363>.
1426. Spece LJ, Epler EM, Duan K, et al. Reassessment of Home Oxygen Prescription after Hospitalization for Chronic Obstructive Pulmonary Disease. A Potential Target for Deimplementation. *Ann Am Thorac Soc* 2021; **18**(3): 426-32 <https://pubmed.ncbi.nlm.nih.gov/33075243>.
1427. Martinez-Garcia MA, de la Rosa Carrillo D, Soler-Cataluna JJ, et al. Prognostic value of bronchiectasis in patients with moderate-to-severe chronic obstructive pulmonary disease. *Am J Respir Crit Care Med* 2013; **187**(8): 823-31 <https://pubmed.ncbi.nlm.nih.gov/23392438>.
1428. Alsallakh MA, Sivakumaran S, Kennedy S, et al. Impact of COVID-19 lockdown on the incidence and mortality of acute exacerbations of chronic obstructive pulmonary disease: national interrupted time series analyses for Scotland and Wales. *BMC Med* 2021; **19**(1): 124 <https://pubmed.ncbi.nlm.nih.gov/33993870>.
1429. Chan KPF, Ma TF, Kwok WC, et al. Significant reduction in hospital admissions for acute exacerbation of chronic obstructive pulmonary disease in Hong Kong during coronavirus disease 2019 pandemic. *Respir Med* 2020; **171**: 106085 <https://pubmed.ncbi.nlm.nih.gov/32917356>.
1430. Huh K, Kim YE, Ji W, et al. Decrease in hospital admissions for respiratory diseases during the COVID-19 pandemic: a nationwide claims study. *Thorax* 2021; **76**(9): 939-41 <https://pubmed.ncbi.nlm.nih.gov/33782081>.
1431. Tan JY, Conceicao EP, Wee LE, Sim XYJ, Venkatachalam I. COVID-19 public health measures: a reduction in hospital admissions for COPD exacerbations. *Thorax* 2021; **76**(5): 512-3 <https://pubmed.ncbi.nlm.nih.gov/33273024>.
1432. Barnes PJ, Celli BR. Systemic manifestations and comorbidities of COPD. *Eur Respir J* 2009; **33**(5): 1165-85 <https://pubmed.ncbi.nlm.nih.gov/19407051>.
1433. Iversen KK, Kjaergaard J, Akkan D, et al. The prognostic importance of lung function in patients admitted with heart failure. *Eur J Heart Fail* 2010; **12**(7): 685-91 <https://pubmed.ncbi.nlm.nih.gov/20395261>.
1434. Almagro P, Soriano JB, Cabrera FJ, et al. Short- and medium-term prognosis in patients hospitalized for COPD exacerbation: the CODEX index. *Chest* 2014; **145**(5): 972-80 <https://pubmed.ncbi.nlm.nih.gov/24077342>.
1435. Campo G, Napoli N, Serenelli C, Tebaldi M, Ferrari R. Impact of a recent hospitalization on treatment and prognosis of ST-segment elevation myocardial infarction. *Int J Cardiol* 2013; **167**(1): 296-7 <https://pubmed.ncbi.nlm.nih.gov/23084113>.

1436. Fabbri LM, Luppi F, Beghe B, Rabe KF. Complex chronic comorbidities of COPD. *Eur Respir J* 2008; **31**(1): 204-12 <https://pubmed.ncbi.nlm.nih.gov/18166598>.
1437. Divo M, Cote C, de Torres JP, et al. Comorbidities and risk of mortality in patients with chronic obstructive pulmonary disease. *Am J Respir Crit Care Med* 2012; **186**(2): 155-61 <https://pubmed.ncbi.nlm.nih.gov/22561964>.
1438. Krahnke JS, Abraham WT, Adamson PB, et al. Heart failure and respiratory hospitalizations are reduced in patients with heart failure and chronic obstructive pulmonary disease with the use of an implantable pulmonary artery pressure monitoring device. *J Card Fail* 2015; **21**(3): 240-9 <https://pubmed.ncbi.nlm.nih.gov/25541376>.
1439. Yeoh SE, Dewan P, Serenelli M, et al. Effects of mineralocorticoid receptor antagonists in heart failure with reduced ejection fraction patients with chronic obstructive pulmonary disease in EMPHASIS-HF and RALES. *Eur J Heart Fail* 2022; **24**(3): 529-38 <https://pubmed.ncbi.nlm.nih.gov/34536265>.
1440. Maclagan LC, Croxford R, Chu A, et al. Quantifying COPD as a risk factor for cardiac disease in a primary prevention cohort. *Eur Respir J* 2023; **62**(2): <https://pubmed.ncbi.nlm.nih.gov/37385658>.
1441. Bhatt SP, Dransfield MT. Chronic obstructive pulmonary disease and cardiovascular disease. *Transl Res* 2013; **162**(4): 237-51 <https://pubmed.ncbi.nlm.nih.gov/23727296>.
1442. Matamis D, Tsagourias M, Papathanasiou A, et al. Targeting occult heart failure in intensive care unit patients with acute chronic obstructive pulmonary disease exacerbation: effect on outcome and quality of life. *J Crit Care* 2014; **29**(2): 315 e7-14 <https://pubmed.ncbi.nlm.nih.gov/24369757>.
1443. MacDonald MI, Shafuddin E, King PT, Chang CL, Bardin PG, Hancox RJ. Cardiac dysfunction during exacerbations of chronic obstructive pulmonary disease. *Lancet Respir Med* 2016; **4**(2): 138-48 <https://pubmed.ncbi.nlm.nih.gov/26781000>.
1444. Masa JF, Utrabo I, Gomez de Terrerros J, et al. Noninvasive ventilation for severely acidotic patients in respiratory intermediate care units : Precision medicine in intermediate care units. *BMC Pulm Med* 2016; **16**(1): 97 <https://pubmed.ncbi.nlm.nih.gov/27387544>.
1445. National Heart Lung & Blood Institute. Assessing Cardiovascular Risk: Systematic Evidence Review from the Risk Assessment Work Group. 2013. <https://www.nhlbi.nih.gov/health-topics/assessing-cardiovascular-risk> (accessed Oct 2021).
1446. Dransfield MT, Criner GJ, Halpin DMG, et al. Time-Dependent Risk of Cardiovascular Events Following an Exacerbation in Patients With Chronic Obstructive Pulmonary Disease: Post Hoc Analysis From the IMPACT Trial. *J Am Heart Assoc* 2022; **11**(18): e024350 <https://pubmed.ncbi.nlm.nih.gov/36102236>.
1447. Wang M, Lin EP, Huang LC, Li CY, Shyr Y, Lai CH. Mortality of Cardiovascular Events in Patients With COPD and Preceding Hospitalization for Acute Exacerbation. *Chest* 2020; **158**(3): 973-85 <https://pubmed.ncbi.nlm.nih.gov/32184108>.
1448. Adamson PD, Anderson JA, Brook RD, et al. Cardiac Troponin I and Cardiovascular Risk in Patients With Chronic Obstructive Pulmonary Disease. *J Am Coll Cardiol* 2018; **72**(10): 1126-37 <https://pubmed.ncbi.nlm.nih.gov/30165984>.
1449. Hoiseith AD, Neukamm A, Karlsson BD, Omland T, Brekke PH, Soyseth V. Elevated high-sensitivity cardiac troponin T is associated with increased mortality after acute exacerbation of chronic obstructive pulmonary disease. *Thorax* 2011; **66**(9): 775-81 <https://pubmed.ncbi.nlm.nih.gov/21653926>.
1450. Liu X, Chen Z, Li S, Xu S. Association of Chronic Obstructive Pulmonary Disease With Arrhythmia Risks: A Systematic Review and Meta-Analysis. *Front Cardiovasc Med* 2021; **8**: 732349 <https://pubmed.ncbi.nlm.nih.gov/34660734>.
1451. Buch P, Friberg J, Scharling H, Lange P, Prescott E. Reduced lung function and risk of atrial fibrillation in the Copenhagen City Heart Study. *Eur Respir J* 2003; **21**(6): 1012-6 <https://pubmed.ncbi.nlm.nih.gov/12797497>.
1452. Graul EL, Nordon C, Rhodes K, et al. Factors associated with non-fatal heart failure and atrial fibrillation or flutter within the first 30 days post COPD exacerbation: a nested case-control study. *BMC Pulm Med* 2024; **24**(1): 221 <https://pubmed.ncbi.nlm.nih.gov/38704538>.
1453. Terzano C, Romani S, Conti V, Paone G, Oriolo F, Vitarelli A. Atrial fibrillation in the acute, hypercapnic exacerbations of COPD. *Eur Rev Med Pharmacol Sci* 2014; **18**(19): 2908-17 <https://pubmed.ncbi.nlm.nih.gov/25339486>.
1454. Singh S, Loke YK, Enright P, Furberg CD. Pro-arrhythmic and pro-ischaemic effects of inhaled anticholinergic medications. *Thorax* 2013; **68**(1): 114-6 <https://pubmed.ncbi.nlm.nih.gov/22764216>.
1455. Wilchesky M, Ernst P, Brophy JM, Platt RW, Suissa S. Bronchodilator use and the risk of arrhythmia in COPD: part 2: reassessment in the larger Quebec cohort. *Chest* 2012; **142**(2): 305-11 <https://pubmed.ncbi.nlm.nih.gov/22871756>.
1456. Salpeter SR, Ormiston TM, Salpeter EE. Cardiovascular effects of beta-agonists in patients with asthma and COPD: a meta-analysis. *Chest* 2004; **125**(6): 2309-21 <https://pubmed.ncbi.nlm.nih.gov/15189956>.
1457. Tashkin DP, Fabbri LM. Long-acting beta-agonists in the management of chronic obstructive pulmonary disease: current and future agents. *Respir Res* 2010; **11**(1): 149 <https://pubmed.ncbi.nlm.nih.gov/21034447>.
1458. Calverley P, Pauwels R, Vestbo J, et al. Combined salmeterol and fluticasone in the treatment of chronic obstructive pulmonary disease: a randomised controlled trial. *Lancet* 2003; **361**(9356): 449-56 <https://pubmed.ncbi.nlm.nih.gov/12583942>.
1459. Szafranski W, Cukier A, Ramirez A, et al. Efficacy and safety of budesonide/formoterol in the management of chronic obstructive pulmonary disease. *Eur Respir J* 2003; **21**(1): 74-81 <https://pubmed.ncbi.nlm.nih.gov/12570112>.
1460. Calverley PM, Boonsawat W, Cseke Z, Zhong N, Peterson S, Olsson H. Maintenance therapy with budesonide and formoterol in chronic obstructive pulmonary disease. *Eur Respir J* 2003; **22**(6): 912-9 <https://pubmed.ncbi.nlm.nih.gov/14680078>.

1461. Calverley PM, Anderson JA, Celli B, et al. Cardiovascular events in patients with COPD: TORCH study results. *Thorax* 2010; **65**(8): 719-25 <https://pubmed.ncbi.nlm.nih.gov/20685748>.
1462. Wilchesky M, Ernst P, Brophy JM, Platt RW, Suissa S. Bronchodilator use and the risk of arrhythmia in COPD: part 1: Saskatchewan cohort study. *Chest* 2012; **142**(2): 298-304 <https://pubmed.ncbi.nlm.nih.gov/22871755>.
1463. January CT, Wann LS, Alpert JS, et al. 2014 AHA/ACC/HRS guideline for the management of patients with atrial fibrillation: a report of the American College of Cardiology/American Heart Association Task Force on practice guidelines and the Heart Rhythm Society. *Circulation* 2014; **130**(23): e199-267 <https://pubmed.ncbi.nlm.nih.gov/24682347>.
1464. Ohta K, Fukuchi Y, Grouse L, et al. A prospective clinical study of theophylline safety in 3810 elderly with asthma or COPD. *Respir Med* 2004; **98**(10): 1016-24 <https://pubmed.ncbi.nlm.nih.gov/15481279>.
1465. Sessler CN, Cohen MD. Cardiac arrhythmias during theophylline toxicity. A prospective continuous electrocardiographic study. *Chest* 1990; **98**(3): 672-8 <https://pubmed.ncbi.nlm.nih.gov/2394145>.
1466. Humbert M, Kovacs G, Hoeper MM, et al. 2022 ESC/ERS Guidelines for the diagnosis and treatment of pulmonary hypertension. *Eur Heart J* 2022; **43**(38): 3618-731 <https://pubmed.ncbi.nlm.nih.gov/36017548>.
1467. Humbert M, Kovacs G, Hoeper MM, et al. 2022 ESC/ERS Guidelines for the diagnosis and treatment of pulmonary hypertension. *Eur Respir J* 2023; **61**(1): <https://pubmed.ncbi.nlm.nih.gov/36028254>.
1468. Pepke-Zaba J, Delcroix M, Lang I, et al. Chronic thromboembolic pulmonary hypertension (CTEPH): results from an international prospective registry. *Circulation* 2011; **124**(18): 1973-81 <https://pubmed.ncbi.nlm.nih.gov/21969018>.
1469. Hoeper MM, Humbert M, Souza R, et al. A global view of pulmonary hypertension. *Lancet Respir Med* 2016; **4**(4): 306-22 <https://pubmed.ncbi.nlm.nih.gov/26975810>.
1470. Zeder K, Avian A, Bachmaier G, et al. Elevated pulmonary vascular resistance predicts mortality in COPD patients. *The European respiratory journal* 2021:
1471. Thabut G, Dauriat G, Stern JB, et al. Pulmonary hemodynamics in advanced COPD candidates for lung volume reduction surgery or lung transplantation. *Chest* 2005; **127**(5): 1531-6 <https://pubmed.ncbi.nlm.nih.gov/15888824>.
1472. Dauriat G, Reynaud-Gaubert M, Cottin V, et al. Severe pulmonary hypertension associated with chronic obstructive pulmonary disease: A prospective French multicenter cohort. *J Heart Lung Transplant* 2021; **40**(9): 1009-18 <https://pubmed.ncbi.nlm.nih.gov/34218966>.
1473. Vizza CD, Hoeper MM, Huscher D, et al. Pulmonary Hypertension in Patients With COPD: Results From the Comparative, Prospective Registry of Newly Initiated Therapies for Pulmonary Hypertension (COMPERA). *Chest* 2021; **160**(2): 678-89 <https://pubmed.ncbi.nlm.nih.gov/33581097>.
1474. Nathan SD, Argula R, Trivieri MG, et al. Inhaled treprostinil in pulmonary hypertension associated with COPD: PERFECT study results. *Eur Respir J* 2024; **63**(6): <https://pubmed.ncbi.nlm.nih.gov/38811045>.
1475. Houben-Wilke S, Jorres RA, Bals R, et al. Peripheral Artery Disease and Its Clinical Relevance in Patients with Chronic Obstructive Pulmonary Disease in the COPD and Systemic Consequences-Comorbidities Network Study. *Am J Respir Crit Care Med* 2017; **195**(2): 189-97 <https://pubmed.ncbi.nlm.nih.gov/27532739>.
1476. Abusaid GH, Barbagelata A, Tuero E, Mahmood A, Sharma G. Diastolic dysfunction and COPD exacerbation. *Postgrad Med* 2009; **121**(4): 76-81 <https://pubmed.ncbi.nlm.nih.gov/19641273>.
1477. Lopez-Sanchez M, Munoz-Esquerre M, Huertas D, et al. High Prevalence of Left Ventricle Diastolic Dysfunction in Severe COPD Associated with A Low Exercise Capacity: A Cross-Sectional Study. *PLoS One* 2013; **8**(6): e68034 <https://pubmed.ncbi.nlm.nih.gov/23826360>.
1478. Dransfield MT, McAllister DA, Anderson JA, et al. beta-Blocker Therapy and Clinical Outcomes in Patients with Moderate Chronic Obstructive Pulmonary Disease and Heightened Cardiovascular Risk. An Observational Substudy of SUMMIT. *Ann Am Thorac Soc* 2018; **15**(5): 608-14 <https://pubmed.ncbi.nlm.nih.gov/29406772>.
1479. Ferlay J, Soerjomataram I, Dikshit R, et al. Cancer incidence and mortality worldwide: sources, methods and major patterns in GLOBOCAN 2012. *Int J Cancer* 2015; **136**(5): E359-86 <https://pubmed.ncbi.nlm.nih.gov/25220842>.
1480. Tanoue LT, Tanner NT, Gould MK, Silvestri GA. Lung cancer screening. *Am J Respir Crit Care Med* 2015; **191**(1): 19-33 <https://pubmed.ncbi.nlm.nih.gov/25369325>.
1481. Lopez-Encuentra A, Astudillo J, Cerezal J, et al. Prognostic value of chronic obstructive pulmonary disease in 2994 cases of lung cancer. *Eur J Cardiothorac Surg* 2005; **27**(1): 8-13 <https://pubmed.ncbi.nlm.nih.gov/15736303>.
1482. Mannino DM, Aguayo SM, Petty TL, Redd SC. Low lung function and incident lung cancer in the United States: data From the First National Health and Nutrition Examination Survey follow-up. *Arch Intern Med* 2003; **163**(12): 1475-80 <https://pubmed.ncbi.nlm.nih.gov/12824098>.
1483. de Torres JP, Marin JM, Casanova C, et al. Lung cancer in patients with chronic obstructive pulmonary disease--incidence and predicting factors. *Am J Respir Crit Care Med* 2011; **184**(8): 913-9 <https://pubmed.ncbi.nlm.nih.gov/21799072>.
1484. Caramori G, Casolari P, Cavallesco GN, Giuffre S, Adcock I, Papi A. Mechanisms involved in lung cancer development in COPD. *Int J Biochem Cell Biol* 2011; **43**(7): 1030-44 <https://pubmed.ncbi.nlm.nih.gov/20951226>.
1485. Celli BR. Chronic obstructive pulmonary disease and lung cancer: common pathogenesis, shared clinical challenges. *Proc Am Thorac Soc* 2012; **9**(2): 74-9 <https://pubmed.ncbi.nlm.nih.gov/22550249>.
1486. Houghton AM. Mechanistic links between COPD and lung cancer. *Nat Rev Cancer* 2013; **13**(4): 233-45 <https://pubmed.ncbi.nlm.nih.gov/23467302>.

1487. de Torres JP, Bastarrika G, Wisnivesky JP, et al. Assessing the relationship between lung cancer risk and emphysema detected on low-dose CT of the chest. *Chest* 2007; **132**(6): 1932-8 <https://pubmed.ncbi.nlm.nih.gov/18079226>.
1488. Wilson DO, Leader JK, Fuhrman CR, Reilly JJ, Sciurba FC, Weissfeld JL. Quantitative computed tomography analysis, airflow obstruction, and lung cancer in the pittsburgh lung screening study. *J Thorac Oncol* 2011; **6**(7): 1200-5 <https://pubmed.ncbi.nlm.nih.gov/21610523>.
1489. Dhariwal J, Tennant RC, Hansell DM, et al. Smoking cessation in COPD causes a transient improvement in spirometry and decreases micronodules on high-resolution CT imaging. *Chest* 2014; **145**(5): 1006-15 <https://pubmed.ncbi.nlm.nih.gov/24522562>.
1490. International Early Lung Cancer Action Program I, Henschke CI, Yankelevitz DF, et al. Survival of patients with stage I lung cancer detected on CT screening. *N Engl J Med* 2006; **355**(17): 1763-71 <https://pubmed.ncbi.nlm.nih.gov/17065637>.
1491. U. S. Preventive Services Task Force, Krist AH, Davidson KW, et al. Screening for Lung Cancer: US Preventive Services Task Force Recommendation Statement. *JAMA* 2021; **325**(10): 962-70 <https://pubmed.ncbi.nlm.nih.gov/33687470>.
1492. Aldrich MC, Mercaldo SF, Sandler KL, Blot WJ, Grogan EL, Blume JD. Evaluation of USPSTF Lung Cancer Screening Guidelines Among African American Adult Smokers. *JAMA Oncol* 2019; **5**(9): 1318-24 <https://pubmed.ncbi.nlm.nih.gov/31246249>.
1493. Bandiera FC, Assari S, Livaudais-Toman J, Perez-Stable EJ. Latino and Black smokers in the Health and Retirement Study are more likely to quit: the role of light smoking. *Tob Induc Dis* 2016; **14**: 23 <https://pubmed.ncbi.nlm.nih.gov/27436994>.
1494. Haiman CA, Stram DO, Wilkens LR, et al. Ethnic and racial differences in the smoking-related risk of lung cancer. *N Engl J Med* 2006; **354**(4): 333-42 <https://pubmed.ncbi.nlm.nih.gov/16436765>.
1495. Kaplan RC, Bangdiwala SI, Barnhart JM, et al. Smoking among U.S. Hispanic/Latino adults: the Hispanic community health study/study of Latinos. *Am J Prev Med* 2014; **46**(5): 496-506 <https://pubmed.ncbi.nlm.nih.gov/24745640>.
1496. Lin HH, Murray M, Cohen T, Colijn C, Ezzati M. Effects of smoking and solid-fuel use on COPD, lung cancer, and tuberculosis in China: a time-based, multiple risk factor, modelling study. *Lancet* 2008; **372**(9648): 1473-83 <https://pubmed.ncbi.nlm.nih.gov/18835640>.
1497. Park HY, Kang D, Shin SH, et al. Chronic obstructive pulmonary disease and lung cancer incidence in never smokers: a cohort study. *Thorax* 2020; **75**(6): 506-9 <https://pubmed.ncbi.nlm.nih.gov/32241883>.
1498. Centers for Disease Control and Prevention. Lung Cancer Among People Who Never Smoked, November 2020, <https://www.cdc.gov/lung-cancer/nonsmokers/> [accessed Oct 2024].
1499. de-Torres JP, Casanova C, Marin JM, et al. Exploring the impact of screening with low-dose CT on lung cancer mortality in mild to moderate COPD patients: a pilot study. *Respir Med* 2013; **107**(5): 702-7 <https://pubmed.ncbi.nlm.nih.gov/23465176>.
1500. Lam VK, Miller M, Dowling L, Singhal S, Young RP, Cabebe EC. Community low-dose CT lung cancer screening: a prospective cohort study. *Lung* 2015; **193**(1): 135-9 <https://pubmed.ncbi.nlm.nih.gov/25503535>.
1501. Ashraf H, Saghir Z, Dirksen A, et al. Smoking habits in the randomised Danish Lung Cancer Screening Trial with low-dose CT: final results after a 5-year screening programme. *Thorax* 2014; **69**(6): 574-9 <https://pubmed.ncbi.nlm.nih.gov/24443174>.
1502. Raymakers AJN, Sadatsafavi M, Sin DD, Fitzgerald JM, Marra CA, Lynd LD. Inhaled corticosteroids and the risk of lung cancer in COPD: a population-based cohort study. *Eur Respir J* 2019; **53**(6): <https://pubmed.ncbi.nlm.nih.gov/30956205>.
1503. Seijo LM, Soriano JB, Peces-Barba G. New evidence on the chemoprevention of inhaled steroids and the risk of lung cancer in COPD. *Eur Respir J* 2019; **53**(6): <https://pubmed.ncbi.nlm.nih.gov/31167885>.
1504. Ge F, Feng Y, Huo Z, et al. Inhaled corticosteroids and risk of lung cancer among chronic obstructive pulmonary disease patients: a comprehensive analysis of nine prospective cohorts. *Transl Lung Cancer Res* 2021; **10**(3): 1266-76 <https://pubmed.ncbi.nlm.nih.gov/33889508>.
1505. Kiri VA, Fabbri LM, Davis KJ, Soriano JB. Inhaled corticosteroids and risk of lung cancer among COPD patients who quit smoking. *Respir Med* 2009; **103**(1): 85-90 <https://pubmed.ncbi.nlm.nih.gov/18793832>.
1506. Lee YM, Kim SJ, Lee JH, Ha E. Inhaled corticosteroids in COPD and the risk of lung cancer. *Int J Cancer* 2018; **143**(9): 2311-8 <https://pubmed.ncbi.nlm.nih.gov/29943812>.
1507. Parimon T, Chien JW, Bryson CL, McDonnell MB, Udris EM, Au DH. Inhaled corticosteroids and risk of lung cancer among patients with chronic obstructive pulmonary disease. *Am J Respir Crit Care Med* 2007; **175**(7): 712-9 <https://pubmed.ncbi.nlm.nih.gov/17185647>.
1508. Sandelin M, Mindus S, Thuresson M, et al. Factors associated with lung cancer in COPD patients. *Int J Chron Obstruct Pulmon Dis* 2018; **13**: 1833-9 <https://pubmed.ncbi.nlm.nih.gov/29922050>.
1509. Raymakers AJ, McCormick N, Marra CA, Fitzgerald JM, Sin D, Lynd LD. Do inhaled corticosteroids protect against lung cancer in patients with COPD? A systematic review. *Respirology* 2017; **22**(1): 61-70 <https://pubmed.ncbi.nlm.nih.gov/27761973>.
1510. Sorli K, Thorvaldsen SM, Hatlen P. Use of Inhaled Corticosteroids and the Risk of Lung Cancer, the HUNT Study. *Lung* 2018; **196**(2): 179-84 <https://pubmed.ncbi.nlm.nih.gov/29427221>.

1511. Wu MF, Jian ZH, Huang JY, et al. Post-inhaled corticosteroid pulmonary tuberculosis and pneumonia increases lung cancer in patients with COPD. *BMC Cancer* 2016; **16**(1): 778 <https://pubmed.ncbi.nlm.nih.gov/27724847>.
1512. Docherty AB, Harrison EM, Green CA, et al. Features of 20 133 UK patients in hospital with covid-19 using the ISARIC WHO Clinical Characterisation Protocol: prospective observational cohort study. *BMJ* 2020; **369**: m1985 <https://pubmed.ncbi.nlm.nih.gov/32444460>.
1513. Tal-Singer R, Crapo JD. COPD at the Time of COVID-19: A COPD Foundation Perspective. *Chronic Obstr Pulm Dis* 2020; **7**(2): 73-5 <https://pubmed.ncbi.nlm.nih.gov/32324976>.
1514. Greenhalgh T, Knight M, A'Court C, Buxton M, Husain L. Management of post-acute covid-19 in primary care. *BMJ* 2020; **370**: m3026 <https://pubmed.ncbi.nlm.nih.gov/32784198>.
1515. Tenforde MW, Kim SS, Lindsell CJ, et al. Symptom Duration and Risk Factors for Delayed Return to Usual Health Among Outpatients with COVID-19 in a Multistate Health Care Systems Network - United States, March-June 2020. *MMWR Morb Mortal Wkly Rep* 2020; **69**(30): 993-8 <https://pubmed.ncbi.nlm.nih.gov/32730238>.
1516. Carfi A, Bernabei R, Landi F, Gemelli Against C-P-ACSG. Persistent Symptoms in Patients After Acute COVID-19. *JAMA* 2020; **324**(6): 603-5 <https://pubmed.ncbi.nlm.nih.gov/32644129>.
1517. Alkodaymi MS, Omrani OA, Fawzy NA, et al. Prevalence of post-acute COVID-19 syndrome symptoms at different follow-up periods: a systematic review and meta-analysis. *Clin Microbiol Infect* 2022; **28**(5): 657-66 <https://pubmed.ncbi.nlm.nih.gov/35124265>.
1518. Ballering AV, van Zon SKR, Olde Hartman TC, Rosmalen JGM. Persistence of somatic symptoms after COVID-19 in the Netherlands: an observational cohort study. *Lancet* 2022; **400**(10350): 452-61 <https://pubmed.ncbi.nlm.nih.gov/35934007>.
1519. Evans RA, McAuley H, Harrison EM, et al. Physical, cognitive, and mental health impacts of COVID-19 after hospitalisation (PHOSP-COVID): a UK multicentre, prospective cohort study. *Lancet Respir Med* 2021; **9**(11): 1275-87 <https://pubmed.ncbi.nlm.nih.gov/34627560>.
1520. Subramanian A, Nirantharakumar K, Hughes S, et al. Symptoms and risk factors for long COVID in non-hospitalized adults. *Nat Med* 2022; **28**(8): 1706-14 <https://pubmed.ncbi.nlm.nih.gov/35879616>.
1521. O'Brien C, Guest PJ, Hill SL, Stockley RA. Physiological and radiological characterisation of patients diagnosed with chronic obstructive pulmonary disease in primary care. *Thorax* 2000; **55**(8): 635-42 <https://pubmed.ncbi.nlm.nih.gov/10899238>.
1522. Polverino E, De Soya A, Dimakou K, et al. The Association Between Bronchiectasis and Chronic Obstructive Pulmonary Disease: Data from the European Bronchiectasis Registry (EMBARC). *Am J Respir Crit Care Med* 2024: <https://pubmed.ncbi.nlm.nih.gov/38271696>.
1523. Jemal A, Ward E, Hao Y, Thun M. Trends in the leading causes of death in the United States, 1970-2002. *JAMA* 2005; **294**(10): 1255-9 <https://pubmed.ncbi.nlm.nih.gov/16160134>.
1524. Mannino DM, Gagnon RC, Petty TL, Lydick E. Obstructive lung disease and low lung function in adults in the United States: data from the National Health and Nutrition Examination Survey, 1988-1994. *Arch Intern Med* 2000; **160**(11): 1683-9 <https://pubmed.ncbi.nlm.nih.gov/10847262>.
1525. Young T, Palta M, Dempsey J, Skatrud J, Weber S, Badr S. The occurrence of sleep-disordered breathing among middle-aged adults. *N Engl J Med* 1993; **328**(17): 1230-5 <https://pubmed.ncbi.nlm.nih.gov/8464434>.
1526. Flenley DC. Sleep in chronic obstructive lung disease. *Clin Chest Med* 1985; **6**(4): 651-61 <https://pubmed.ncbi.nlm.nih.gov/2935359>.
1527. Chaouat A, Weitzenblum E, Krieger J, Ifoundza T, Oswald M, Kessler R. Association of chronic obstructive pulmonary disease and sleep apnea syndrome. *Am J Respir Crit Care Med* 1995; **151**(1): 82-6 <https://pubmed.ncbi.nlm.nih.gov/7812577>.
1528. Shepard JW, Jr., Garrison MW, Grither DA, Evans R, Schweitzer PK. Relationship of ventricular ectopy to nocturnal oxygen desaturation in patients with chronic obstructive pulmonary disease. *Am J Med* 1985; **78**(1): 28-34 <https://pubmed.ncbi.nlm.nih.gov/2578248>.
1529. Bradley TD, Rutherford R, Grossman RF, et al. Role of daytime hypoxemia in the pathogenesis of right heart failure in the obstructive sleep apnea syndrome. *Am Rev Respir Dis* 1985; **131**(6): 835-9 <https://pubmed.ncbi.nlm.nih.gov/4003933>.
1530. Weitzenblum E, Krieger J, Apprill M, et al. Daytime pulmonary hypertension in patients with obstructive sleep apnea syndrome. *Am Rev Respir Dis* 1988; **138**(2): 345-9 <https://pubmed.ncbi.nlm.nih.gov/3143285>.
1531. Sterling KL, Pepin JL, Linde-Zwirble W, et al. Impact of Positive Airway Pressure Therapy Adherence on Outcomes in Patients with Obstructive Sleep Apnea and Chronic Obstructive Pulmonary Disease. *Am J Respir Crit Care Med* 2022; **206**(2): 197-205 <https://pubmed.ncbi.nlm.nih.gov/35436176>.
1532. Luyster FS, Boudreaux-Kelly MY, Bon JM. Insomnia in chronic obstructive pulmonary disease and associations with healthcare utilization and costs. *Respir Res* 2023; **24**(1): 93 <https://pubmed.ncbi.nlm.nih.gov/36964552>.
1533. Hobbins S, Chapple IL, Sapey E, Stockley RA. Is periodontitis a comorbidity of COPD or can associations be explained by shared risk factors/behaviors? *Int J Chron Obstruct Pulmon Dis* 2017; **12**: 1339-49 <https://pubmed.ncbi.nlm.nih.gov/28496317>.
1534. Sapey E, Yonel Z, Edgar R, et al. The clinical and inflammatory relationships between periodontitis and chronic obstructive pulmonary disease. *J Clin Periodontol* 2020; **47**(9): 1040-52 <https://pubmed.ncbi.nlm.nih.gov/32567697>.

1535. Shen TC, Chang PY, Lin CL, et al. Risk of Periodontal Diseases in Patients With Chronic Obstructive Pulmonary Disease: A Nationwide Population-based Cohort Study. *Medicine (Baltimore)* 2015; **94**(46): e2047 <https://pubmed.ncbi.nlm.nih.gov/26579813>.
1536. Takahashi T, Muro S, Tanabe N, et al. Relationship between periodontitis-related antibody and frequent exacerbations in chronic obstructive pulmonary disease. *PLoS One* 2012; **7**(7): e40570 <https://pubmed.ncbi.nlm.nih.gov/22792372>.
1537. Apeossos I, Voulgaris A, Agrafiotis M, Andreadis D, Steiropoulos P. Effect of periodontal therapy on COPD outcomes: a systematic review. *BMC Pulm Med* 2021; **21**(1): 92 <https://pubmed.ncbi.nlm.nih.gov/33736634>.
1538. Noh E, Jeong H, Cho IS, et al. Risk of Cardiovascular Events Associated with Chronic Obstructive Pulmonary Disease and/or Metabolic Syndrome: A Large-Scale Nationwide Population-Based Cohort Study. *Int J Chron Obstruct Pulmon Dis* 2024; **19**: 1447-56 <https://pubmed.ncbi.nlm.nih.gov/38948908>.
1539. Zaigham S, Tanash H, Nilsson PM, Muhammad IF. Triglyceride-Glucose Index is a Risk Marker of Incident COPD Events in Women. *Int J Chron Obstruct Pulmon Dis* 2022; **17**: 1393-401 <https://pubmed.ncbi.nlm.nih.gov/35746923>.
1540. Cebron Lipovec N, Beijers RJ, van den Borst B, Doehner W, Lainscak M, Schols AM. The Prevalence of Metabolic Syndrome In Chronic Obstructive Pulmonary Disease: A Systematic Review. *COPD* 2016; **13**(3): 399-406 <https://pubmed.ncbi.nlm.nih.gov/26914392>.
1541. Martinez CH, Okajima Y, Murray S, et al. Impact of self-reported gastroesophageal reflux disease in subjects from COPDGene cohort. *Respir Res* 2014; **15**(1): 62 <https://pubmed.ncbi.nlm.nih.gov/24894541>.
1542. Ingebrigtsen TS, Marott JL, Vestbo J, Nordestgaard BG, Hallas J, Lange P. Gastro-esophageal reflux disease and exacerbations in chronic obstructive pulmonary disease. *Respirology* 2015; **20**(1): 101-7 <https://pubmed.ncbi.nlm.nih.gov/25297724>.
1543. Sasaki T, Nakayama K, Yasuda H, et al. A randomized, single-blind study of lansoprazole for the prevention of exacerbations of chronic obstructive pulmonary disease in older patients. *J Am Geriatr Soc* 2009; **57**(8): 1453-7 <https://pubmed.ncbi.nlm.nih.gov/19515110>.
1544. Baumeler L, Papakonstantinou E, Milenkovic B, et al. Therapy with proton-pump inhibitors for gastroesophageal reflux disease does not reduce the risk for severe exacerbations in COPD. *Respirology* 2016; **21**(5): 883-90 <https://pubmed.ncbi.nlm.nih.gov/26970108>.
1545. Benson VS, Mullerova H, Vestbo J, et al. Associations between gastro-oesophageal reflux, its management and exacerbations of chronic obstructive pulmonary disease. *Respir Med* 2015; **109**(9): 1147-54 <https://pubmed.ncbi.nlm.nih.gov/26166017>.
1546. Madsen H, Brixen K, Hallas J. Screening, prevention and treatment of osteoporosis in patients with chronic obstructive pulmonary disease - a population-based database study. *Clin Respir J* 2010; **4**(1): 22-9 <https://pubmed.ncbi.nlm.nih.gov/20298414>.
1547. Bon J, Fuhrman CR, Weissfeld JL, et al. Radiographic emphysema predicts low bone mineral density in a tobacco-exposed cohort. *Am J Respir Crit Care Med* 2011; **183**(7): 885-90 <https://pubmed.ncbi.nlm.nih.gov/20935108>.
1548. Bolton CE, Cannings-John R, Edwards PH, et al. What community measurements can be used to predict bone disease in patients with COPD? *Respir Med* 2008; **102**(5): 651-7 <https://pubmed.ncbi.nlm.nih.gov/18308533>.
1549. Bolton CE, Ionescu AA, Shiels KM, et al. Associated loss of fat-free mass and bone mineral density in chronic obstructive pulmonary disease. *Am J Respir Crit Care Med* 2004; **170**(12): 1286-93 <https://pubmed.ncbi.nlm.nih.gov/15374843>.
1550. Jaramillo JD, Wilson C, Stinson DS, et al. Reduced Bone Density and Vertebral Fractures in Smokers. Men and COPD Patients at Increased Risk. *Ann Am Thorac Soc* 2015; **12**(5): 648-56 <https://pubmed.ncbi.nlm.nih.gov/25719895>.
1551. Jaramillo J, Wilson C, Stinson D, et al. Erratum: reduced bone density and vertebral fractures in smokers. men and COPD patients at increased risk. *Ann Am Thorac Soc* 2015; **12**(7): 1112 <https://pubmed.ncbi.nlm.nih.gov/26203620>.
1552. Yohannes AM, Ershler WB. Anemia in COPD: a systematic review of the prevalence, quality of life, and mortality. *Respir Care* 2011; **56**(5): 644-52 <https://pubmed.ncbi.nlm.nih.gov/21276321>.
1553. Balasubramanian A, Henderson RJ, Putcha N, et al. Haemoglobin as a biomarker for clinical outcomes in chronic obstructive pulmonary disease. *ERJ Open Res* 2021; **7**(3): <https://pubmed.ncbi.nlm.nih.gov/34322549>.
1554. Boutou AK, Karrar S, Hopkinson NS, Polkey MI. Anemia and survival in chronic obstructive pulmonary disease: a dichotomous rather than a continuous predictor. *Respiration* 2013; **85**(2): 126-31 <https://pubmed.ncbi.nlm.nih.gov/22759351>.
1555. Chambellan A, Chailleux E, Similowski T, Group AO. Prognostic value of the hematocrit in patients with severe COPD receiving long-term oxygen therapy. *Chest* 2005; **128**(3): 1201-8 <https://pubmed.ncbi.nlm.nih.gov/16162707>.
1556. Cote C, Zilberberg MD, Mody SH, Dordelly LJ, Celli B. Haemoglobin level and its clinical impact in a cohort of patients with COPD. *Eur Respir J* 2007; **29**(5): 923-9 <https://pubmed.ncbi.nlm.nih.gov/17251227>.
1557. Martinez-Rivera C, Portillo K, Munoz-Ferrer A, et al. Anemia is a mortality predictor in hospitalized patients for COPD exacerbation. *COPD* 2012; **9**(3): 243-50 <https://pubmed.ncbi.nlm.nih.gov/22360381>.
1558. Xu Y, Hu T, Ding H, Chen R. Effects of anemia on the survival of patients with chronic obstructive pulmonary disease: a systematic review and meta-analysis. *Expert Rev Respir Med* 2020; **14**(12): 1267-77 <https://pubmed.ncbi.nlm.nih.gov/32869670>.
1559. Schneckenpointner R, Jorres RA, Meidenbauer N, Kollert F, Pfeifer M, Budweiser S. The clinical significance of anaemia and disturbed iron homeostasis in chronic respiratory failure. *Int J Clin Pract* 2014; **68**(1): 130-8 <https://pubmed.ncbi.nlm.nih.gov/24341307>.

1560. Vasquez A, Logomarsino JV. Anemia in Chronic Obstructive Pulmonary Disease and the Potential Role of Iron Deficiency. *COPD* 2016; **13**(1): 100-9 <https://pubmed.ncbi.nlm.nih.gov/26418826>.
1561. Andreas S, Herrmann-Lingen C, Raupach T, et al. Angiotensin II blockers in obstructive pulmonary disease: a randomised controlled trial. *Eur Respir J* 2006; **27**(5): 972-9 <https://pubmed.ncbi.nlm.nih.gov/16446313>.
1562. Bakris GL, Sauter ER, Hussey JL, Fisher JW, Gaber AO, Winsett R. Effects of theophylline on erythropoietin production in normal subjects and in patients with erythrocytosis after renal transplantation. *N Engl J Med* 1990; **323**(2): 86-90 <https://pubmed.ncbi.nlm.nih.gov/2163024>.
1563. Ferrucci L, Maggio M, Bandinelli S, et al. Low testosterone levels and the risk of anemia in older men and women. *Arch Intern Med* 2006; **166**(13): 1380-8 <https://pubmed.ncbi.nlm.nih.gov/16832003>.
1564. Ilan Y, Dranitzki-Elhallel M, Rubinger D, Silver J, Popovtzer MM. Erythrocytosis after renal transplantation. The response to theophylline treatment. *Transplantation* 1994; **57**(5): 661-4 <https://pubmed.ncbi.nlm.nih.gov/8140628>.
1565. Incalzi RA, Corsonello A, Pedone C, et al. Chronic renal failure: a neglected comorbidity of COPD. *Chest* 2010; **137**(4): 831-7 <https://pubmed.ncbi.nlm.nih.gov/19903974>.
1566. Mrug M, Stopka T, Julian BA, Prchal JF, Prchal JT. Angiotensin II stimulates proliferation of normal early erythroid progenitors. *J Clin Invest* 1997; **100**(9): 2310-4 <https://pubmed.ncbi.nlm.nih.gov/9410909>.
1567. Oren R, Beeri M, Hubert A, Kramer MR, Matzner Y. Effect of theophylline on erythrocytosis in chronic obstructive pulmonary disease. *Arch Intern Med* 1997; **157**(13): 1474-8 <https://pubmed.ncbi.nlm.nih.gov/9224226>.
1568. Similowski T, Agusti A, MacNee W, Schonhofer B. The potential impact of anaemia of chronic disease in COPD. *Eur Respir J* 2006; **27**(2): 390-6 <https://pubmed.ncbi.nlm.nih.gov/16452598>.
1569. Vlahakos DV, Marathias KP, Madias NE. The role of the renin-angiotensin system in the regulation of erythropoiesis. *Am J Kidney Dis* 2010; **56**(3): 558-65 <https://pubmed.ncbi.nlm.nih.gov/20400218>.
1570. Ferrari M, Manea L, Anton K, et al. Anemia and hemoglobin serum levels are associated with exercise capacity and quality of life in chronic obstructive pulmonary disease. *BMC Pulm Med* 2015; **15**: 58 <https://pubmed.ncbi.nlm.nih.gov/25952923>.
1571. Zhang J, DeMeo DL, Silverman EK, et al. Secondary polycythemia in chronic obstructive pulmonary disease: prevalence and risk factors. *BMC Pulm Med* 2021; **21**(1): 235 <https://pubmed.ncbi.nlm.nih.gov/34261472>.
1572. Kent BD, Mitchell PD, McNicholas WT. Hypoxemia in patients with COPD: cause, effects, and disease progression. *Int J Chron Obstruct Pulmon Dis* 2011; **6**: 199-208 <https://pubmed.ncbi.nlm.nih.gov/21660297>.
1573. Zeng Z, Song Y, He X, et al. Obstructive Sleep Apnea is Associated with an Increased Prevalence of Polycythemia in Patients with Chronic Obstructive Pulmonary Disease. *Int J Chron Obstruct Pulmon Dis* 2022; **17**: 195-204 <https://pubmed.ncbi.nlm.nih.gov/35068930>.
1574. Calverley PM, Leggett RJ, McElderry L, Flenley DC. Cigarette smoking and secondary polycythemia in hypoxic cor pulmonale. *Am Rev Respir Dis* 1982; **125**(5): 507-10 <https://pubmed.ncbi.nlm.nih.gov/7081807>.
1575. Chambellan A, Coulon S, Cavailles A, Hermine O, Similowski T. [COPD and erythropoiesis: interactions and consequences]. *Rev Mal Respir* 2012; **29**(2): 213-31 <https://pubmed.ncbi.nlm.nih.gov/22405115>.
1576. Nakamura A, Kasamatsu N, Hashizume I, et al. Effects of hemoglobin on pulmonary arterial pressure and pulmonary vascular resistance in patients with chronic emphysema. *Respiration* 2000; **67**(5): 502-6 <https://pubmed.ncbi.nlm.nih.gov/11070452>.
1577. Samareh Fekri M, Torabi M, Azizi Shoul S, Mirzaee M. Prevalence and predictors associated with severe pulmonary hypertension in COPD. *Am J Emerg Med* 2018; **36**(2): 277-80 <https://pubmed.ncbi.nlm.nih.gov/28797558>.
1578. Guo L, Chughtai AR, Jiang H, et al. Relationship between polycythemia and in-hospital mortality in chronic obstructive pulmonary disease patients with low-risk pulmonary embolism. *J Thorac Dis* 2016; **8**(11): 3119-31 <https://pubmed.ncbi.nlm.nih.gov/28066591>.
1579. Xu L, Chen Y, Xie Z, et al. High hemoglobin is associated with increased in-hospital death in patients with chronic obstructive pulmonary disease and chronic kidney disease: a retrospective multicenter population-based study. *BMC Pulm Med* 2019; **19**(1): 174 <https://pubmed.ncbi.nlm.nih.gov/31533673>.
1580. Kunik ME, Roundy K, Veazey C, et al. Surprisingly high prevalence of anxiety and depression in chronic breathing disorders. *Chest* 2005; **127**(4): 1205-11 <https://pubmed.ncbi.nlm.nih.gov/15821196>.
1581. Ng TP, Niti M, Tan WC, Cao Z, Ong KC, Eng P. Depressive symptoms and chronic obstructive pulmonary disease: effect on mortality, hospital readmission, symptom burden, functional status, and quality of life. *Arch Intern Med* 2007; **167**(1): 60-7 <https://pubmed.ncbi.nlm.nih.gov/17210879>.
1582. Maurer J, Rebbapragada V, Borson S, et al. Anxiety and depression in COPD: current understanding, unanswered questions, and research needs. *Chest* 2008; **134**(4 Suppl): 43S-56S <https://pubmed.ncbi.nlm.nih.gov/18842932>.
1583. Eisner MD, Blanc PD, Yelin EH, et al. Influence of anxiety on health outcomes in COPD. *Thorax* 2010; **65**(3): 229-34 <https://pubmed.ncbi.nlm.nih.gov/20335292>.
1584. Bolton CE, Bevan-Smith EF, Blakey JD, et al. British Thoracic Society guideline on pulmonary rehabilitation in adults. *Thorax* 2013; **68** Suppl 2: ii1-30 <https://pubmed.ncbi.nlm.nih.gov/23880483>.
1585. Coventry PA, Bower P, Keyworth C, et al. The effect of complex interventions on depression and anxiety in chronic obstructive pulmonary disease: systematic review and meta-analysis. *PLoS One* 2013; **8**(4): e60532 <https://pubmed.ncbi.nlm.nih.gov/23585837>.

1586. Himelhoch S, Lehman A, Kreyenbuhl J, Daumit G, Brown C, Dixon L. Prevalence of chronic obstructive pulmonary disease among those with serious mental illness. *Am J Psychiatry* 2004; **161**(12): 2317-9 <https://pubmed.ncbi.nlm.nih.gov/15569908>.
1587. Jones DR, Macias C, Barreira PJ, Fisher WH, Hargreaves WA, Harding CM. Prevalence, severity, and co-occurrence of chronic physical health problems of persons with serious mental illness. *Psychiatr Serv* 2004; **55**(11): 1250-7 <https://pubmed.ncbi.nlm.nih.gov/15534013>.
1588. Sampaio MS, Vieira WA, Bernardino IM, Herval AM, Flores-Mir C, Paranhos LR. Chronic obstructive pulmonary disease as a risk factor for suicide: A systematic review and meta-analysis. *Respir Med* 2019; **151**: 11-8 <https://pubmed.ncbi.nlm.nih.gov/31047105>.
1589. Siraj RA, McKeever TM, Gibson JE, Bolton CE. Incidence of depression and antidepressant prescription in patients with COPD: A large UK population-based cohort study. *Respir Med* 2022; **196**: 106804 <https://pubmed.ncbi.nlm.nih.gov/35325742>.
1590. van Beers M, Janssen DJA, Gosker HR, Schols A. Cognitive impairment in chronic obstructive pulmonary disease: disease burden, determinants and possible future interventions. *Expert Rev Respir Med* 2018; **12**(12): 1061-74 <https://pubmed.ncbi.nlm.nih.gov/30296384>.
1591. Yohannes AM, Chen W, Moga AM, Leroi I, Connolly MJ. Cognitive Impairment in Chronic Obstructive Pulmonary Disease and Chronic Heart Failure: A Systematic Review and Meta-analysis of Observational Studies. *J Am Med Dir Assoc* 2017; **18**(5): 451 e1- e11 <https://pubmed.ncbi.nlm.nih.gov/28292570>.
1592. Pierobon A, Ranzini L, Torlaschi V, et al. Screening for neuropsychological impairment in COPD patients undergoing rehabilitation. *PLoS One* 2018; **13**(8): e0199736 <https://pubmed.ncbi.nlm.nih.gov/30067787>.
1593. Cleutjens FA, Franssen FM, Spruit MA, et al. Domain-specific cognitive impairment in patients with COPD and control subjects. *Int J Chron Obstruct Pulmon Dis* 2017; **12**: 1-11 <https://pubmed.ncbi.nlm.nih.gov/28031706>.
1594. Cleutjens F, Spruit MA, Ponds R, et al. Cognitive impairment and clinical characteristics in patients with chronic obstructive pulmonary disease. *Chron Respir Dis* 2018; **15**(2): 91-102 <https://pubmed.ncbi.nlm.nih.gov/28553720>.
1595. Rusanen M, Ngandu T, Laatikainen T, Tuomilehto J, Soininen H, Kivipelto M. Chronic obstructive pulmonary disease and asthma and the risk of mild cognitive impairment and dementia: a population based CAIDE study. *Curr Alzheimer Res* 2013; **10**(5): 549-55 <https://pubmed.ncbi.nlm.nih.gov/23566344>.
1596. Xie F, Xie L. COPD and the risk of mild cognitive impairment and dementia: a cohort study based on the Chinese Longitudinal Health Longevity Survey. *Int J Chron Obstruct Pulmon Dis* 2019; **14**: 403-8 <https://pubmed.ncbi.nlm.nih.gov/30863040>.
1597. Baird C, Lovell J, Johnson M, Shiell K, Ibrahim JE. The impact of cognitive impairment on self-management in chronic obstructive pulmonary disease: A systematic review. *Respir Med* 2017; **129**: 130-9 <https://pubmed.ncbi.nlm.nih.gov/28732820>.
1598. Martinez CH, Richardson CR, Han MK, Cigolle CT. Chronic obstructive pulmonary disease, cognitive impairment, and development of disability: the health and retirement study. *Ann Am Thorac Soc* 2014; **11**(9): 1362-70 <https://pubmed.ncbi.nlm.nih.gov/25285360>.
1599. von Siemens SM, Perneczky R, Vogelmeier CF, et al. The association of cognitive functioning as measured by the DemTect with functional and clinical characteristics of COPD: results from the COSYCONET cohort. *Respir Res* 2019; **20**(1): 257 <https://pubmed.ncbi.nlm.nih.gov/31727165>.
1600. Schure MB, Borson S, Nguyen HQ, et al. Associations of cognition with physical functioning and health-related quality of life among COPD patients. *Respir Med* 2016; **114**: 46-52 <https://pubmed.ncbi.nlm.nih.gov/27109810>.
1601. Chang SS, Chen S, McAvey GJ, Tinetti ME. Effect of coexisting chronic obstructive pulmonary disease and cognitive impairment on health outcomes in older adults. *J Am Geriatr Soc* 2012; **60**(10): 1839-46 <https://pubmed.ncbi.nlm.nih.gov/23035917>.
1602. Dodd JW, Charlton RA, van den Broek MD, Jones PW. Cognitive dysfunction in patients hospitalized with acute exacerbation of COPD. *Chest* 2013; **144**(1): 119-27 <https://pubmed.ncbi.nlm.nih.gov/23349026>.
1603. Fried LP, Tangen CM, Walston J, et al. Frailty in older adults: evidence for a phenotype. *J Gerontol A Biol Sci Med Sci* 2001; **56**(3): M146-56 <https://pubmed.ncbi.nlm.nih.gov/11253156>.
1604. Roberts MH, Mapel DW, Ganvir N, Dodd MA. Frailty Among Older Individuals with and without COPD: A Cohort Study of Prevalence and Association with Adverse Outcomes. *Int J Chron Obstruct Pulmon Dis* 2022; **17**: 701-17 <https://pubmed.ncbi.nlm.nih.gov/35411140>.
1605. Xu J, Xu W, Qiu Y, Gong D, Man C, Fan Y. Association of Prefrailty and Frailty With All-Cause Mortality, Acute Exacerbation, and Hospitalization in Patients With Chronic Obstructive Pulmonary Disease: A Meta-Analysis. *J Am Med Dir Assoc* 2023; **24**(7): 937-44.e3 <https://pubmed.ncbi.nlm.nih.gov/37150209>.
1606. Osadnik CR, Brighton LJ, Burtin C, et al. European Respiratory Society statement on frailty in adults with chronic lung disease. *Eur Respir J* 2023; **62**(2): <https://pubmed.ncbi.nlm.nih.gov/37414420>.

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