Global Initiative for Chronic Obstructive Lung Disease

2026 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

(2026 REPORT)

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GLOBAL ALLIANCE AGAINST CHRONIC RESPIRATORY DISEASES

GOLD is a member of The Global Alliance against Chronic Respiratory Diseases (GARD)

GOLD 2026 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 2026 major revision of the GOLD report several important changes have been made as follows:

i. In Chapter 1 the section on the **Burden of COPD** has been updated with the latest epidemiological statistics and references.
ii. In Chapter 2 **Screening and Case-finding** has been updated and two new figures have been added (**Figures 2.8 and 2.9**)
iii. **Vaccination Recommendations** for people with COPD have been updated with the latest information on RSV and influenza vaccination.
iv. The criteria defining **GOLD A, B and E categories have been adjusted** due to emerging evidence from observational studies that even one moderate or severe exacerbation prior to initiating maintenance pharmacological therapy increases the risk of subsequent events (**Figure 3.7, 3.8 and 3.9**). The threshold of one moderate exacerbation should now be used to consider treatment escalation, with the aim of achieving a low disease activity state characterized by no exacerbations.
v. A new section on **Disease Activity** has been included in the report.
vi. **The Management Cycle** and **Treatment Algorithms** in **Chapter 3** have been further clarified to emphasize the distinction between **INITIAL** pharmacological treatment (for treatment naïve COPD patients) versus **FOLLOW-UP** pharmacological treatment (for patients on existing pharmacological treatment regimens) as shown in updated **Figures 3.7, 3.8 and 3.9**.
vii. A new **Figure 3.11** has been added to outline the evidence for the use of **Biologic Therapy** in COPD.
viii. **Chapter 4 – Exacerbations of COPD** has been completely revised, and new figures have been introduced.
ix. **Chapter 5 – Multimorbidity in COPD** has been completely revised, and new figures have been introduced.
x. A new **Chapter 6 – Artificial Intelligence & Emerging Technologies in COPD** has been added.
xi. **The GOLD Report has been re-structured** with a significant amount of text and figures moved to Appendices 1-4 to improve flow and clarity and reduce repetition.
xii. A **Table of Abbreviations** has been included, and abbreviations are being used throughout the report to improve readability.
xiii. **References** have been checked and updated throughout the document.

GOLD has been fortunate to have a network of internationally 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 public, to raise awareness of the burden of COPD and to develop programs for early detection, prevention and approaches to management.

Alvar G. Agusti, MD
Chair, GOLD Board of Directors

Claus Vogelmeier, MD
Chair, GOLD Science Committee

GLOBAL STRATEGY FOR THE DIAGNOSIS, MANAGEMENT AND PREVENTION OF COPD 2026 UPDATE[a]

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 Committee[b] 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 2026 GOLD Report is the 6th major revision. 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, US 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

[a] The Global Strategy for Diagnosis, Management and Prevention of COPD (updated 2026), the Pocket Guide (updated 2026) and the complete list of references examined by the Committee is available on the GOLD website: www.goldcopd.org.

[b] GOLD Science Committee Members (2025-2026): C. Vogelmeier, Chair, S. Aaron, 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, T. Troosters, J. Wedzicha, J. Zheng.

Committee. Only high-quality systematic reviews and meta-analyses that provide strong evidence for changing clinical 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 2026 report is a major revision of the previous years' reports. 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 2024 to July 2025. In total, 338 new references have been added to the GOLD 2026 report.

ABBREVIATIONS

The abbreviations are expanded in Appendix 1.

TABLE OF CONTENTS

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.

Simple and reliable questionnaires designed for use in routine daily clinical practice are available in many languages. This has 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

COPD is now one of the top three causes of death worldwide and nearly 90% of these deaths occur in LMICs.[1,2] More than 3 million people died of COPD in 2021 accounting for 5% of all deaths globally.[3] 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.[4]

In 1998, with the cooperation of the NHLBI, NIH and the WHO, 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.[5] 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.[6]

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, *post hoc* 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

- 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.

Diagnostic criteria

- In the appropriate clinical context (see 'Definition' & 'Causes and Risk Factors' above), the presence of non-fully reversible airflow obstruction (i.e., FEV1/FVC < 0.7 post-bronchodilation) measured by spirometry confirms the diagnosis of COPD.

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. 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

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.[7]

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.[8]

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[9,10] and host factors (including abnormal lung development and accelerated lung aging) can also contribute.[8]

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.[11] Onset of smoking in childhood, prior to age 15, has been found to increase the relative risk of developing COPD, independent of cigarette pack-years and smoking duration.[12] Most COPD studies have included patients with a minimum cigarette exposure of 10 pack-years. However, one study has suggested that even at a 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.[13] Yet fewer than 50% of heavy smokers develop COPD[14] 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.[10]

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);[15] and longer life expectancy will allow greater lifetime exposure to risk factors.

Other types of tobacco (e.g., pipe, cigar, water pipe)[16-18] and marijuana[19] are also risk factors for COPD. Passive exposure to cigarette smoke, also known as environmental tobacco smoke and second-hand smoking, may also contribute to respiratory symptoms and COPD,[20] especially after long-term exposure.[21] Data derived from the GBD 2021, showed that globally, ischemic heart disease, COPD, and lower respiratory infections were the three leading causes of second-hand smoke-attributable numbers of deaths and DALYs for both sexes.[22] 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.[23] 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.[8]

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,[24] it has become apparent that non-smoking risk factors are 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.[10] 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.[10]

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.[25] Household air pollution exposure is associated with an increased risk of developing COPD in LMICs[26] although the extent to which household air pollution versus other poverty-related exposures explain the association is unclear.[27-32] However, there is limited research about household air pollution related COPD or the interventions that could reduce the risk of developing it.[33] 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.[34]

Occupational exposures

Occupational exposures, including organic and inorganic dusts, chemical agents and fumes, are an under-appreciated environmental risk factor for COPD.[35,36] Individuals with exposure to inhalation of high doses of pesticides have a higher incidence of respiratory symptoms, airways obstruction and COPD.[37,38] 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.[39] 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.[40] An analysis of the large US 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.[41] These estimates are consistent with a statement published by the ATS that concluded that occupational exposures account for 10-20% of either symptoms or functional impairment consistent with COPD.[42] 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, ozone, oxides of nitrogen or sulfur, heavy metals, and other greenhouse gases, and is a major worldwide cause of COPD, responsible for approximately 50% of the attributable risk for COPD in LMICs.[43] In never smokers, air pollution is the leading known risk factor for COPD.[44] Data from China from the GBD Study (2021) showed that while smoking was a major risk factor for COPD in men, ambient particulate matter pollution had a greater impact on women and younger adults (30-34 years).[45] 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 PM2.5 and nitrogen dioxides significantly impairs lung growth in children,[46] accelerates lung function decline in adults and increases the risk for COPD, especially among those with additional risk factors for COPD.[47] Poor air quality from air pollution also increases the risk of exacerbations, hospitalizations and mortality.[48-50] A study among the population residing near a coke plant at the time of its closure found a 19% reduction in the risk of long-term hospitalizations due to COPD and related diseases in the population after closure (annual hospitalization IRR 0.81; 95% CI 0.69,0.94).[51] These results suggest that reducing exposure to fossil fuel-related air pollution produces both short- and long-term respiratory health benefits.[51] Thus, reduction in both indoor and outdoor air pollution is a key goal in the prevention and management of COPD.

Genetic factors

The most relevant (albeit epidemiologically rare) genetic risk factor for COPD identified to date is mutations in the SERPINA1 gene, leading to AATD, but other genetic variants, with a low individual effect size, are associated with reduced lung function and risk of COPD too.[52]

A significant familial risk of airflow obstruction has been observed in people who smoke and are siblings of patients with COPD who had irreversible airflow obstruction with a reduced gas transfer factor,[53] 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,[54] a major circulating inhibitor of serine proteases. Although AATD 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 patients with COPD (range 0.08-0.24%), and a prevalence ranging from 1 in 408 in Northern Europe to 1 in 1,274 in Eastern Europe.[55]

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[56] who may potentially benefit from augmentation therapy. Careful sibling studies[57,58]

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,[59] 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 (albeit epidemiologically rare), including genes encoding matrix metalloproteinase 12, glutathione S-transferase, the alpha-nicotinic acetylcholine receptor, and the hedgehog interacting protein.[60,61] Yet, their individual effect size is small,[52] and it remains uncertain whether these genes are directly responsible for COPD or are merely markers of other causal genes.[62-66]

Diagnostic criteria

In the appropriate clinical context (See 'Definition' and 'Causes and Risk Factors' above), the presence of non-fully reversible airflow obstruction (FEV1/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 (FEV1/FVC ≥ 0.7 post-bronchodilation). These subjects are labeled 'pre-COPD'. The term 'PRISm' 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.[67,68] 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. 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, 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.[69]

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.[70-74] COPD prevalence, morbidity and mortality vary across countries,[70-73,75] and although it is often directly related to the prevalence of tobacco smoking, in many countries outdoor, occupational and household air pollution (resulting from the burning of wood and other biomass fuels) are important COPD risk factors.

The number of COPD cases globally is projected to increase over the coming decades, approaching nearly 600 million COPD patients by 2050 and the increase will be greater among women and in LMICs.[72] This is due to a combination of continued exposure to COPD risk factors and an increase in both the total number and average age of the world's population.[70,73]

Information on the burden of COPD can be found on international websites, such as the WHO[76] and the World Bank/WHO GBD Study.[70,75]

Prevalence

Existing COPD prevalence data vary widely due to differences in survey methods, diagnostic criteria, and analytical approaches.

In the past two decades, BOLD, PLATINO and GBD collaborators have pioneered efforts to collect country-specific population-based data on prevalence and risk factors for COPD, providing updates on global estimates of deaths, prevalence, and DALYs.[70,73,77-80]

GBD data include margins of error, are internally consistent with mortality and other health indicators, and help assess trends in COPD and risk factors over time worldwide since 1990, even in countries without adequate health statistics, as well as the potential impact of different prevention and treatment strategies on health outcomes. The GBD collaborators have combined data from various sources in complex statistical models.[70,74] However, GBD COPD burden estimates appear to be inconsistent with other epidemiological studies based on spirometric measurements and may underestimate the true burden of COPD.[73] Disparities between the GBD and other epidemiological surveys or meta-analyses on prevalence may lie primarily in the use of different definitions of COPD, the inclusion of the entire population (people aged ≥ 15 years) in the GBD, and the adoption of different methods for building predictive models.

The 2021 GBD data estimates a total of 213.39 million cases of COPD of all ages, which represents a prevalence of 2.7% (2.5 age-standardized prevalence per 100,000) a change of −1.46% since 1990.[70] A higher total number of female COPD patients and a higher age-standardized prevalence of male COPD patients was observed from 1990 to 2021.[70,73] High-income North America and South Asia had the highest age-standardized prevalence of COPD, with more than 3,000 cases per 100,000 people. The lowest age-standardized prevalence was reported in southern Latin America and high-income Asia Pacific.[70]

A systematic review and modeling study that included data from population-based studies using spirometric measurements for the diagnosis of COPD in 65 countries estimated a global prevalence of COPD in 2019 in people aged 30-79 years of 10.3%, which translates to 392 million people with COPD worldwide, the majority (315 million, 80.5%) living in LMICs.[71] After considering the demographic characteristics (age, sex, and population distribution), the overall prevalence of GOLD-COPD was slightly higher in LMICs (10.3%) than in HICs (10.1%).[71] Worldwide, the COPD prevalence in men was more than double that in women in the same age range (14.1% vs. 6.5%).[71] The overall prevalence of GOLD-COPD was highest in the Western Pacific region (11.7%) and lowest in the Americas (6.8%). The ten countries with the highest number of COPD cases are: China, India, Indonesia, USA, Bangladesh, Japan, Pakistan, Russia, Vietnam, and Germany, accounting for 255 million (65.2%) of global COPD cases in 2019.[71] **Figure 1.1** shows a summary of COPD prevalence according to different sources.

Of note, the lowest estimates of COPD prevalence are those based on the self-reporting of a 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.[81] This is likely to be a reflection of the widespread under-recognition and under-diagnosis of COPD.[82] A study using data from 30,874 participants in several epidemiological surveys indicates that COPD underdiagnosis is universally high, estimating that, overall, 81.4% of COPD cases (defined spirometrically) are

undiagnosed. Global determinants of COPD underdiagnosis were male sex, younger age, current and never smoking, lower educational, absence of reported symptoms, no previous spirometry, and less severe airflow limitation.[82]

Estimated COPD Prevalence According to Different Sources

Figure 1.1

	GBD 2019[a]	GBD 2021[b]	Population-based study 2019[c]	Other sources 2020[d]
Prevalence (%)	2.6	2.5	10.3	10.6
Number of cases (per million)	212	213	392	479

References: [a]Safiri et al. BMJ 2022;378:e069679; [b]Wang et al. Respir Res 2025;26:2; [c]Adeloye et al. Lancet Respir Med 2022;10:447–458; [d]Boers et al. JAMA Netw Open 2023;6:E2346598.

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.[83-85]

Morbidity

Morbidity measures traditionally include physician visits, emergency department visits, and hospitalizations. Morbidity due to COPD increases with age,[79,81] and in patients with COPD the development of comorbidities is seen at an earlier age than in the general population.[86,87] Morbidity in COPD may also be influenced by concomitant chronic conditions (e.g., cardiovascular disease, musculoskeletal impairment, diabetes mellitus)[88] that are related to smoking, aging and/or COPD.[89]

Mortality

COPD is the third leading cause of death worldwide.[74] Data from the GBD study estimated that the number of COPD-attributable deaths increased from 2.50 million in 1990 to 3.72 million in 2021, with an age-standardized mortality of 45.22 per 100,000, a decrease of 37.1% since 1990.[70] East Asia, South Asia, and Southeast Asia had the highest number of deaths (1.32; 1.23; and 0.23; million, respectively).[70]

Smoking contributes to 35% of the COPD deaths globally (51% in men and 15% in women), followed by outdoor and household air pollution.[73] Global data also demonstrate reductions in death rates across all leading COPD risk factors. The age-standardized death rate from COPD attributed to smoking has significantly decreased in all countries, with

HMICs showing the largest decreases.[73] In LICs household air pollution is the leading risk factor in both sexes for age-standardized death rate.[73]

Although age-standardized COPD mortality rates have decreased globally since 1990, the total number of COPD deaths, people living with the disease (prevalence), and the overall health burden (DALYs) of COPD have increased substantially, with direct effects on health systems worldwide.[70] 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.[90]

The WHO publishes mortality statistics for selected causes of death annually for all WHO regions.[91] However, data must be interpreted with caution because of the inconsistent use of COPD terminology. In the 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.[92] Furthermore, the accuracy of COPD diagnosis codes recorded in administrative health databases is also uncertain.[93,94] In some jurisdictions, reliance on administrative health data, particularly those that only record hospitalizations, may underestimate the burden of COPD.[95] 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.[96]

Economic burden

COPD is associated with a significant economic burden. In the EU, the total direct costs (excluding indirect costs, such as the economic value of care provided by family members) 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.[97] In the US 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.[98,99] Another projections study using the GBD database, WHO, and meta-analysis indicates that globally by 2050, the direct costs related to COPD are estimated to be $24.35 trillion (a relative growth of 526% compared to 2025), indirect costs are estimated to be $15.43 trillion (a relative growth of 518% compared to 2025), and exacerbations are estimated to be $15.60 billion (a relative growth of 584% compared with 2025).[100] Exacerbations account for the greatest proportion of the total COPD burden on the healthcare system.[101] 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. The WHO and other organizations suggest that inhaled medicines for COPD are poorly available and largely unaffordable in LMICs.[102] 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.[103] 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 DALY.[104] 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 2019 estimated a COPD DALY rate of 926.1 per 100,000, and GBD 2021 estimated it to be 940.7 per 100,000.[70,105] According to the GBD Study, COPD was the primary driver of increased DALYs worldwide, especially in LMICs. Predictions indicated that in 2022, COPD DALYs will rank sixth, but by 2050, are expected to rise to the fourth position.[70,106] In 2021, the number of DALYs for COPD was estimated to be 79.8 million, with an age-standardized DALYs rate of 940.7 per 100,000, a decrease of 36.98% since 1990.[70] East Asia, South Asia, and Southeast Asia had the highest DALYs (24.39, 28.01, and 5.56 million, respectively).[70] Although East Asia had a higher age standardized COPD DALYs from 1990 to 2021, it's important to highlight that this region also had a significant decline in COPD-related deaths and DALYs during the same period. Taking China as an example, the country implemented various measures over the past 30 years to reduce burden due to COPD. These measures included reducing smoking rates, decreasing the use of fossil fuels to improve air quality, promoting clean energy sources, encouraging environmentally friendly practices, and improving access to quality healthcare for early diagnosis and treatment.[70,73]

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.[8] 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.[8,107] 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).[8]

Trajectories of lung function: development and aging

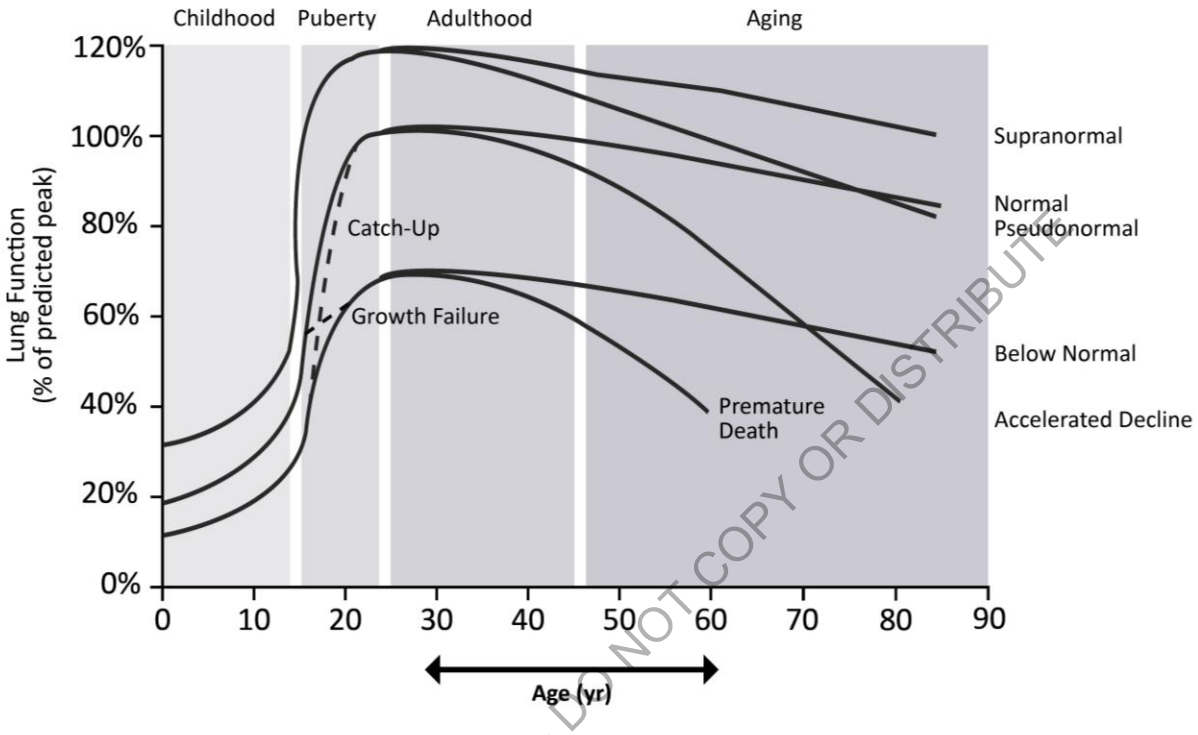
At birth, the lungs are not fully developed. They grow and mature until about 20-25 years of age (earlier in females), when lung function reaches its peak (**Figure 1.2**).[11] This is followed by a short plateau and a final phase of mild lung function decline due to physiological lung aging.[11] This constitutes the normal lung function trajectory in **Figure 1.2**.[108] 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).[109-111]

As a result, a given individual may follow one of a range of potential lung function trajectories through her/his lifetime, both below and above the normal one (**Figure 1.2**). It is now well established that those above the normal trajectory are associated with healthier aging[112] whereas those below it have an increased prevalence and incidence of respiratory, cardiovascular and metabolic diseases and premature death.[87,113] 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/).[114,115]

Spirometrically-measured reduced maximal attained lung function can identify individuals who are at increased risk for the development of COPD.[116,117] A large study and meta-analysis confirmed a positive association between birthweight and FEV1 in adulthood.[118] Factors in early life termed "childhood disadvantage factors" are key determinants of lung function in adult life.[118-126] 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),[127] while the other 50% developed COPD due to abnormal lung growth and development (with normal lung function decline over time; **Figure 1.2**).[108]

FEV1 Trajectories (TR) Over the Life Course

Figure 1.2



Modified from: Agusti A, Hogg JC. N Engl J Med. 2019;381:1248-56.

Age is often listed as a risk factor for COPD because there is a physiological decline in lung function with age. Yet, it is unclear whether healthy aging as such leads to COPD or if age reflects the sum of cumulative exposures throughout life.[128] However, aging of the airways and parenchyma mimic some of the structural changes associated with COPD,[128] and there is evidence of accelerated aging in patients with COPD.[120] 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 patients with COPD who were followed over 10 years.[129] Further, persistently shorter telomeres over this observation time increase the risk for all-cause mortality.[129] Age-related epigenetic changes in DNA in immune cells are also associated with increased risk of exacerbations and mortality in patients with COPD.[124,130,131]

The term *dysanapsis* refers to an anthropometric mismatch of airway tree caliber relative to lung volume.[132,133] It was first proposed by Green and colleagues in 1974 from maximal expiratory airflow variation among healthy adults.[119] There are still major gaps in our understanding of the origins and clinical implications of dysanapsis, but recent research using CT has shown that: (1) it is common in the general population;[119,123,134] (2) it is associated with FEV1/FVC from early adulthood;[135] (3) in explanted lungs from adult healthy donors, central airway dysanapsis (detectable by CT) extended to peripheral airways (non-visible on CT);[135] (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.[123] 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;[108] (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;[136-138] 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[119,121,123] and factors affecting airway tree homeostasis later in life have been implicated.[120,122] Of note, investigating the etiology 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[109,139] opens novel opportunities for prevention, and earlier diagnosis and treatment of the disease[69] but, at the same time, has generated several nosological terms that require proper definition to avoid confusion and facilitate future research.[140]

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.[141] 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.[109] Further, “mild” disease can occur at any age and may progress or not over time.[139] 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,[11] we propose to operationally consider “young COPD” in patients aged 20–50 years.[142,143] 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.[144,145] 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.[140,145]

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.[146] These patients may (or not) develop persistent airflow obstruction (i.e., COPD) over time.[147] A 2022 publication highlighted the need for RCTs, both in patients with 'pre-COPD', and in young people with COPD.[67]

PRISm

The term PRISm describes individuals with preserved ratio (FEV1/FVC ≥ 0.7 after bronchodilation) but impaired spirometry (FEV1 < 80% of reference, after bronchodilation).[68,148] The prevalence of PRISm in population-based studies ranges from 7.1% to 11%[149-152] and from 10.4% to 11.3% in a selected population of current and former smokers such as the COPDGene cohort.[153] The prevalence of PRISm is particularly high in current and former smokers, and it is associated with both high and low BMI values, female sex, obesity and multimorbidity.[149-152] 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.[149,150,152,154-158]

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 forced expiratory time in the second assessment.[150,152,153] 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.[159]

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, adults diagnosed with asthma had a 12-fold higher risk of acquiring COPD compared to those without asthma, after adjusting for smoking.[160] In other longitudinal studies, around 20% of people with asthma developed irreversible airflow obstruction and reduced diffusing lung capacity,[161] and self-reported asthma was associated with excess loss of FEV1.[162] In addition, 11% of children with asthma had lung function impairment consistent with the spirometric classification of COPD by early adulthood.[163-165] 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.[160,166,167] 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 1.2**), these infants and adolescents may have been mislabeled as having 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[168,169] as well as an indicator of risk of excess decline in lung function in patients with mild COPD.[170]

Chronic bronchitis

Chronic bronchitis is a common, but variable condition in patients with COPD, defined by the presence of cough with expectorated sputum on a regular basis over a defined period. Variability in the prevalence of chronic bronchitis

depends upon the definition used, which differ in the regularity or duration of symptoms.[171] The classic description defines chronic bronchitis 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 chronic bronchitis ranges from 27-35% in large observational studies in patients with COPD.[172-174] Other factors associated with increased prevalence of chronic bronchitis in COPD includes male sex, younger age, greater pack-years of smoking, more severe airflow obstruction, rural location and increased occupational exposures.[171-177] Although the primary risk for chronic bronchitis is smoking, 4-22% of chronic bronchitis is found in never smokers suggesting other factors are involved.[178,179] Inhalational exposures to dusts, biomass fuels, chemical fumes or domestic heating and cooking fuels may be important.[176,177,180] Gastroesophageal reflux is also associated with an increased incidence of chronic bronchitis.[181,182]

Lung health depends upon effective mucus clearance. In disease states, thick and viscous mucus can lead to airway inflammation and infection, with cough and dyspnea the principal symptoms of impaired mucus clearance.[183,184] 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.[185,186] Radiographic manifestations of mucus plugging may be present and persist in patients with COPD despite a lack of chronic bronchitis symptoms and is associated with greater airflow obstruction, lower oxygen saturation, poorer exercise tolerance, more exacerbations and worsened quality of life[187-189] and all-cause mortality.[164,190][191]

The relationship between chronic mucus production and lung function, exacerbations and mortality has been the subject of multiple investigations. In adults less than 50 years of age, chronic bronchitis without airflow obstruction is an early marker for susceptibility to the long-term risk of COPD and all-cause mortality.[192] In smokers between 36 and 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.[193] Importantly, the longer chronic mucus hypersecretion is present, the greater the concurrent decrease in FEV1.[194,195] After adjustment for height, age and smoking history, men with cough or phlegm and women with cough show accelerated loss of lung function,[196] and there is an association between chronic sputum production and lower lung function, or greater FEV1 decline in patients with COPD.[196-200]

The association between 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;[201-203] other studies state sputum production has an independent role in predicting both overall and COPD-specific mortality.[175,204-206] In the Copenhagen City Heart Study, chronic mucus hypersecretion was associated with pulmonary infection that was implicated in 54% of the deaths.[207] Moreover, chronic mucus hypersecretion was associated with excessive FEV1 decline and increased COPD hospitalizations.[199] In patients with advanced emphysema, chronic bronchitis has been associated with increased hospitalizations and mortality.[208] In patients with non-obstructive chronic bronchitis, increased all-cause and respiratory disease related mortality has been reported.[209,210]

Infections

A history of severe childhood respiratory infections is associated with reduced lung function and increased respiratory symptoms in adulthood.[165] 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.[211] Chronic bronchial infection, particularly with *Pseudomonas aeruginosa*, is associated with accelerated FEV1 decline.[212] TB is a risk factor for COPD,[213,214] and is both a differential diagnosis for COPD and a potential comorbidity.[215,216] Nontuberculous mycobacterial pulmonary disease is also associated with an increased risk of incident COPD.[217] Finally, patients with HIV are at increased risk of COPD compared to HIV negative controls,[218,219] probably due to methylation disruptions in airway epithelium.[164,220,221]

Sex

Sex-related differences in immune pathways and the 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.[222] Although controversial, some studies have suggested that women may be more susceptible to the harmful effects of smoking than men,[85,223-225] leading to more severe disease for the equivalent quantity of cigarettes consumed.[226] The results of a population-based cohort study that selected individuals from a Danish population-based cohort, indicate that females have more severe disease with comparable smoking exposure, manifesting as lower lung function and a higher risk of airway obstruction, chronic bronchitis and dyspnea. Additionally, females exhibit a poorer prognosis with higher smoking exposure, including a higher risk of COPD exacerbations and early death.[227] A systematic review and meta-analysis of the global prevalence of COPD reported sex-based prevalence differences across WHO GBD sub-regions. In females the highest prevalence of COPD was observed in North America and in urban settings. Using the World Bank's income categories prevalence was highest in upper-middle income countries for males 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.[228]

Race and ethnicity

An ATS workshop report[229] 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.[49,229]

Socioeconomic status

Poverty is consistently associated with airflow obstruction[230] and lower socioeconomic status is associated with an increased risk of developing COPD.[231,232] 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.[233] These include inflammatory and structural changes which increase with the severity of airflow obstruction and can persist on smoking cessation.

Inflammatory changes

The inflammation observed in the lungs of patients with COPD 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[234] which attract inflammatory cells from the circulation (chemotactic factors), amplify the inflammatory process (via proinflammatory cytokines), and induce structural changes (via growth factors).[235] Lung inflammation can persist after smoking cessation through as yet unclear mechanisms, although autoantigens and perturbations in the lung microbiome may play a role.[236,237] Systemic inflammation may also be present and could play a role in the comorbid conditions frequently found in

patients with COPD.[234] 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.[238] albeit some patients with COPD have an inflammatory pattern with increased eosinophils and Type 2 innate lymphoid cells, similar to that of asthma.[239]

Oxidative stress can also contribute to COPD.[234,240] Biomarkers of oxidative stress (e.g., hydrogen peroxide, 8-isoprostane) are increased in the exhaled breath condensate, sputum, and systemic circulation of patients with COPD. 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.[215,241]

Structural changes

There is compelling evidence for an imbalance in the lungs of patients with COPD between proteases derived from inflammatory and epithelial cells that break down connective tissue components and antiproteases that counterbalance this action.[242] 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.[243]

Peribronchiolar fibrosis and interstitial opacities have been reported in patients with COPD and in asymptomatic smokers,[236,244-246] and an excessive production of growth factors may be found in smokers and patients with COPD.[247] 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,[248] which may contribute to the development of small airways obstruction.[249]

The lung vasculature can also be altered in patients with COPD, even those with mild disease.[250]

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 altered mucosal immunity and gut and airway microbiota, which interact in both directions (the 'gut-lung axis') through immune cross-talk and microbial metabolites and peptides.[251] Dysbiosis is cross-sectionally associated with the presence of COPD and different disease characteristics such as frequency of exacerbations,[252] likely through the alteration of mucosal defenses (vicious circle) and stimulation of lung inflammation by immune responses.[253,254] The microbiome profile is modified following viral infections and during exacerbations and is differentially altered by antibiotics and oral or inhaled corticosteroids.[255-257] Overall, these observations suggest a role for dysbiosis in the development and progression of COPD, but the paucity of longitudinal data[258] and interventional studies underline the need for further research to ascertain the direction(s) of causality and possible prognostic, diagnostic or therapeutic applications.[257]

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.[259] The reduced number of small airways identified in patients with COPD[259] may be due to an enhanced loss of airways and/or to deficient lung development (see dysanapsis above; **Figure 1.2**).[139] Collectively, 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.[260]

Hyperinflation

Hyperinflation occurs when gas volume in the lungs is increased compared to normal values at the end of spontaneous expiration.[261,262] Hyperinflation is clinically relevant in patients with COPD and contributes to dyspnea,[263-266] impaired exercise tolerance,[267-269] increased number of hospitalizations,[270] development of respiratory failure[271] and increased mortality.[268,270,272] In patients with COPD, hyperinflation arises due to loss of elastic recoil and expiratory flow obstruction.[273] 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.[261] 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.[261,262]

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.[274,275] 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.[261,267]

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.[276,277] 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.[278] Hyperinflation can also be detected on chest imaging but standardization is lacking.[261]

Pulmonary gas exchange abnormalities

Structural abnormalities in the airways, alveoli and pulmonary circulation in patients with COPD alter the normal 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.[279] Rarely, reduced ventilation may also be due to reduced ventilatory drive (e.g., sedatives and hypnotic drugs), causing hypercapnic respiratory failure and acidosis.[280]

Parenchymal destruction due to emphysema also leads to decreased DLco. In general, pulmonary gas exchange worsens as the disease progresses.

Pulmonary hypertension

In smokers with normal spirometry and in patients with COPD who have mild airflow obstruction there may be abnormalities in the pulmonary circulation that include intimal hyperplasia and smooth muscle hypertrophy/hyperplasia.[281-284] Moreover, an inflammatory response in pulmonary blood 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.[285,286] 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.[287] The diameter of pulmonary artery as measured on CT scans has been shown to relate to the increased risk of suffering exacerbations, independent of previous history of exacerbations.[288]

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,[289] and worsening of V_A/Q abnormalities that can result in arterial hypoxemia with or without hypercapnia.[290] Other conditions, such as pneumonia, pulmonary, and/or heart failure, among others, may mimic or aggravate an exacerbation, and need to be considered in the clinical management of these episodes.[291] 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.[292,293] The term syndemics has been introduced to describe the co-occurrence of COPD with other conditions that have possible shared mechanisms and risk factors.[294] Airflow obstruction and particularly hyperinflation affect cardiac function.[289] 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.[127] Accordingly, most efforts have been devoted to the study of the pathogenetic mechanisms of only one major cause of COPD (tobacco smoking), failing to expand the horizon about the heterogeneity of processes that we know can contribute to its final clinical presentation.[8] 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*.[295] **Figure 1.3** combines two recent taxonomic proposals developed independently.[7,296] 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 1.3

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)	• Exposure to tobacco smoke, including *in utero* 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, ASSESSMENT AND MONITORING

KEY POINTS:

Diagnosis

- 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; **spirometry** with post-bronchodilator FEV1/FVC < 0.7 is **mandatory** to establish the diagnosis of COPD.
- Pre-bronchodilator spirometry can be used to exclude a diagnosis of COPD.

Initial assessment

- The goals of the initial COPD assessment are to determine the severity of airflow obstruction, assess the impact of current symptoms on the patient, and their risk of future events (such as exacerbations, hospital admissions, or death), to guide therapy.

Monitoring and follow-up

- Routine follow-up of lung function, symptoms and exacerbations is essential to determine when to modify management and to identify any complications and/or comorbidities.
- Virtual and hybrid virtual/in-person care models may offer improved healthcare access, outcomes, and affordability, but use should be based on evidence.

Additional investigations

- Additional clinical assessment, including the measurement of lung volumes, diffusion capacity, exercise testing and/or lung imaging may be considered in patients with COPD who have a marked discordance between the level of airflow obstruction and the perceived symptoms.
- Concomitant chronic diseases (multimorbidity) occur frequently in patients with COPD, 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 FEV1/FVC < 0.7 is **mandatory** to establish the diagnosis of COPD.[297] GOLD is aware that other proposals for confirming the diagnosis of COPD, and assessing and categorizing its severity and prognosis, have been made.[298,299] These proposals include criteria derived from CT scans which are not readily available or accessible in many countries. For this reason, GOLD still believes that a definition based on spirometry in the appropriate clinical context (symptoms and risk factors) is more appropriate for global use across primary and secondary care.

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[300] 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*.[301] 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.[302] Dyspnea comprises a sensory and an affective component.[303] Typically, patients with COPD describe their dyspnea as a sense of increased effort to breathe, chest heaviness, air hunger, or gasping.[304] However, the terms used to describe dyspnea may vary both individually and culturally.[304]

Dyspnea is highly prevalent across all stages of airflow obstruction.[305] 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.[306]

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.[307,308]

Dyspnea measured by the 5-level mMRC scale is integrated in the GOLD clinical classification scheme (see below) because patients with high dyspnea scores incur higher healthcare resource utilization and costs.[309] Dyspnea in daily life can be measured by a number of detailed questionnaires that are more discriminant and sensitive to change.[310,311]

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.[312] 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 COPD who have severe airflow obstruction 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

Patients with COPD 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,[313] 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.[193] Patients producing large volumes of sputum may have underlying bronchiectasis.[314,315] The presence of purulent sputum reflects an increase in inflammatory mediators,[316,317] and its development may identify the onset of a bacterial exacerbation, though the association is relatively weak.[317,318]

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 wheeze 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.

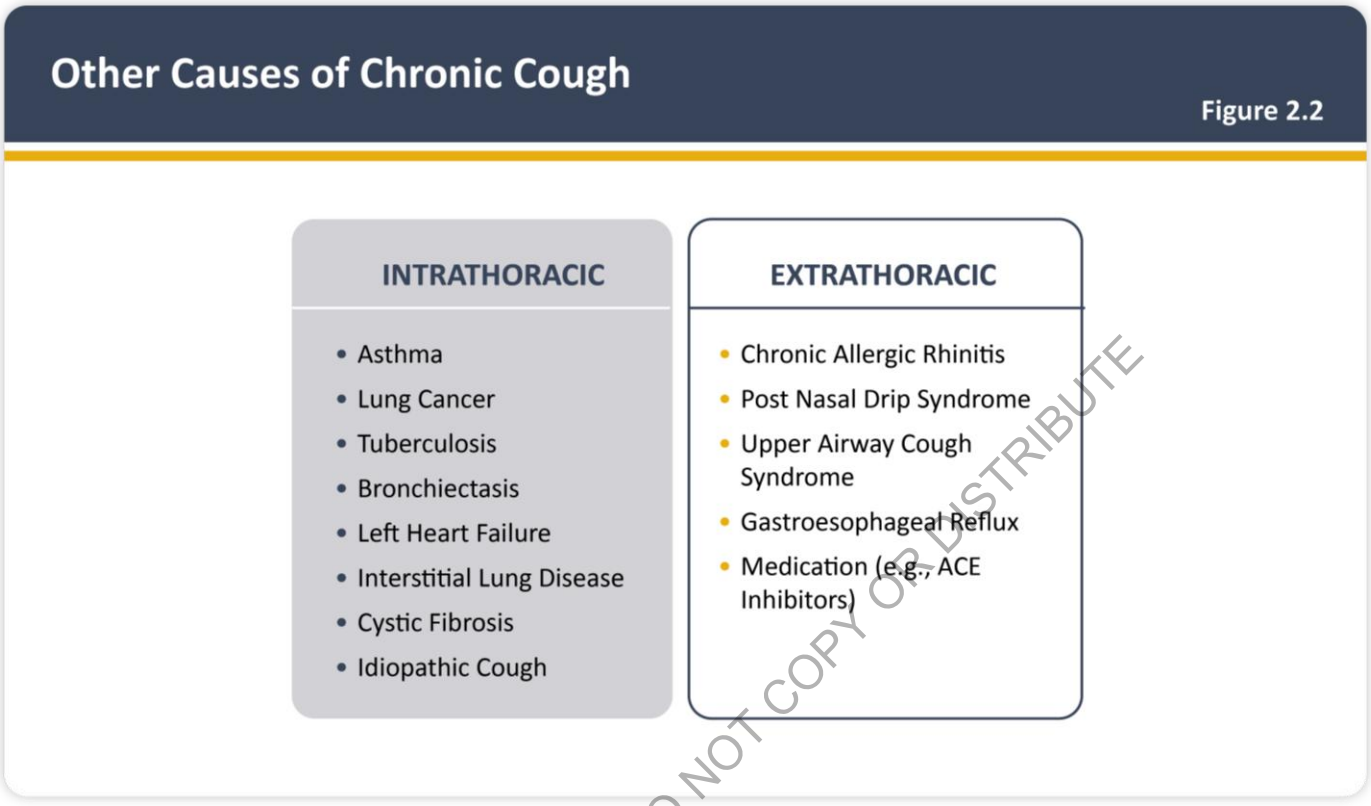
Fatigue

Fatigue is the subjective feeling of tiredness or exhaustion and is one of the most common and distressing symptoms experienced by people with COPD.[319] People with COPD describe their fatigue as a feeling of "general tiredness" or as a feeling of being "drained of energy".[320,321] 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 COPD who have severe and very severe airflow obstruction.[322-324] They have prognostic importance[325,326] 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,[327] are associated with poorer health status, increased risk of exacerbations, and emergency hospital admission, and are treatable.[328]



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.[329] Most other potential differential diagnoses are easier to distinguish from COPD (**Figure 2.3**).

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).

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.*

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,[330,331] 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**.[332,333] Despite its good sensitivity, peak expiratory flow measurement alone cannot be reliably used as the only diagnostic test because of its weak specificity.[334,335]

Considerations in Performing Spirometry

Figure 2.4

PREPARATION	• 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	• 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	• Possible dosage protocols are 400 mcg short-acting beta$_2$-agonist, 160 mcg short-acting anticholinergic, or the two combined[b]; FEV1 should be measured 10-15 minutes after a short-acting beta$_2$-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	• 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

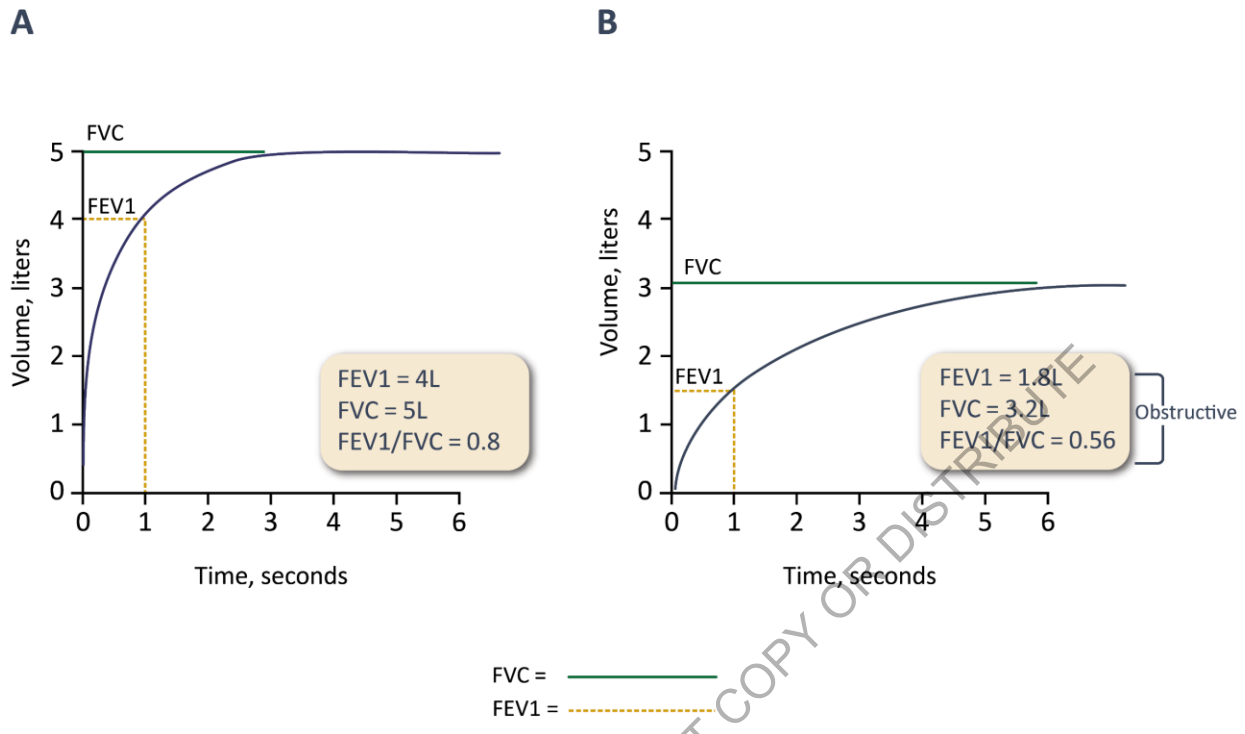
[a]Miller et al. Eur Respir J 2005; **26**(2): 319-38;
[b]Pellegrino et al. Eur Respir J 2005; **26**(5): 948-68.

As shown in **Figure 2.5**, forced spirometry measures: (1) the volume of air forcibly exhaled from the point of maximal inspiration (FVC); (2) the volume of air exhaled during the first second of this maneuver (FEV1); and (3) the ratio of these two measurements (FEV1/FVC). Spirometry measurements are evaluated by comparison with reference values[333,336,337] 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).

A. Spirometry - Normal Trace B. Spirometry - Airflow Obstruction

Figure 2.5

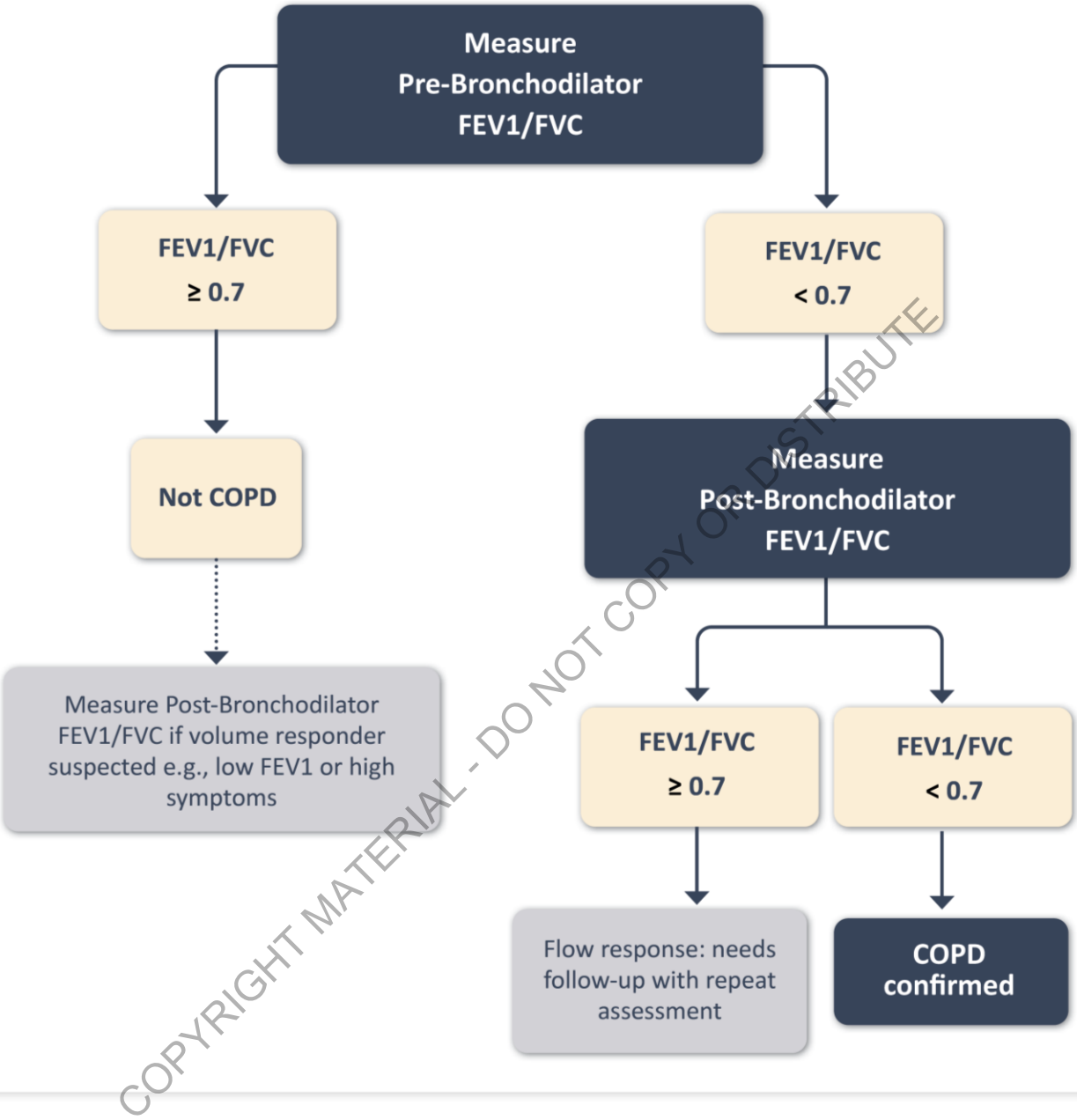


Pre- or post-bronchodilator spirometry to confirm the diagnosis of COPD

In line with other national and international guidelines, GOLD recommends 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.[338] However, it is now recognized that the bronchodilator response has little value in differentiating asthma from COPD,[339] that pre-bronchodilator values are reproducible[340] and obstruction only on post-bronchodilator measurements is uncommon.[341] 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 individuals 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.[342]

Spirometry to Confirm a COPD Diagnosis

Figure 2.6

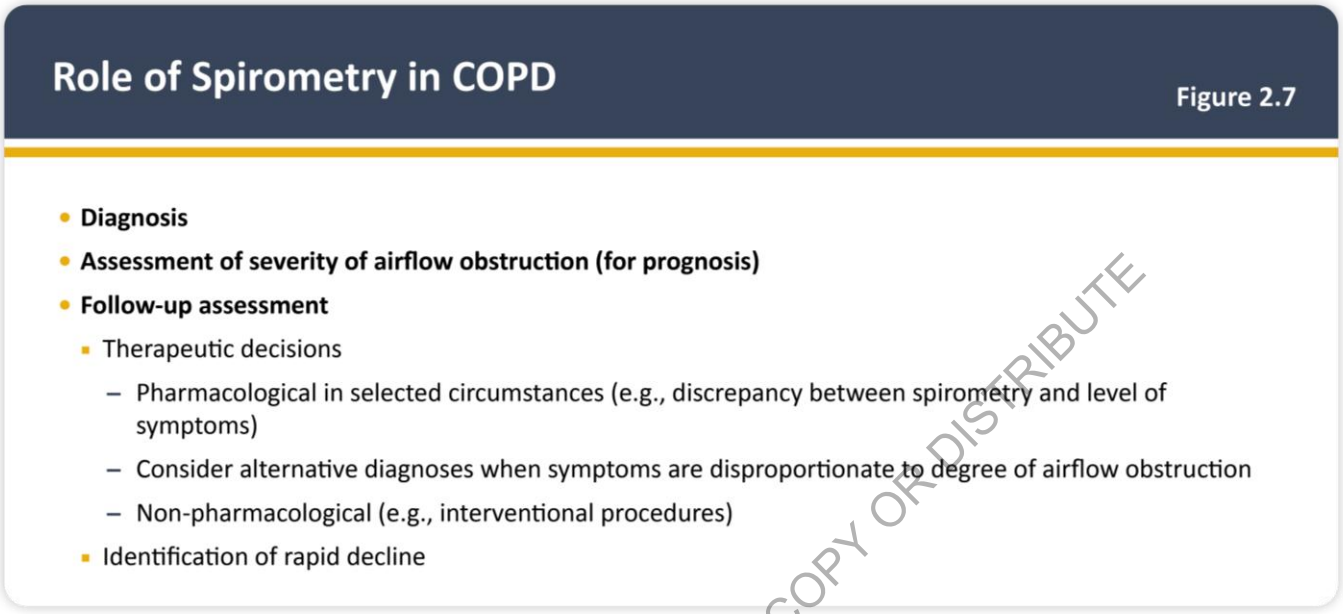


While post-bronchodilator spirometry is required for the diagnosis and assessment of COPD, using the degree of reversibility of airflow obstruction (e.g., measuring FEV1 before and after bronchodilator or corticosteroids) to inform therapeutic decisions is no longer recommended.[343] The degree of reversibility 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.[344] 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.

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,[345,346] and under-diagnosis in approximately 1% of young adults,[346-348] especially in mild disease, compared to using a cut-off based on the 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 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,[349,350] but whether this is of clinical relevance remains uncertain.

LLN values and z-scores are highly dependent on the choice of valid reference equations used to calculate them. 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 Swedish CArdioPulmonary bioImage Study (SCAPIS).[351] 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.[352]

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.[353,354] If the initial post-bronchodilator FEV1/FVC ratio is less than 0.6 it is very unlikely to rise spontaneously above 0.7.[353]

It is important to emphasize that airflow obstruction that is not fully reversible is not specific to 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.

Assessing the severity of airflow obstruction

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 study that analyzed pre-bronchodilator spirometry data from 153,996 healthy people with < 5 pack-year smoking histories in 17 countries and observed wide variation by region.[92] 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.[92] However, race-correction may have important consequences for patients from these areas and eliminating race-based reference values has been proposed[337] because they can lead to underestimation of disease severity and normalize the effects of malnutrition and childhood illness on lung development. In 2022, GLI published new race neutral equations (GLI-Global equations)[355] and these are now the only reference equations officially endorsed by ATS and ERS.[229] In a study of 369,077 participants in the National Health and Nutrition Examination Survey, UK 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.[356] 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.[357-359] In addition, lung reference values change over time and require periodic revision.[360] 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.

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 considers 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.[337] Using these thresholds inevitably leads to differences in the classification of some patients compared to using the percentage predicted[361] 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 obstruction. 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.[362]

Assessing pulmonary function during airborne viral epidemics

Performing spirometry and pulmonary function testing during airborne viral epidemics may lead to viral transmission as a result of coughing and droplet formation during the tests.[363,364] During periods of high prevalence of airborne viral infections 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.[363,365,366]

When routine spirometry is not available, home measurement of PEF combined with validated patient questionnaires could be used to support or refute a possible diagnosis of COPD.[367-370] However, PEF does not correlate well with the results of spirometry,[371-373] has low specificity,[335] and cannot differentiate obstructive and restrictive lung function abnormalities. When making a diagnosis of COPD, airflow obstruction could also be confirmed by personal electronic portable spirometers,[374,375] and instructing them in their use and observing them in their homes using video conferencing technology.

SCREENING AND CASE-FINDING

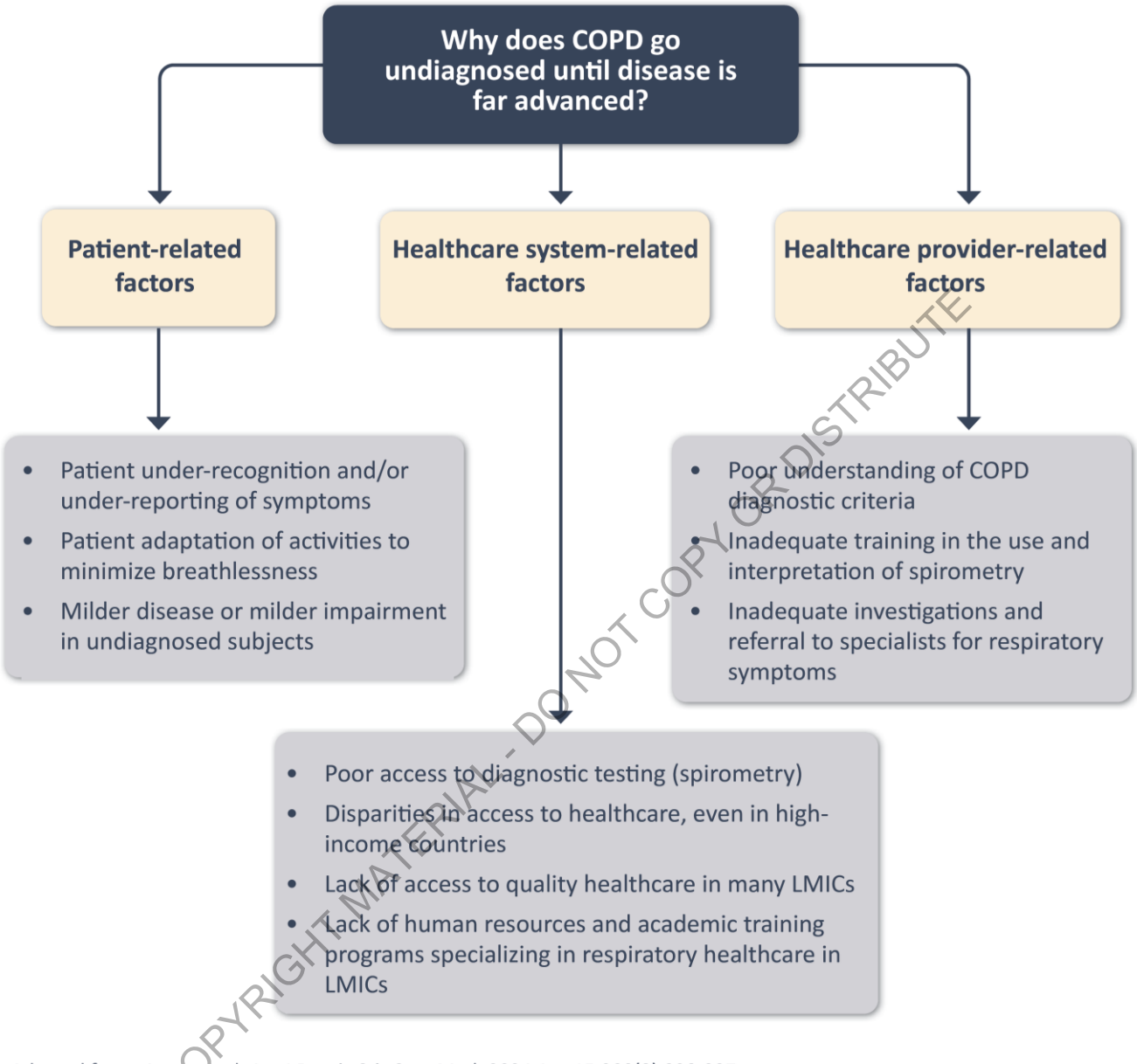
The impact of undiagnosed COPD

Studies from across the world suggest that up to 70% of adults with COPD remain undiagnosed. The 2007-2012 US National Health and Nutritional Examination Survey found obstructive lung disease in 13.4% of randomly selected American adults who underwent spirometry, however 71% had never received a prior diagnosis of COPD.[376] A 27-country collaborative study found a prevalence of COPD (FEV1/FVC < LLN), of 9.7%, with 81% of COPD cases being undiagnosed.[82] The problem of COPD underdiagnosis was worse in low and middle-income countries, and in these countries more than 90%-95% of COPD cases were undiagnosed.[82,377] Reasons for under-diagnosis of COPD are complex and are summarized in **Figure 2.8**.

Individuals with undiagnosed COPD are afflicted by poor quality of life and they suffer from exacerbations like those seen in patients with diagnosed disease.[378] A Canadian study of individuals with symptomatic undiagnosed COPD showed that undiagnosed COPD was associated with greater symptom burden, poorer disease-specific quality of life, impaired work productivity, and poorer overall general health status.[379] A Danish study showed that individuals with previously undiagnosed COPD had age- and sex-adjusted hazard ratios for exacerbations and pneumonia that were 15.5 and 2.8 times higher than age-matched individuals without COPD. In addition, adults with undiagnosed, symptomatic COPD had a 4.3 times greater risk of death from respiratory causes, and a 2.0 times greater risk of death from any cause, compared to individuals without COPD.[377]

Factors that May Be Associated with COPD Underdiagnosis

Figure 2.8



Adapted from: Aaron et al. Am J Respir Crit Care Med. 2024 Apr 15;209(8):928-937.

Finding undiagnosed COPD: screening vs case-finding

Earlier diagnosis of COPD is achieved when an individual undergoes targeted assessment for obstructive lung disease, and disease is identified prior to a conventional diagnosis being made by the individual's healthcare professionals. This can be potentially achieved by either: i) screening or ii) case-finding.

i. Screening is performed in the general population and involves testing mostly asymptomatic individuals with spirometry. This approach is expensive and has a relatively low yield, and screening of low-risk, asymptomatic individuals is not recommended by the US Preventive Services Task Force.[380] In asymptomatic individuals without any significant exposures to tobacco or other risk factors, screening spirometry is probably not indicated, and this approach is not recommended by GOLD.

The potential use of screening 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.[87]

ii. Case-finding targets only those who have unexplained respiratory symptoms, or specific risk factors for COPD, for subsequent testing with spirometry. Case-finding is a potential strategy for identifying undiagnosed individuals at high risk of COPD to allow earlier identification of disease and to direct resources to these individuals. In turn, case-finding approaches can be divided into 1) active case-finding or 2) opportunistic case-finding:

   a. Active case-finding involves proactively searching for individuals at higher risk of the condition, often based on presence of symptoms. In active case-finding, respiratory symptoms and risks for COPD (e.g. unexplained dyspnea, or > 20 pack-years of smoking, or history of recurrent chest infections, or history of early life events) are elicited from the individual via questionnaire and based on positive responses they are targeted to receive spirometry.

      Active case-finding approaches first involve identifying individuals at higher risk for COPD using risk assessment tools such as case finding questionnaires or risk prediction models,[381] and the diagnosis is then confirmed with an objective measure such as pre-/post bronchodilator spirometry. A pragmatic case-finding algorithm (**Figure 2.9**) has been recently proposed to enable accurate COPD diagnoses for most populations.[382]

      Several COPD case-finding questionnaires, including the CDQ and the CAPTURE questionnaire, have been validated in different populations. Hand-held devices, such as the PEF and micro-spirometers (COPD-6 and the Piko-6) have also been widely tested to try to improve identification of people with undiagnosed COPD. Increasingly, it appears that combining questionnaires with simple physiological measurements provided by hand-held devices enhances case-finding performance.[383-385]

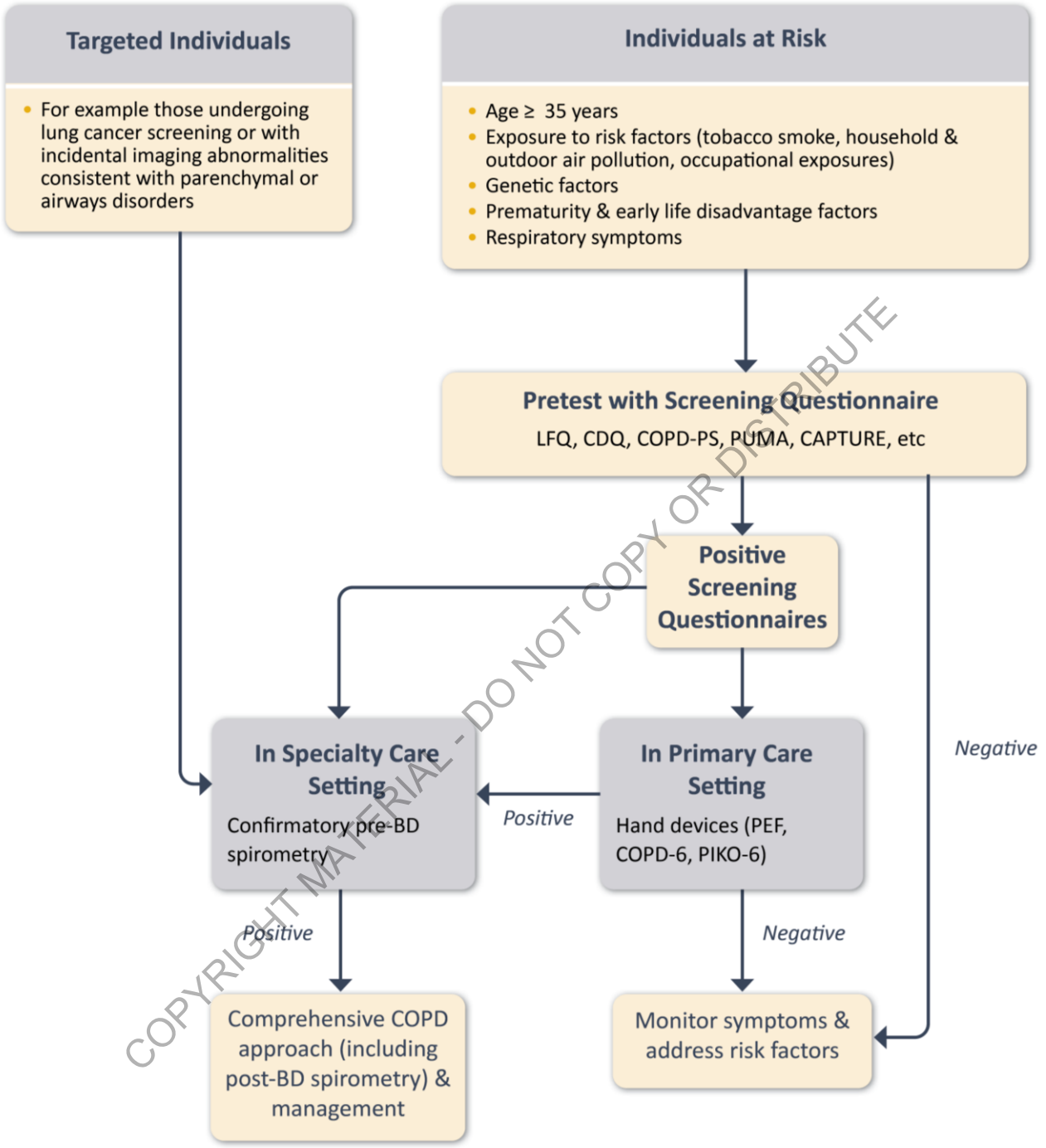
   b. Opportunistic case-finding involves identification of individuals when they present themselves for healthcare services for reasons other than the condition being screened for. An example would be performing diagnostic spirometry in individuals who present for lung cancer screening.

Active case-finding in the population

Prior to 2024, multiple studies had demonstrated that earlier identification and diagnosis of adults with previously undiagnosed COPD was feasible, however no studies had coupled earlier diagnosis of COPD with a treatment strategy to demonstrate that such a strategy improves health outcomes. The Undiagnosed COPD and Asthma in the Population Study (UCAP) coupled an active, community-based case-finding study to a randomized, controlled clinical trial.[386] This study was the first to show that identification and diagnosis of COPD via active telephone-based case-finding of symptomatic community-dwelling individuals, coupled to a comprehensive intervention, reduces patients' healthcare utilization and improves quality of life and health outcomes.[386] Based on the above evidence, GOLD advocates for active case finding,[387-389] i.e., performing spirometry in individuals with symptoms and/or risk factors.

An Algorithm for COPD Case-finding

Figure 2.9



Adapted from: Aaron et al. Am J Respir Crit Care Med. 2024 Apr 15;209(8):928-937.

Opportunistic case-finding in primary care

Systematic active case-finding in a primary care setting via mail-out of a screening questionnaire has been found to be an effective way to identify undiagnosed COPD patients.[390]

Although COPD 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, there is limited data suggesting a significant impact on patient outcomes.[390-393] In the Veterans Affairs system, the use of a clinical decision support system algorithm that incorporated case-finding for COPD and alpha-1 antitrypsin deficiency (AATD), improved correct COPD diagnosis rates and improved screening rates for AATD in a primary care setting.[394]

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.[395] However, a recently completed cluster-randomized trial of 100 family practices in the US, which employed the CAPTURE tool to try to identify patients with undiagnosed COPD, was unable to show a significant effect. Randomizing family practices to knowledge of patients' CAPTURE scores did not significantly impact on the process of care nor did patients' CAAT™ scores significantly improve.[396] The trial was affected by the COVID pandemic, and more research is needed to determine if opportunistic case-finding for COPD in primary care will improve patient outcomes.

Opportunistic case-finding for COPD in targeted populations

Leveraging lung cancer imaging for COPD case-finding

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. 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.[397-400] Thoroughly assessing symptoms and performing spirometry in individuals undergoing LDCT for lung cancer screening therefore represents a unique opportunity to simultaneously assess patients for both the presence of unrecognized symptoms of COPD and airflow obstruction.

Studies that have evaluated individuals 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%.[398,401,402] Male sex, younger age, lower smoking duration and being asymptomatic were associated with detection of airflow obstruction without a prior diagnosis of COPD.[402,403] Those without a prior diagnosis of COPD were less symptomatic; however, the prevalence of symptoms was still high, being 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.[404-410]

In a lung cancer screening cohort, over half of those with visually detected emphysema had airflow obstruction.[411] Quantitative analysis of density can also be used to detect COPD with varying sensitivity and specificity depending on the threshold chosen.[412] 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.[413]

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.[400,404-406,408-410,414]

Leveraging incidental lung imaging abnormalities for COPD case-finding

Factors other than cigarette smoking can increase the risk of COPD (e.g., premature birth, genetic predisposition, 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.

Emphysema is a hallmark of COPD and easily detected on chest imaging, either through visual inspection via a radiologist or through quantitative lung density.[411-413] Lung imaging may also identify other abnormalities that may indicate the presence of COPD including air trapping, airway wall thickening and mucus plugging.[189,403,407,415-417] These abnormalities not only associate with the presence of airflow obstruction but may indicate patients that have a more rapid decline in lung function and worse quality of life.[418-421]

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. The use of spirometry in targeted patients undergoing lung cancer screening, or when incidental imaging abnormalities consistent with airways disorders are found, is recommended by GOLD.[422]

The case for universal spirometry

While case-finding strategies for COPD remain the most immediately actionable approach, it is also worth considering longer-term, population-level strategies to better understand and preserve lung health. Increasing evidence highlights the remarkable variability in pulmonary function both within individuals over time and between individuals across the life course. Genetics, infections, and environmental exposures all contribute to differences in lung growth and decline. By analogy to pediatric growth charts, one could envision universal spirometry beginning around age five or six and continuing periodically into adulthood. Mapping individual trajectories in this way could allow people to serve as their own controls, enabling earlier identification of deviations from expected patterns.[423] Although such an approach may not yet be feasible on a large scale, articulating this concept underscores the potential for future prevention strategies to maintain lung health before overt disease develops.

INITIAL ASSESSMENT

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

- 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 2.10**).

Symptoms

Because there is only a weak correlation between the severity of airflow obstruction (**Figure 2.10**) and the symptoms experienced by the patient or the impairment of their health status,[424,425] formal assessment of symptoms using validated questionnaires is required.

Dyspnea questionnaire: the 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.[426] (**Figure 2.11**) Of note, the mMRC score relates well to other multidimensional health status measures[427] and predicts future mortality risk.[428,429]

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

Figure 2.10

In patients with COPD (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

Modified MRC Dyspnea Scale

Figure 2.11

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 ☐

Reference: American Thoracic Society. Am Rev Respir Dis 1982;126(5):952-6.

Multidimensional questionnaires

It is now recognized that COPD impacts patients beyond dyspnea.[430] For this reason, multidimensional questionnaires are recommended. The most comprehensive disease-specific health status questionnaires such as the CRQ[431] and SGRQ[432] are important research tools but they are too complex to use in routine practice. Shorter comprehensive measures, such as the CAAT™ and the CCQ© have been developed and are suitable for use in the clinic. Below we discuss the CAAT™ and the SGRQ.

The CAAT™*/CAT™† is an 8-item questionnaire that assesses health status in patients with COPD (**Figure 2.12**).[433,434] 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.[435]

CAAT™ Assessment

Figure 2.12

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

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

TOTAL SCORE: ☐

CAT™ has been renamed as the Chronic Airways Assessment Test CAAT™; CAT™ and CAAT™ are equivalent and the scores are interchangeable.

* 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 the Chronic Airways Assessment Test CAAT™. CAT™ and CAAT™ are equivalent, and the scores are interchangeable.

The SGRQ is the most widely documented comprehensive measure; scores < 25 are uncommon in diagnosed patients with COPD,[172] and scores ≥ 25 are very uncommon in healthy persons.[436,437] 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 CAAT™ is 10.[438] 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.[439] 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.[439]

Exacerbation risk

An exacerbation of COPD is an acute event with symptoms worsening over a few days (up to 14 days) and characterized by increased dyspnea and/or cough and sputum 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. (see **Chapter 4**).[440-443] Even one moderate or severe exacerbation treated with steroids and/or antibiotics is key in the natural history of the disease as these episodes significantly impact 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 much of the healthcare costs of COPD.[444] Exacerbation rates vary greatly between patients[445] and during follow-up.[446] The most commonly used predictor of having an exacerbation is a previous history of an exacerbation event with greater risk seen in those experiencing more than one exacerbation requiring steroids and/or antibiotics, particularly one requiring hospitalization.[445] Worsening of airflow obstruction is associated with an increasing prevalence of exacerbations, hospitalization[388,447] and risk of death.[172,448]

Blood eosinophil count

There is evidence that on average blood eosinophil counts are higher in patients with COPD, although there is marked overlap with healthy individuals.[449,450] Higher blood eosinophil counts in patients with COPD are associated with increased numbers of eosinophils in the lungs and higher levels of markers of T2 inflammation in the airways, although the concordance between blood and lung/airways T2 biomarkers is not strict.[451,452] These differences in airway inflammation may explain the differential response to ICS treatment according to blood eosinophil counts.[453]

The repeatability of blood eosinophil counts appears reasonable,[454] although greater variability is observed at higher thresholds,[455] with better reproducibility at lower thresholds (e.g., ≤ 100 cells/µL).[456]

Cohort studies have produced differing results with regard to the ability of blood eosinophils to predict future exacerbation outcomes, with either no relationship[457] or a positive relationship reported.[458,459] 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 patients with COPD. Greater FEV1 decline was observed in patients with COPD who had mild to moderate airflow obstruction and higher blood eosinophil counts in a population where ICS use was low,[460] 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.[461]

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; blood eosinophil counts are recommended by GOLD to guide the use of ICS as part of pharmacological management (see **Chapter 3**, **Figures**

3.8, 3.9 and 3.10).[462-467]

Multimorbidity

People with COPD often suffer other concomitant chronic diseases (multimorbidity). This can occur in patients with mild, moderate or severe airflow obstruction.[172] Multimorbidity influences mortality and hospitalizations independently of the severity of airflow obstruction,[468] 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 CVD,[88] metabolic syndrome, osteoporosis, depression, and anxiety, with the coexistence likely due to shared risk factors (e.g., aging, smoking, alcohol, diet, and inactivity).[444,469-471] In addition, COPD itself may increase the risk for other comorbid diseases (e.g., COPD (particularly emphysema) and lung cancer).[472,473] 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.[474] 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.[475] A more detailed description of the management of COPD and morbidities is provided in **Chapter 5**.

Cardiovascular risk in COPD

Patients with COPD often suffer CVD and *vice versa*, although these may be ignored by the attending physician who focuses on her/his disease of interest (lung or heart).[476,477] 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 patients with clinically stable disease and patients suffering acute episodes of increased symptoms, so-called exacerbations of COPD.

Clinically stable COPD

The prevalence of CVD, including arterial hypertension, coronary artery disease, heart failure and arrhythmias is increased in patients with *clinically stable* COPD.[294,477] CVDs are a prominent cause of death in COPD, particularly in patients with mild-moderate airflow obstruction.[478] Unfortunately, these CVDs often go unnoticed and, therefore, untreated.[476,477]

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.[294] 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;[479] 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, arrythmia) needs to be investigated in any patient with COPD,[480,481] and if present treated according to available guidelines.[477] Of note, the use of established CV risk scores in the general population, such as Framingham or QRisk, may underestimate CVD in patients with COPD, and merits further research.[480,482] Likewise, the inclusion of spirometric variables (e.g., FEV1) may augment the predictive value of the standard cardiovascular risk scores in use.[480,482] This also merits research.

Exacerbations

Many patients with COPD develop exacerbation episodes during the course of their disease that impact their health status and prognosis. The mechanisms and management of exacerbations 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 exacerbations. As a result, during an exacerbation the risk of an acute cardiovascular event, such as myocardial infarction, arrhythmias and stroke, increases further,[483] particularly in those severe exacerbations that require hospitalization.[484] Importantly, this risk remains high during the first few weeks after hospital discharge, and it can still remain significantly increased even one year later.[481,483,485] A multi-country real-world analysis of studies based on a common protocol reported significant increased risk of severe cardiovascular events following both moderate and severe exacerbations, including newly diagnosed patients.[486]

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

1) The current GOLD recommendations emphasize the importance of an appropriate *differential* diagnosis of exacerbations from other conditions that may mimic/aggravate them (e.g., heart failure).[487] Yet, if they do exist, they need to be treated appropriately.

2) It may be advisable to measure *routinely during* exacerbations markers of CVD, such as troponin and brain-natriuretic peptides.[480,481] The evidence supporting this proposal is still weak, but the observations discussed above support it.[483,484] If any of these markers are abnormal *during* the exacerbation, 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 exacerbation, but this again merits research. Similarly, β-blockers and statins need to be prescribed following their CVD indications although these drugs did not show any benefit in clinically stable patients with COPD without CVD indications. Importantly, patients with COPD should not be denied β-blocker use if there is a CVD indication.

4) Finally, although preventing exacerbations is already a main goal of COPD treatment because of their impact on the prognosis, lung function and health status of the patient,[477] 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**.

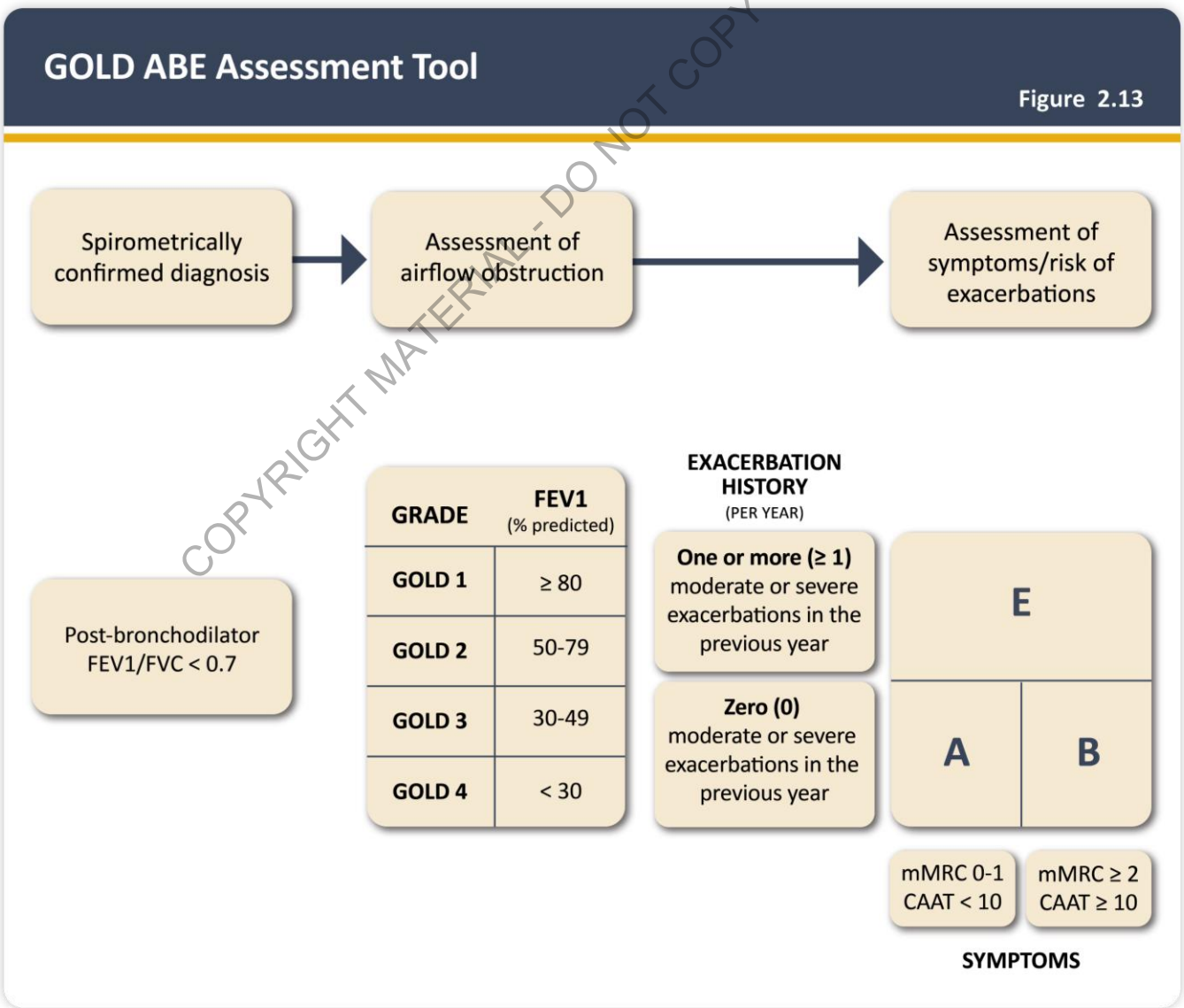
Combined initial COPD assessment

In 2011, GOLD proposed moving 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 CAAT™), 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.[425,448,488,489]

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 2.13** presents the recommendations for patients who are naïve to pharmacological treatment. 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 needs to be validated by appropriate clinical research. Observational studies[490,491] have shown that even one moderate or severe exacerbation prior to initiating maintenance pharmacological therapy increases the risk of subsequent events; this risk is further increased if there are more frequent or severe events.[467,492-494] Consequently, Group E has been modified to include individuals with one moderate exacerbation in the previous year.



MONITORING AND FOLLOW-UP

Routine follow-up of patients with COPD 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 CAAT™[433] can be used; trends and changes are more valuable than single measurements.

Exacerbations

The frequency, severity, type and likely causes of all exacerbations[495] 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 patients with COPD 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

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 (6MWD or shuttle-walking test) provides additional information regarding prognosis.[496,497] 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 should be recorded.

If present, an appropriate diagnostic work-up should follow (see also **Chapter 5**).

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., CT) and/or comorbidities (e.g., ischemic heart disease) that might impact patient symptoms.

Physiological tests

Lung volumes

Patients with COPD 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. Lung volumes are helpful in determining the cause of persistent dyspnea, exercise intolerance and in the consideration of lung reduction treatments.

Carbon monoxide diffusing capacity of the lungs

The single breath DLco measurement[498] evaluates the gas transfer properties of the respiratory system. DLco is well-standardized, with valid predicted values of practical utility.[336,499-501] 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.[502] 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,[503-506] and increased risk of death, independently of the severity of airflow obstruction and other clinical variables.[507-510] Further, DLco has been shown to be a strong predictor of COPD hospitalizations, independent of airflow obstruction and prior hospitalizations.[511] Additionally, in patients with COPD, low DLco values help preclude surgical lung resection in patients with lung cancer[512] while in smokers without airflow obstruction, values < 80% predicted (as a marker of emphysema) signal an increased risk for developing COPD over time.[513]

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.[514,515] 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 oxygen saturation is ≤ 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.[516] Further, pulse oximetry does not provide information on $PaCO_2$ 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[517] and/or life-style adaptations (sedentarism) to reduce dyspnea generation. In these cases, exercise tests such as the 6MWD 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[518,519] or during incremental exercise testing in a laboratory,[520] is a powerful indicator of health status impairment and predictor of prognosis.[521] 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[522] and are used to assess the effectiveness of pulmonary rehabilitation. Both the paced shuttle walk test[523] and the self-paced 6MWD test can be used.[524,525] 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.[526]

Monitoring physical activity may be more relevant regarding prognosis than evaluating only exercise capacity.[527] 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 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 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.[528,529] 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.[412,421,510,530,531] Additionally there is evidence to indicate that upper lobe emphysema, in particular, may also help identify individuals most at risk for rapid lung function decline[532] and emphysema progression.[533]

CT and lung nodules

While chest CT is not required for COPD diagnosis, more patients with COPD 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 access to such screening 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 patients with COPD. Bronchiectasis is associated with increased exacerbation frequency and mortality,[534] 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 CAAT™ score, more frequent exacerbations and increased mortality, although there is incomplete overlap between presence of mucus plugs and mucus specific symptoms.[188,190,535,536] Mucus plugging has also been associated with elevated blood eosinophils, suggesting it is associated with Type 2 inflammation, although plugging may also be associated with other phenotypes.[190] 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,[531,537,538] 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.[539,540] Small airway abnormality may also be present even among individuals without detectable spirometric obstruction and identify individuals at increased risk for lung function decline.[541]

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.[529] As technology advances, such information is likely to become increasingly available to clinicians to enhance patient management.

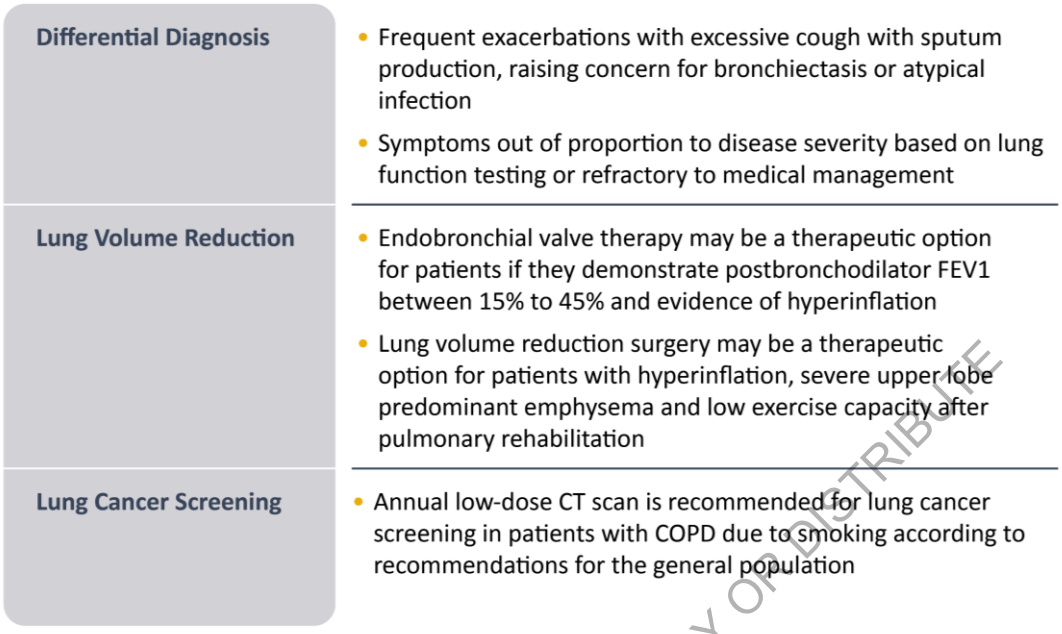
In summary, chest CT imaging should be considered for patients with COPD who have persistent exacerbations, symptoms out of proportion to disease severity on lung function testing or refractory to medical management, FEV1 between 15% and 45% predicted with significant hyperinflation and gas trapping, or for those who meet criteria for lung cancer screening (**Figure 2.14**).[510,528,529,534,539-541]

Interstitial lung abnormalities

Findings suggestive of parenchymal lung fibrosis or inflammation are common on chest CT imaging of both smokers and nonsmokers, and have been termed ILA when discovered incidentally in patients without known ILD.[542] 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.[542] Among 4,360 COPDGene participants, ILA was present in 8% of individuals, with half meeting criteria for suspected ILD, which was defined as definite fibrosis on CT, FVC < 80% predicted or DLco < 70% predicted.[245,543] Individuals with suspected ILD had increased respiratory symptoms and mortality.[543] 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.[544,545] Given the clinical relevance of ILA, multiple studies support clinical evaluation, risk stratification and follow up monitoring of individuals with these findings.

Use of CT in Stable COPD

Figure 2.14



Alpha-1 antitrypsin deficiency

GOLD recommends that all patients with a diagnosis of COPD should be tested for AATD.[546,547] Although the classical patient at the time of diagnosis 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).[548] A low concentration (< 20% normal) is highly suggestive of homozygous deficiency. Family members should also be tested 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 method gives a composite score that is a better predictor of subsequent survival than any single component.[549,550] 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.[551,552]

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.[553]

At present blood eosinophil counts provide guidance to identify patients with COPD who are more likely to benefit

from preventive treatment with ICSs (see **Chapter 3**).[553]

Treatable traits

To address the heterogeneity and complexity of COPD in clinical practice, a strategy based on so-called 'treatable traits' has been proposed.[554] Treatable traits 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 patients with COPD who are at risk of exacerbations (a treatable trait) in whom treatment with ICS is most effective).[555] Treatable traits can co-exist in the same patient[329] and change with time (spontaneously or because of treatment). GOLD highlights the role of two key treatable traits (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.[329]

CHAPTER 3: PREVENTION & MANAGEMENT OF COPD

KEY POINTS:

Risk reduction, lifestyle and patient education

- 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.
- People with COPD should receive all recommended vaccinations in line with the relevant local guidelines.
- 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, pneumococcal and RSV vaccines have been shown to decrease the incidence of lower respiratory tract infections.
- The immunization committees recommend Tdap vaccination (dTaP/dTPa; pertussis, tetanus and diptheria) for people with COPD who were not vaccinated in adolescence; and routine use of shingles vaccine.

Pharmacological maintenance treatment of COPD

- Initial pharmacological treatment of COPD should be individualized and guided by the severity of symptoms, risk of exacerbations, side-effects, comorbidities, drug availability and cost, and the patient's preference, and ability to use various drug delivery devices.
- Patients should be reviewed after a suitable interval (shorter in patients with more severe disease, and longer in patients with less severe disease) and reassessed for attainment of treatment goals and identification of any barriers for successful treatment.
- Inhaler technique and adherence need to be assessed regularly.

Non-pharmacological treatment of COPD

- Non-pharmacological treatment of COPD is complementary to pharmacological maintenance treatment and should form part of comprehensive management.
- Pulmonary rehabilitation, including exercise training combined with disease-specific education, improves exercise capacity, symptoms, and quality of life across all grades of COPD severity.
- LTOT should not be prescribed routinely for patients with stable COPD and resting or exercise-induced moderate desaturation, but it may improve survival in patients with severe resting chronic hypoxemia ($PaO_2 \leq 55$ mmHg or < 60 mmHg if there is *cor pulmonale* or secondary polycythemia).
- Long-term NIV may be of some use in a selected group of patients, particularly those with pronounced daytime hypercapnia and recent hospitalization.

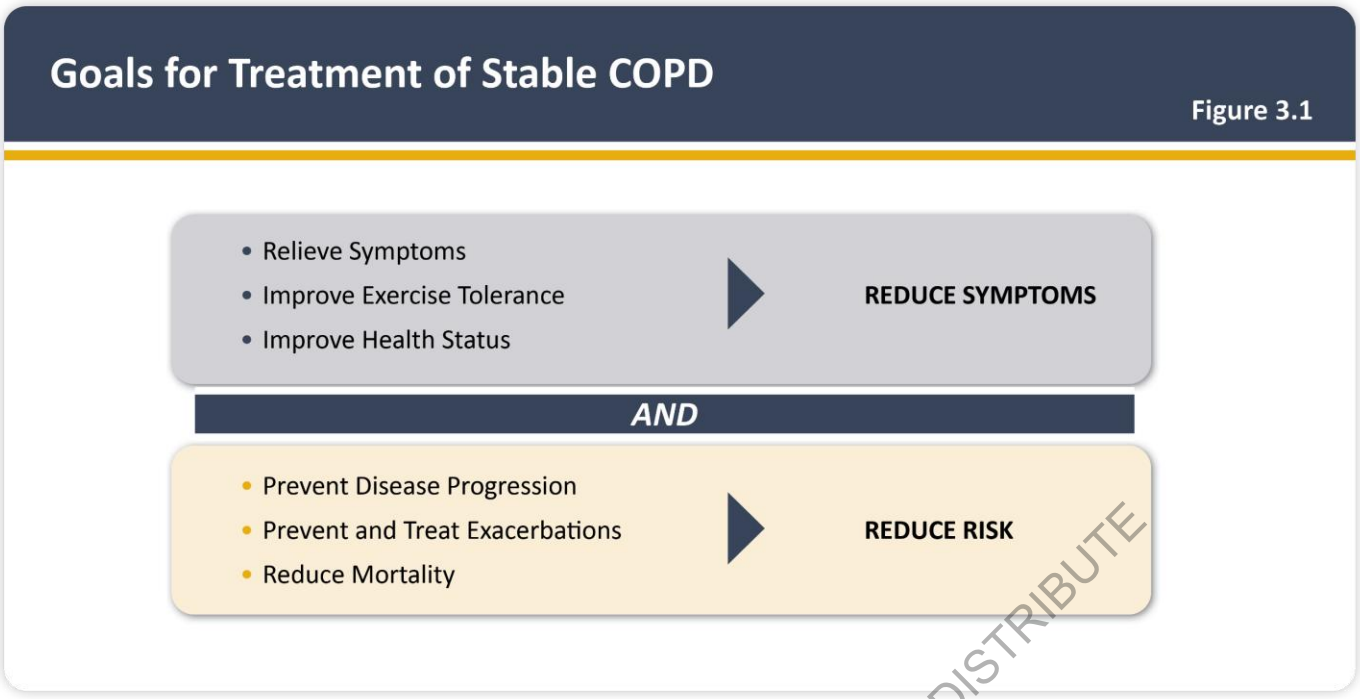
Palliative, interventional and surgical therapies

- 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**). Patients with COPD 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.

Disease activity

In chronic inflammatory diseases, the term "disease activity" is often used to refer to biological pathways that (1) cause the pathological outcomes of the disease and (2) are potentially reversible (or controllable) with treatment. If left untreated or if treatment is ineffective, disease activity processes can lead to disease progression with permanent organ damage and dysfunction. Pharmacological treatment with anti-inflammatory drugs can reduce disease activity and therefore potentially prevent organ damage in COPD, while some non-pharmacological interventions (e.g., smoking cessation, pulmonary rehabilitation and volume reduction in hyperinflated emphysematous patients) can also reduce disease activity.

Assessing disease activity and its modulation by interventions generally requires the monitoring of biomarkers that are related to the reversible or modifiable biological processes. In COPD, there has been progress using biomarkers (blood eosinophil counts) to identify individuals with type 2 inflammation, but there is a need to identify and validate other biomarkers of disease activity. Clinical features such as exacerbations, chronic worsening of respiratory symptoms or disease progression (e.g. lung function decline that is greater than the anticipated normal age-related loss or progression of radiological evidence of emphysematous destruction) are all measurable indicators of disease activity.

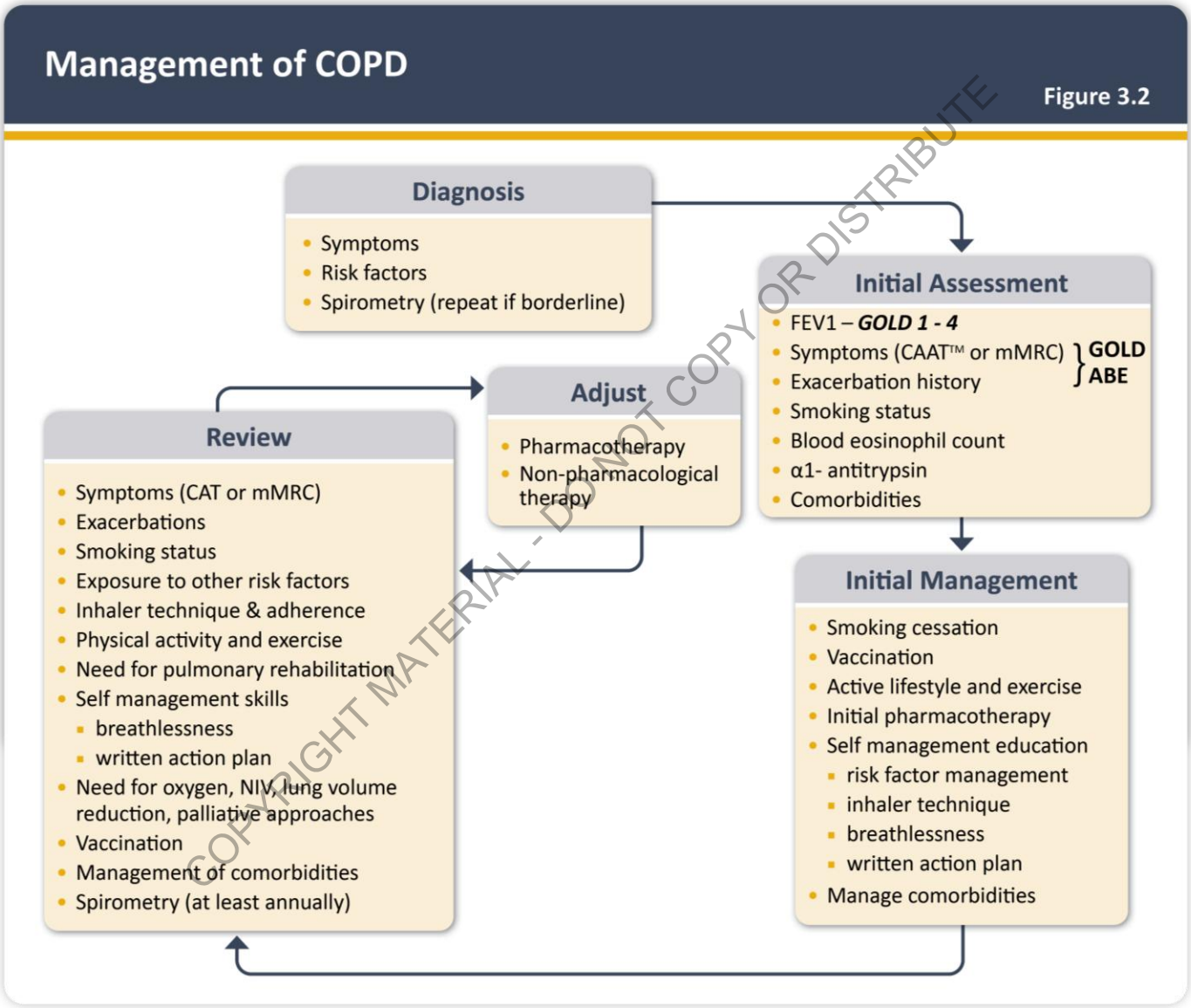
Low disease activity is manifested clinically by having no exacerbations and no worsening of symptoms over a period of time accompanied by no accelerated loss of lung function. Achieving low disease activity is a treatment target in COPD with the aim to prevent any exacerbations over both the short and long term. GOLD recommends that a key objective of COPD management should be to reduce disease activity with the aim that patients have:

- no exacerbations
- no worsening of symptoms

- no accelerated loss of lung function.

While reducing disease activity can prevent symptom worsening and may improve symptoms, additional interventions to further optimize symptom relief may be required. Two terms with similar, but importantly different definitions, have been proposed to describe the clinical state achieved when considering these outcomes over time:

- disease stability – a low disease activity state with no exacerbations, no worsening of symptoms and no accelerated loss of lung function[556]
- disease control – a state of low disease activity, defined by no exacerbations and no worsening of symptoms, plus low impact on the patient defined as symptoms below a threshold value.[557]



While aiming for control may appear more ambitious than stability, control is unachievable for individuals with extensive end-organ damage causing a high symptom burden. Although disease control may be more difficult to achieve in patients with later stage disease due to structural damage, improvements in disease activity may be achieved with combined pharmacological and non-pharmacological interventions.

Late diagnosis of COPD contributes to a high symptom burden due to the severity of lung pathology with structural damage at the time of diagnosis. Targeting disease activity at earlier stages of the natural history of COPD has the

potential to minimize disease progression and associated structural damage, thereby resulting in lower levels of symptoms and disability. This paradigm requires earlier diagnoses, disease activity evaluation using biomarkers and therapy that suppresses disease activity.

RISK REDUCTION, LIFESTYLE, AND PATIENT EDUCATION

Risk reduction

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 patient with COPD. 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**).

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

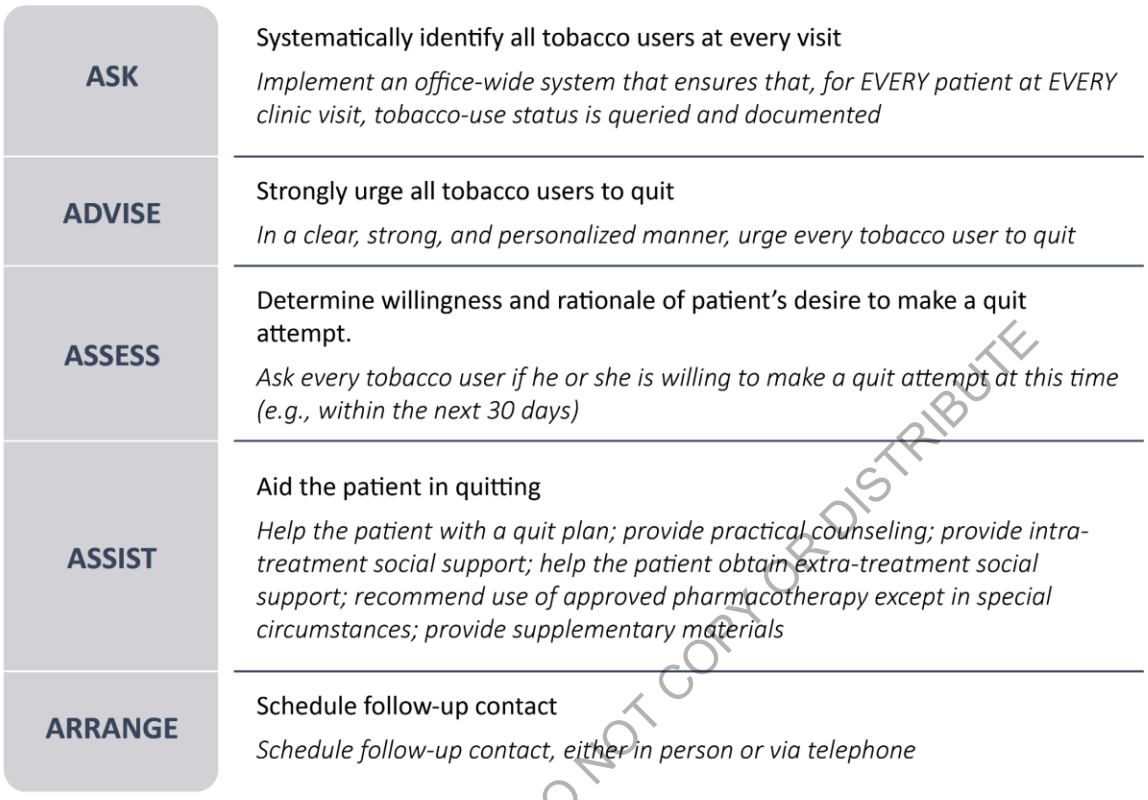
Smoking cessation is a key intervention for all patients with COPD who continue to smoke. Healthcare providers are pivotal in delivering smoking cessation messages and interventions and should encourage patients to quit at every available opportunity (**Figure 3.4**).

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.[558] Smoking cessation has the greatest capacity to influence the natural history of COPD, it also improves daily symptoms,[559] and decreases the frequency of exacerbations.[560]

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.[561-563] In addition, it has been reported that depression is more common in smokers with COPD[564] and this could contribute to failed attempts to quit.[564,565] 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.[565]

Brief Strategies to Help the Patient Willing to Quit

Figure 3.4



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.[565-567] 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.[568,569]

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.[570]

Advice and counseling interventions

A five-step program for intervention (**Figure 3.4**)[571-573] provides a helpful strategic framework to guide healthcare providers interested in helping their patients stop smoking.[571,573,574] 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**.[571] Because tobacco dependence is a chronic disease,[571,573] 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

Reference: The Tobacco Use and Dependence Clinical Practice Guideline Panel. *JAMA* 2000; **283**(24): 3244-54

Counseling delivered by physicians and other health professionals significantly increases quit rates over self-initiated strategies.[575] Even brief (3-minute) periods of counseling urging a smoker to quit improve smoking cessation rates.[575]

In patients with COPD a network meta-analysis showed a trend for smoking cessation counseling alone to be superior than usual care.[576] 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.[566] However, controversy remains as to whether more intensive individual counseling is more effective when combined with pharmacotherapy.[576]

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.[9,10]

Occupational exposures

There are no studies that demonstrate whether interventions that reduce occupational exposure 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 and 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,[577-583] and during periods of cold weather.[584-587] Epidemiological studies confirm the association between exposure to extreme, but not moderate, heat and mortality,[588-590] with the mortality impact of extreme high temperatures increasing with the length of the heat episode.[591] 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.[584,590] The effects of heat also vary with levels of atmospheric humidity and air pollution.[578,592,593]

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,[594-596] with cold leading to a greater risk than heat.[597,598] As well as the effects on mortality, higher outdoor temperatures are associated with an increased risk of hospitalization for COPD[596,599-601] and lower outdoor temperatures are associated with an increased risk of exacerbations.[602]

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 between dwellings 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.[603-605] Indoor temperatures are often higher than outdoor including during heatwaves,[606,607] 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.[608] Even if heating is available, patients with COPD may not heat their bedrooms at night and may keep windows open overnight even in winter.[609,610]

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[611] particularly on days that patients go outside.[612] Higher indoor temperatures are associated with increased symptoms and SABA use[612] and colder indoor and outdoor temperatures are also associated with increased cough and sputum, increased SABA use and a fall in FEV1.[609,611-613] 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 ≥ 21°C.[614]

Weather also has a significant impact on air quality. Ozone levels strongly correlate with temperature, as its generation depends on high temperatures and sunlight,[615] and the generation and dispersion of air pollutants may be influenced by local patterns of wind, solar radiation and precipitation, especially in urban areas.[616] Some studies have shown synergistic effects between heat and air pollution exposure on all-cause mortality, and hospital admissions in general populations;[596,617,618] however, there are also studies showing no interaction.[619,620] 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)[621,622] but not in others.[594,617] Although not widely studied, there is conflicting evidence regarding the interactive effects of outdoor heat and pollution on respiratory outcomes.[596,623,624] 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.[625-628] Outdoor air pollutants, including PM2.5, NO_2, and ozone do not appear to worsen the effect of outdoor temperature on symptoms,[629] but the detrimental effect of higher indoor temperatures on symptoms appears to be potentiated by higher indoor

concentrations of PM2.5 and NO_2.[629] 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,[630] 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.[631] 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

Routine annual influenza vaccination is recommended for all people aged ≥ 6 months who do not have contraindications, and should be prioritized in individuals with chronic conditions like COPD.[632] Influenza vaccination can reduce serious illness (such as lower respiratory tract infections requiring hospitalization),[633] stroke,[634] and death in people with COPD.[635-638] Only a few studies have evaluated exacerbations; they have shown a significant reduction in the total number of exacerbations per vaccinated subject compared with those who received placebo.[635] Vaccines containing either killed or live inactivated viruses are recommended[639] as they are more effective in elderly people with COPD.[640] The CDC recommends high-dose inactivated (HD-IIV3) and adjuvanted inactivated (aIIV3) influenza vaccines as acceptable options for influenza vaccination in older adults.[632] 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.[641] Influenza vaccination during a hospital admission in patients with acute heart failure can improve their survival and reduce likelihood of readmission to hospital over the subsequent 12 months.[642] The occurrence of adverse reactions is generally mild and transient.

Pneumococcal vaccines

Pneumococcal vaccinations, pneumococcal conjugated vaccine (PCV21, PCV20, PCV15 or PCV13) and pneumococcal polysaccharide vaccine (PPSV23), are indicated for all adults aged ≥ 50 years, and adults aged 19-49 years with an underlying medical condition such as chronic lung disease (including COPD, emphysema, cystic fibrosis, and asthma) or solid organ transplant etc.[643] The PCV21[643] covers 11 unique serotypes not included in PCV20; notably many cases of adult disease are caused by subtypes not covered by other FDA-approved pneumococcal vaccines.[644] 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 PCV13 or PCV15 followed by PPSV23 or one-dose PCV20,[645] or one-dose PCV21[643] in adults who have an indication for the vaccine (**Figure 3.6**).[645,646] We recommend the use of PCV20 or PCV21 in patients with COPD.

Vaccination for People with 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)**
- We recommend either one dose of 21-valent pneumococcal conjugate vaccine (PCV21) or one dose PCV20 **(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 ≥ 50 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), in addition to tetanus and diphtheria, 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.[647] A systematic review of injectable vaccines in patients with COPD identified twelve randomized studies for inclusion and observed injectable polyvalent pneumococcal vaccination provides significant protection against community-acquired pneumonia, although there was no evidence that vaccination reduced the risk of confirmed pneumococcal pneumonia, which was a relatively rare event. Vaccination reduced the likelihood of an exacerbation, and moderate-quality evidence suggested the benefits of pneumococcal vaccination in patients with COPD. Evidence was insufficient for comparison of different pneumococcal vaccine types.[648] PPSV23 has been shown to reduce the incidence of community-acquired pneumonia in patients with COPD who are < 65 years, with an FEV1 < 40% predicted, or have comorbidities (especially cardiac comorbidities).[649] The PCV13 has been shown to exhibit at least the same or greater immunogenicity than the PPSV23 up to 2 years after vaccination in patients with COPD.[650] 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.[651] PCV20 covers up to 58% of those strains, while PCV21 covers up to 84% of strains responsible for invasive disease in adults.[644,646]

A study that compared the effectiveness of PPSV23 and PCV13 in patients with COPD over a 5-year follow-up cohort study found that 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 exacerbations.[652]

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.[653]

Respiratory syncytial virus vaccine

The CDC estimates that every year, RSV causes approximately 60,000-160,000 hospitalizations and 6,000-10,000 deaths among older adults in the US.[654,655] 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 five 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 one in 12 adults (8.5%) with no documented underlying CVD.[656] In a report from the UK, RSV was associated with 8.7% of outpatient managed exacerbations.[657]

The Advisory Committee on Immunization Practices and the European Commission recommend use of RSV bivalent prefusion F protein-based vaccine,[658] adjuvanted prefusion F protein vaccine,[659] and mRNA RSV based vaccine in adults aged ≥ 50 years.[660] For adults aged ≥75 years, the vaccination is universally recommended for if they have not been previously vaccinated. For adults aged 50-74 years, vaccination is recommended if they have a risk factor or other indication that increases their risk for severe RSV disease such as chronic heart or lung disease, immune compromise, or living in a nursing home or long-term care facility.[645] 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 three full RSV seasons.[661,662] In other studies RSV vaccination reduced the likelihood of RSV-associated hospitalization.[663,664] The safety of RSV vaccinations has been demonstrated in a CDC publication.[665] RSV vaccines can be co-administered with other adult vaccines during the same visit.[666]

Other vaccines

Patients with COPD are at increased risk of pertussis (whooping cough).[667] 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, together with routine shingles vaccination.[645]

People with COPD should have the COVID-19 vaccinations in line with national recommendations.[645,668] COVID-19 vaccines are highly effective against SARS-CoV-2 infection requiring hospitalization, ICU admission, or an ED or urgent care clinic visit, including those with chronic respiratory disease.[190,669]

Education and self-management

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.[670] 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.[671] 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,[672,673] but it can play a role in improving skills, ability to cope with illness, and health status.[674]

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.

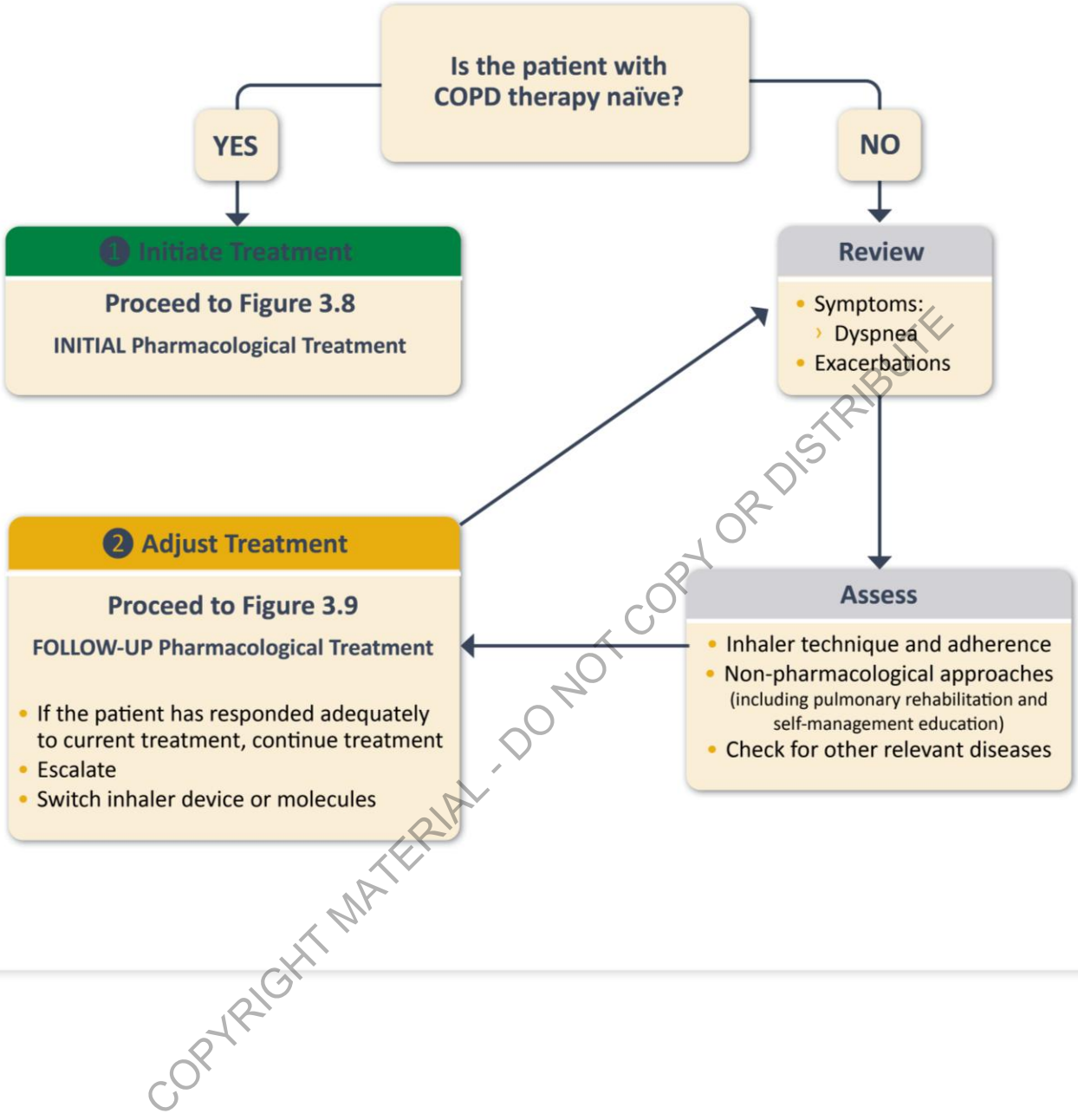
PHARMACOLOGICAL MAINTENANCE TREATMENT OF COPD

We propose a tailored approach to initiate treatment based on the level of symptoms and risk for exacerbations. Treatment can be 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. Studies comparing LABA+ICS versus LABA or triple inhaled therapy (LABA+LAMA+ICS) versus either LABA+ICS or LABA+LAMA, confirmed a significant decrease in exacerbation rate with the addition of an ICS in patients who experienced one moderate or severe exacerbation in the prior year. This recommendation is derived from evidence generated by RCTs. Observational and interventional studies suggest that one moderate or severe exacerbation increases the risk of subsequent events; this risk is further increased if there are more frequent or severe events.[467,492,675,676] Our therapeutic recommendations are intended to support clinician decision-making; they also incorporate expert advice based on clinical experience.

Figure 3.7 gives an overview of the diagnosis and management cycle. **Initial pharmacotherapy** should be based on the patient's GOLD group (**Figure 3.8**). Patients should be offered guidance and follow-up on self-management of breathlessness, and stress management, and be given a written action plan. Comorbidities should be managed as per specific guidelines, irrespective of the presence of COPD (**Chapter 5**). **Follow-up pharmacotherapy** should be based on the patient's symptoms (dyspnea or exacerbations) at review (**Figure 3.9**).

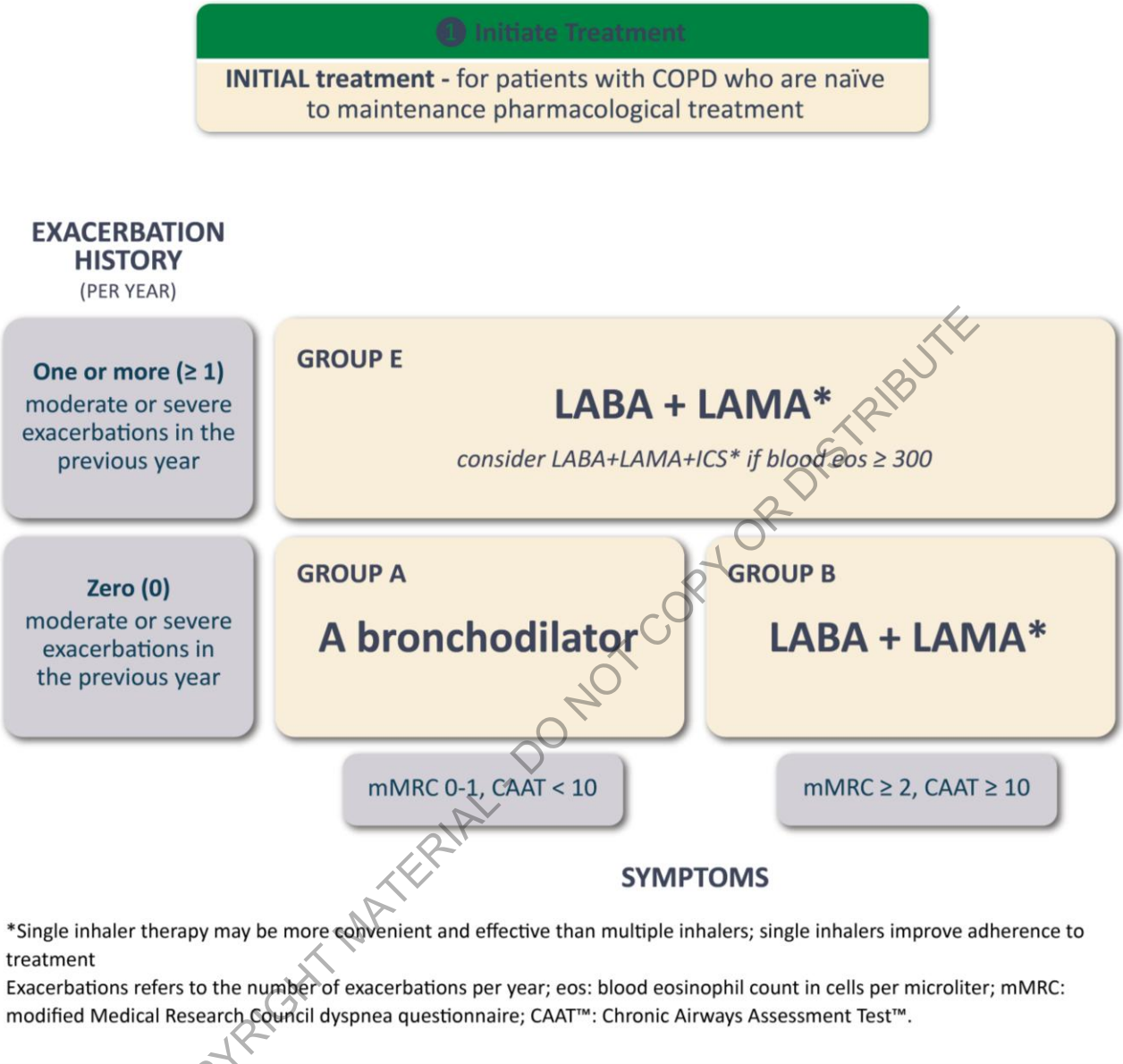
Diagnosis and Management Cycle

Figure 3.7



Initial Pharmacological Treatment

Figure 3.8

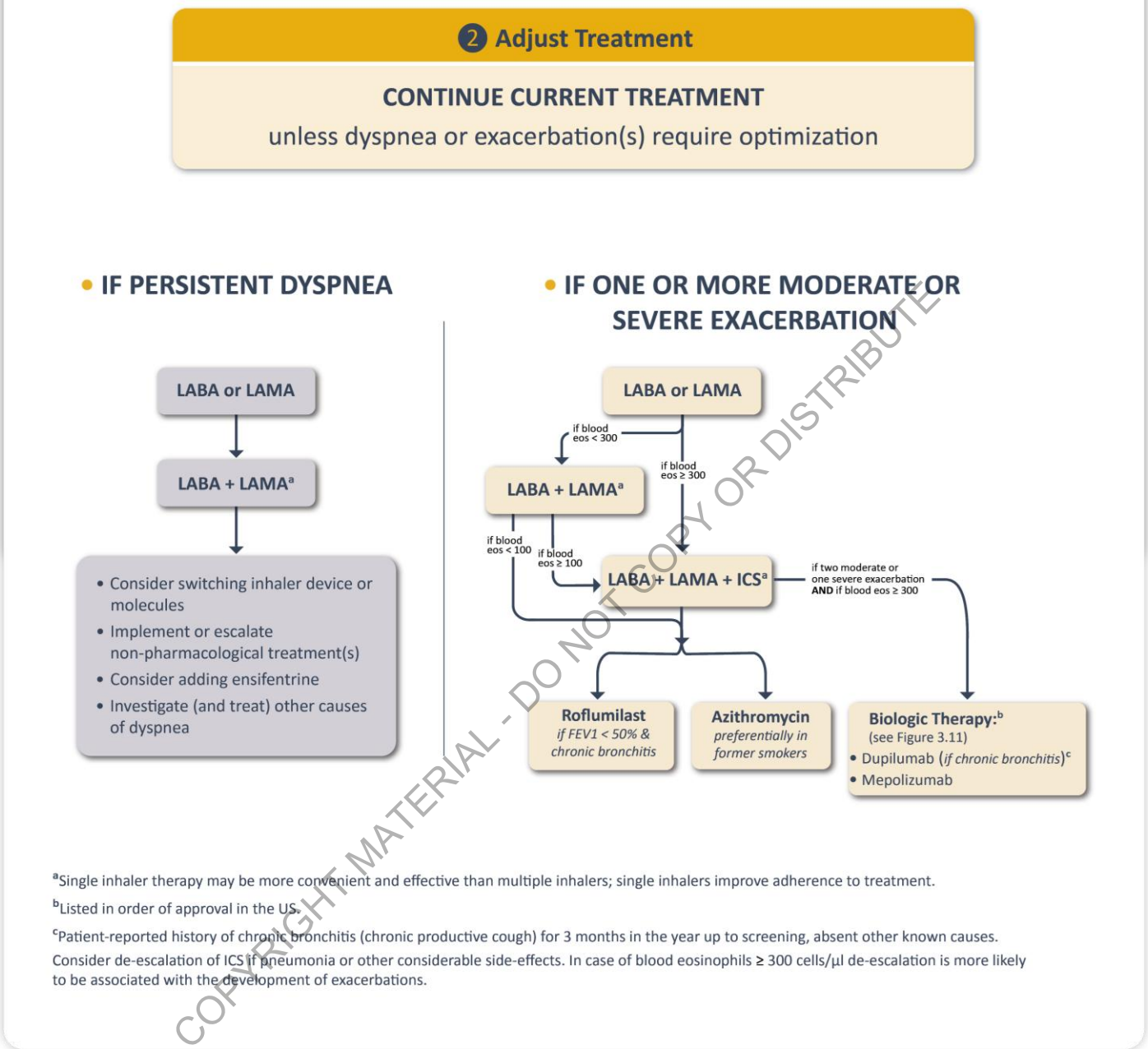


*Single inhaler therapy may be more convenient and effective than multiple inhalers; single inhalers improve adherence to treatment

Exacerbations refers to the number of exacerbations per year; eos: blood eosinophil count in cells per microliter; mMRC: modified Medical Research Council dyspnea questionnaire; CAAT™: Chronic Airways Assessment Test™.

Follow-up Pharmacological Treatment

Figure 3.9



[a]Single inhaler therapy may be more convenient and effective than multiple inhalers; single inhalers improve adherence to treatment.

[b]Listed in order of approval in the US.

[c]Patient-reported history of chronic bronchitis (chronic productive cough) for 3 months in the year up to screening, absent other known causes.

Consider de-escalation of ICS if pneumonia or other considerable side-effects. In case of blood eosinophils ≥ 300 cells/µl de-escalation is more likely to be associated with the development of exacerbations.

Patients should be reviewed after a suitable interval (shorter in patients with more severe disease, and longer in patients with less severe disease) and their current level of symptoms (using either the CAAT™ 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, 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 initial and follow-up pharmacological treatment

Further information on the evidence that underpins these recommendations is given later in **Appendix 3 "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 3.8**. It is an attempt to provide clinical guidance. There is no high-quality evidence such as RCTs to support initial pharmacological treatment strategies in newly diagnosed individuals with COPD.

Group A

► All patients in group A 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 CAAT™ ≥ 10 LABA+LAMA is superior to a LAMA with regard to several endpoints.[677] 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.

► Patients in group B 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.[678,679]

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 exacerbations.[680] Therefore, provided there are no issues regarding availability, cost and side-effects LABA+LAMA is the preferred choice for initial therapy of patients in group E.

► 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.[467,492]

► Consider LABA+LAMA+ICS as initial therapy in group E if eosinophil counts are ≥ 300 cells/µL (practical recommendation). As detailed later in this chapter, the effect of ICS on exacerbation prevention is correlated to blood eosinophil count (**Figure 3.10**). 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 (≥ 300 cells/µL).

► 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.

Follow-up pharmacological management

Following implementation of therapy, patients should be reassessed for attainment of treatment goals and identification of any barriers for successful treatment (**Figure 3.7**). 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 3.7**):

► **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 later 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.

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**).[453,681-683] 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 in **Appendix 3**).

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. This 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 primarily target 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,[684] the use of a LABA plus a LAMA is recommended.

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

- 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 who have an exacerbation on ***bronchodilator*** monotherapy, escalation to LABA+LAMA is recommended.

► In patients who have a moderate or severe exacerbation on **LABA+LAMA** therapy we suggest escalation to **LABA+LAMA+ICS** (**Figure 3.10**). 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.[467]

► 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.[685,686] 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 a prior exacerbation resulting in hospitalization, consider adding roflumilast.[687-689]

► 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 patients with blood eosinophils ≥ 300 cells/µL, consider adding dupilumab (if chronic bronchitis) or mepolizumab (with and without chronic bronchitis) (**Figure 3.11**).[681,682,690,691]
- Among those who are not currently smoking, consider adding azithromycin.[685,686] 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.[687-689]

► Patients treated with **LABA+LAMA+ICS** should not have the ICS component withdrawn unless the ICS was started inappropriately, there has been no response to ICS or 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.[692,693]

Factors to Consider when Initiating ICS Treatment

Figure 3.10

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 3.8 & A3.1 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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Evidence Supporting Use of Biologics in the Treatment of COPD

Figure 3.11

Molecule/RCT*	Key inclusion criteria[a]	Annualized rate of moderate/severe exacerbations	Lung function improvement (pre-BD FEV1)[d]	Quality of life improvement (SGRQ)
Dupilumab (300 mg/2 weeks)				
BOREAS[1] (n=939)	FEV1 post-BD 30-70% chronic bronchitis[b] eos ≥ 300 (screen)	RR 0.70; P < 0.001	83mL; P < 0.001 (95% CI: 42, 125)	-3.4; P = 0.002 (95% CI: -5.5, -1.3)
NOTUS[2] (n=935)	FEV1 post-BD 30-70% chronic bronchitis[b] eos ≥ 300 (screen)	RR 0.66; P < 0.001	62mL; P = 0.02 (95% CI: 11, 113)	-3.4[e] (95% CI: -5.8, -0.9)
Mepolizumab (100 mg/4 weeks)				
METREO[3] (n=674)	FEV1 post-BD 20-80% eos ≥ 150 (screen) or eos ≥ 300 (previous year)	RR 0.80; NS	19mL; NS (95% CI: -29, 67)	-1.8; NS (95% CI: -4.5, 0.8)
METREX[3] (n=836)	FEV1 post-BD 20-80% eos ≥ 150 (screen) or eos ≥ 300 (previous year)[c]	RR 0.82; P = 0.04	-10mL; NS (95% CI: -54, 33)	0.2; NS (95% CI: -2.8, 3.2)
MATINEE[4] (n=804)	FEV1 post-BD 20-80% eos ≥ 300 (screen) and eos ≥ 150 (previous year)	RR 0.79; P = 0.01	-9.0mL; NS (95% CI: -60.1, 42.1)	-2.3; NS (95% CI: -4.6, 0.1)

*Molecules are listed in order of approval in the US.

These results cannot be directly compared across trials as there were different patient populations included.

a: all studies recruited patients with exacerbations in the previous year while receiving inhaled triple therapy
b: patient-reported history of chronic bronchitis (chronic productive cough) for 3 months in the year up to screening, absent other known causes
c: pre-defined eosinophilic population
d: at 52 weeks
e: significance not tested according to hierarchical testing procedure

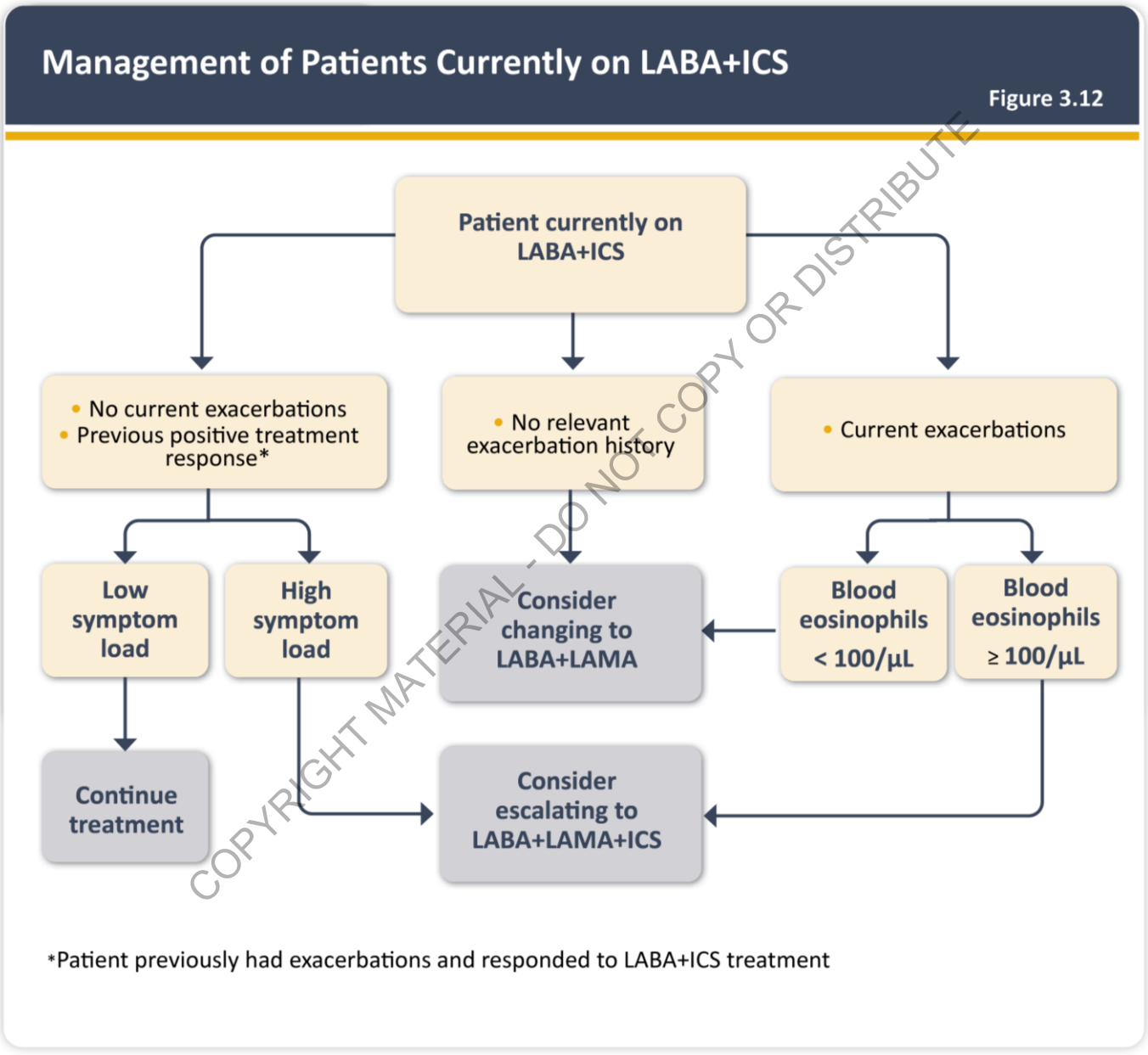
NS: not statistically significant; eos: blood eosinophils (cells/μL); SGRQ: St George's Respiratory Questionnaire; BD: bronchodilator; RR: risk ratio.

References: [1]Bhatt et al. N Engl J Med 2023;389:205-214; [2]Bhatt et al. N Engl J Med 2024;390:2274-2283; [3]Pavord et al. N Engl J Med 2017;377:1613-1629; [4]Sciurba et al. N Engl J Med 2025;392:1710-1720; .

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 3.12**). 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.[467,694]
- **Major symptoms:** change to LABA+LAMA or LABA+LAMA+ICS depending on previous treatment response to ICS (**Figure 3.12**).[695]



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 3.13**).

Key Points for Inhalation of Drugs

Figure 3.13

- 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 more than 30 different inhaled therapies containing different bronchodilators (both short- and long-acting) and ICS alone or in combinations (**Figure A3.1**). In addition, more than 20 different inhaler devices are available,[696] including nebulizers, pMDIs used with or without VHC/spacers, BAIs, SMIs, and DPIs.[697] In multi-dose DPIs, the powder is contained in a reservoir or in individual blisters.[697] More information about inhalation devices is available on the Asthma + Lung UK website.[698]

Devices differ in their size and portability. They also differ in the number of steps required to prepare them,[699] in the force needed to load or actuate them,[700] in the time taken to deliver the drug, and in the need for cleaning and maintenance, as well as in the inspiratory maneuver required to use them effectively.[697] Increased steps reduces the ease of use and likelihood that patients use the inhaler correctly.[701] 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.[702] The proper use of an inhaler has a positive environmental impact through the reduction of exacerbations and their CO_2 footprint (especially when hospitalization is required).[702] 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[703] and can provide objective data on adherence and technique.[704,705]

Particles > 5 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).[697] 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.[697,706] pMDIs 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[707,708] or switch to a pMDI+/-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.[709]

RCTs 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.[697] 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.[710]

Ability to use delivery system correctly

Specific instructions are available for each type of device.[697,698] On average more than two thirds of patients make at least one error in using an inhalational device.[711-714] 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.[715-721] 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.[722]

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.[712,723] Poor inhaler technique and errors using devices are more common with advancing age,[724] but this is likely to be mainly due to cofounders such as cognitive impairment or reduced manual dexterity.[725,726] 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.[700] 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.[700] Tremor may result in shaking of the device and loss of the dose.[727]

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 few older patients using a pMDI and VHC find them easy to use compared to a pMDI alone.[728] Currently available VHCs range in volume from < 50 mL to 750 mL[729] but VHC with volumes from 150 mL to 250 mL have been shown to be as effective as those with larger volumes[730] 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.[697]

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.[701] Using the "teach-back" approach (patients being asked to show how the device has to be used) appears to be particularly effective.[731] Pharmacist-, physician-, physiotherapist- and nurse-led interventions[732] as well as lay health coaching[733] can improve inhalation technique and adherence in patients with COPD. As in asthma, digital inhalers could contribute to improved adherence and inhaler technique in patients with COPD.[734]

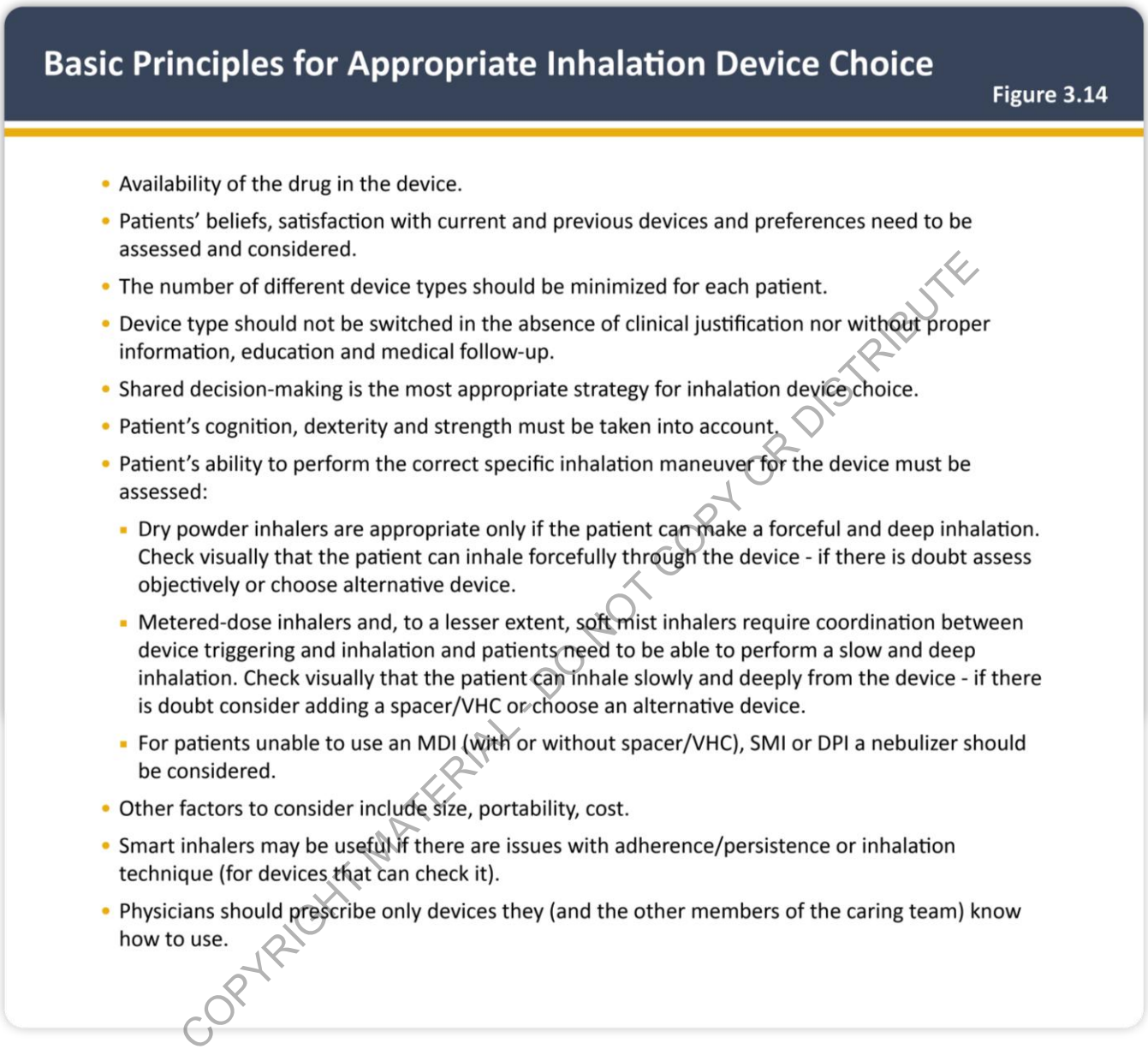
Choice of inhaler device

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. Once a device has been selected and prescribed it should not be changed without clinical justification. Mass switching of devices for cost or supply reasons driven by payors, or even for perceived impact of particular devices on

the environment, without retraining patients to use the new device and ensuring that they can do so, has led to increased prednisolone use and higher healthcare utilization.[735]

Figure 3.14 summarizes the main principles that should be considered to guide the individualized selection of the appropriate device for a given patient.



Appropriate education must be provided by healthcare professionals, including physical, or video-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 COPD

Non-pharmacological treatment is complementary to pharmacological maintenance 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, promote physical activity, prescribe vaccinations, and refer patients to pulmonary rehabilitation. Further information on the evidence that underpins these recommendations is given later in **Appendix 4 "Overview of the evidence: Non-pharmacological therapy"**.

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

Some relevant non-pharmacological measures based on the patient's GOLD A, B, or E group **AT DIAGNOSIS** are summarized in **Figure 3.15**.

Non-Pharmacological Management of COPD*

Figure 3.15

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 3.16**).

Follow-up of Non-Pharmacological Treatment

Figure 3.16

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	EXACERBATIONS
• 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	• 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

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."[674,736] Recently the WHO described a package of interventions for rehabilitation for patients with COPD.[737] This document follows a resolution of WHO that advocates to make pulmonary rehabilitation (as well as other forms of rehabilitation) universally available for patients with COPD.[738]

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 (including extra-pulmonary features such as skeletal muscle dysfunction and exercise intolerance) and comorbidities.[674,739,740] This includes patients who are older, female,

more deprived, or have a comorbidity of diabetes, asthma, or a painful condition, who currently appear less likely to be referred for pulmonary rehabilitation.[741]

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.[739] 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.[742] 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.[742] If a center based pulmonary rehabilitation program is complimented with a physical activity promotion program, clinically significant improvements in physical activity are observed.[743,744] The importance of long-term behavior change to improve physical functionality, and reduce the psychological impact of COPD, should be emphasized to the patient.[745]

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 including health behaviors
- Measurement of post-bronchodilator spirometry
- Assessment of (functional) exercise capacity
- Measurement of health status and impact of breathlessness and fatigue
- Assessment of inspiratory and expiratory muscle strength and lower limb strength in patients who suffer from muscle wasting
- Discussion about individual patient goals, problematic activities of daily living, and expectations and knowledge about the disease

The first two assessments are important for establishing entry suitability and baseline status but are not used in outcome assessment. Most of these were included in a recent consensus around “core outcomes” for pulmonary rehabilitation.[746]

Exercise capacity 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., 6MWD) 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.[747] Walking tests 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 CAAT™, CRQ or SGRQ. The HADS[748] and the PRIME-MD patient questionnaire[749] have been used to improve identification and treatment of anxious and depressed patients.

Oxygen therapy and ventilatory support

Oxygen therapy

The long-term administration of oxygen (> 15 hours per day; LTOT) is indicated for patients with stable COPD 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%).

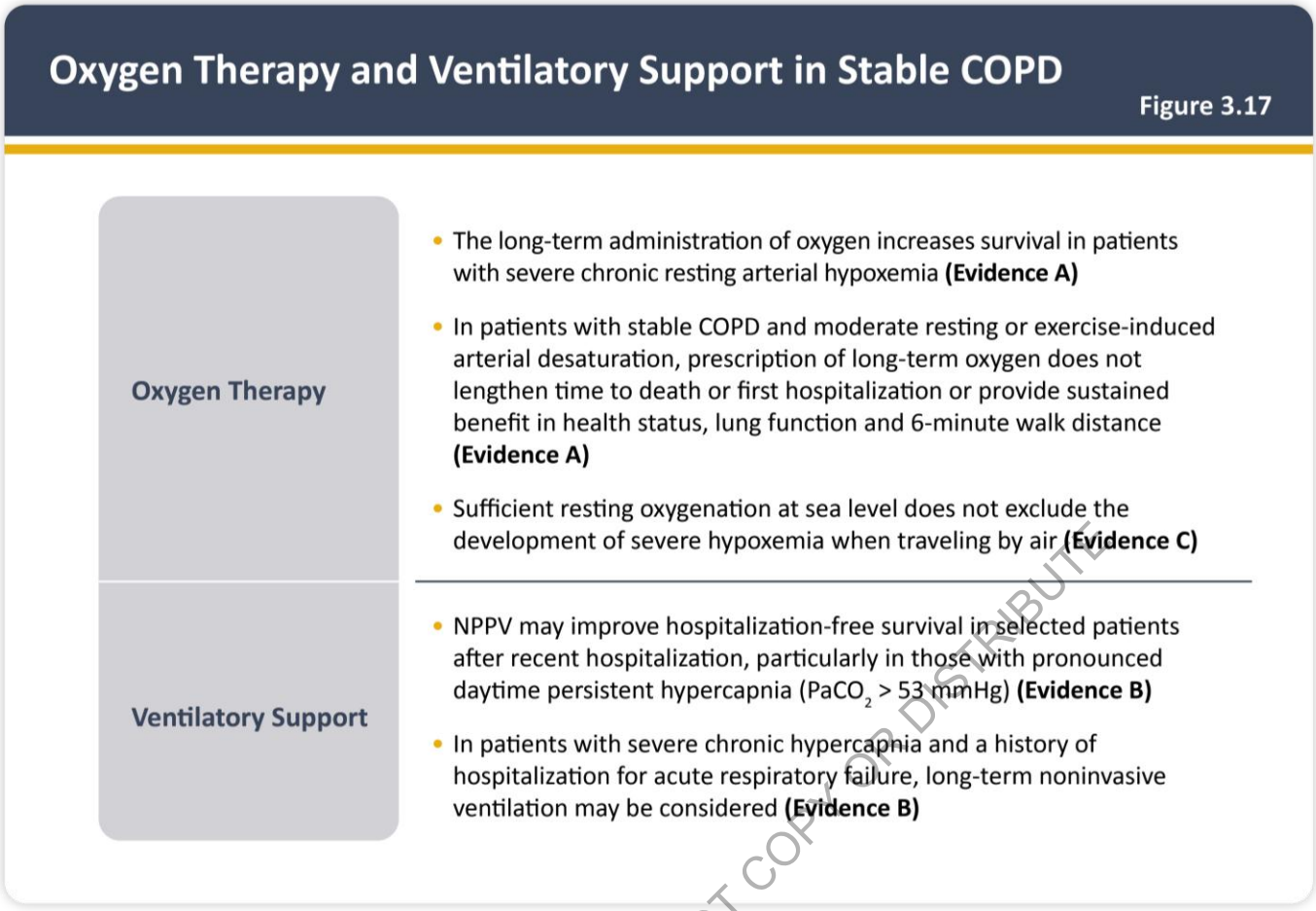
LTOT has been shown to increase survival in patients with severe resting hypoxemia.[750]

Ekström and colleagues[751] reported that among patients with severe hypoxemia agreeing to participate in a study, LTOT 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. Thus, the recommendation to use oxygen > 15 hours per day is not supported by newer evidence.

In patients with moderate resting or exercise-induced arterial oxygen desaturation LTOT does not lengthen time to death or first hospitalization, or provide sustained benefit for any of the measured outcomes.[752] Breathlessness may be relieved in patients with COPD 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 3.17**).[752-754] There are contradictory studies although the majority do not demonstrate changes.[755]

Oxygen Therapy and Ventilatory Support in Stable COPD

Figure 3.17

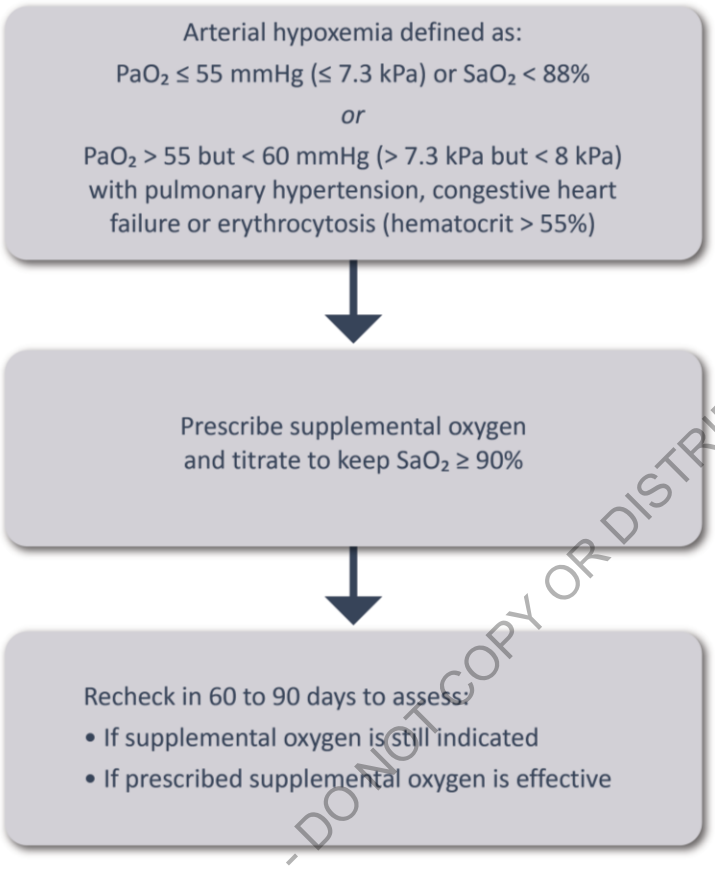


Although air travel is safe for most patients with chronic respiratory failure who are on LTOT,[756] patients should ideally maintain an in-flight PaO_2 of at least 6.7 kPa (50 mmHg). Studies indicate that this can be achieved in those with moderate to severe hypoxemia at sea level by supplementary oxygen at 3 liters/min by nasal cannula or 31% by Venturi facemask.[757] Those with a resting oxygen saturation > 95% and 6MWD oxygen saturation > 84% may travel without further assessment,[758] although it is important to emphasize that resting oxygenation at sea level does not exclude the development of severe hypoxemia when travelling by air.[756] 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 of the airplane may profoundly aggravate hypoxemia.[759]

Once placed on LTOT the patient should be re-evaluated after 60 to 90 days with repeat 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 patients with COPD is shown in **Figure 3.18**.

Prescription of Supplemental Oxygen to Patients with COPD

Figure 3.18



Ventilatory support

Chronic NIV may be 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.[760] In contrast, in patients with both COPD and obstructive sleep apnea there are clear indications for CPAP.[761,762]

In patients with comorbid COPD and obstructive sleep apnea there are clear benefits associated with the use of CPAP to improve both survival and the risk of hospital admissions.[761,762]

Whether to use NPPV chronically at home to treat patients with acute or chronic respiratory failure following hospitalization remains undetermined and outcome may be affected by persistent hypercapnia.[763] A multicenter prospective RCT of patients with COPD who had persistent hypercapnia ($PaCO_2 > 53$ mmHg) 2-4 weeks after hospital discharge following an acute exacerbation compared the effects of home NIV plus oxygen versus home oxygen alone on time to readmission or death.[763] Adding home NIV to oxygen therapy significantly prolonged the time to readmission or death within 12 months.[763] 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 $PaCO_2$) remain unclear.[764]

Two retrospective studies[765,766] and two of three RCTs[763,767-770] reported reductions in re-hospitalization and improved survival with using NPPV post-hospitalization. Two of these studies reported decreases in mortality and

hospitalization rates while another showed no benefit of NPPV for survival.[768] Several factors may account for these discrepancies: differences in patient selection, underpowered studies, NPPV settings incapable of achieving adequate ventilation, and poor adherence with NPPV therapy.[771] NPPV when indicated should be instituted and monitored by personnel familiar with the process and the devices utilized.[772,773]

A meta-analysis suggested that in patients with chronic hypercapnic respiratory failure long-term treatment with HFNT may reduce acute exacerbations and improve SGRQ scores compared to standard care, but its effect on mortality and hospitalizations is uncertain.[774,775]

THERAPEUTIC INTERVENTIONS THAT REDUCE COPD MORTALITY

As we move towards targeting subgroups of patients with COPD 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 exacerbations, , and those with lower FEV1 (particularly FEV1 < 50% predicted).[776] 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 3.19** presents a summary of pharmacological and non-pharmacological therapies with evidence of efficacy in reducing the mortality of patients with COPD.

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

Figure 3.19

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 *cor pulmonale* 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$_2$-agonist; LABD: long-acting bronchodilator; LAMA: long-acting muscarinic antagonist; 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, an RCT that included patients with asymptomatic or mildly symptomatic COPD 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.[777]

Pulmonary rehabilitation. A systematic review of RCTs reported a reduction in mortality for patients who had pulmonary rehabilitation initiated during hospitalization or 4 weeks after discharge compared to those who did not have pulmonary rehabilitation.[778-781] 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 pulmonary rehabilitation within 90 days of discharge, while rare, was associated with a statistically significant reduced mortality.[782]

Long term oxygen therapy. The 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 (≥ 19 hours of continuous oxygen compared to ≤ 13 hours)[783] and a Medical Research Council trial (≥ 15 hours compared to no oxygen),[784] two RCTs in patients with COPD with resting $PaO_2 \leq 55$ 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.[785]

Non-invasive positive pressure ventilation. Meta-analyses[764,786] 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 that enrolled patients with marked hypercapnia and applying higher IPAP levels demonstrated a reduction of mortality.[768,787]

Lung transplantation and lung volume reduction surgery. Due to the absence of randomized trials, observational data have 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 40% of patients with COPD following transplantation.[788]

LVRS has been shown to prolong survival compared to medical therapy in a very select group of patients with severe emphysema, predominantly upper lobe emphysema, and low exercise capacity post-rehabilitation.[789] 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.

Pharmacological therapy

Previous studies such as TORCH[790] and SUMMIT[791] failed to provide evidence for the efficacy of a LABA+ICS combination compared to placebo in reducing mortality (primary outcome) in patients with COPD. 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.

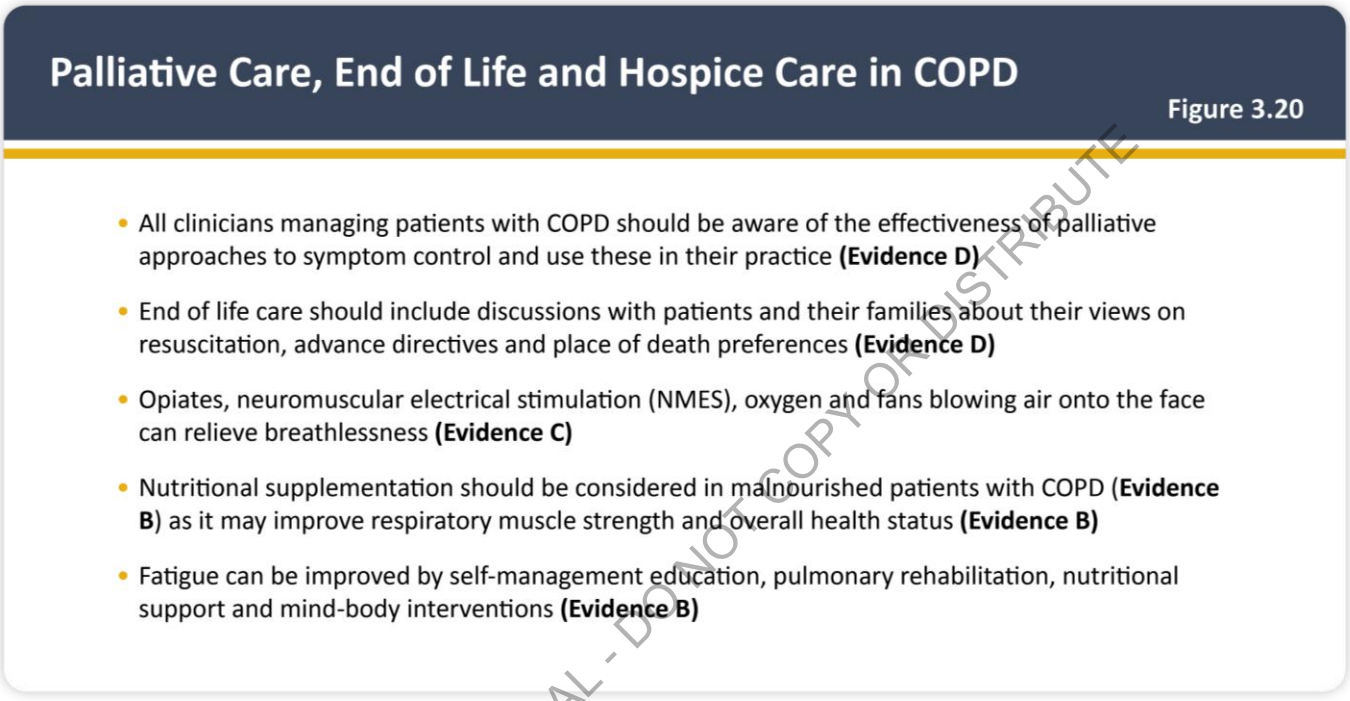
Evidence has emerged from two large randomized clinical trials, IMPACT[467] and ETHOS,[492] that fixed-dose inhaled triple combinations (LABA+LAMA+ICS) reduce all-cause mortality compared to dual inhaled LABD therapy. Together these results suggest a beneficial effect of fixed-dose triple inhaled therapy versus fixed-dose LABA+LAMA combinations on mortality in patients with symptomatic COPD who have a history of frequent and/or severe exacerbations, and 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 (CAAT™ ≥ 10) with a history of frequent (≥ 2 moderate exacerbations) and/or severe exacerbations (≥ 1 exacerbation requiring a hospital admission) (**Figure 3.19**).

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.[792] 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.[793,794] 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.[792] 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.[795] 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.[794] Key points for palliative, end-of-life and hospice care in COPD are summarized in **Figure 3.20**.



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.[796] 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, HFNT and NIV for palliation of dyspnea are debated.[797]

Opiates,[798-800] neuromuscular electrical stimulation,[800,801] chest wall vibration,[800] and fans blowing air onto the face[800,802,803] can relieve breathlessness. Morphine may improve health status in patients with COPD,[309] and no worsening in sleepiness was reported in one study when used for breathlessness in COPD.[804] Immediate-release morphine extended exercise endurance time in over half of the patients with advanced COPD in one study.[309] 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 scores of 3 or 4.[805] Further research is required to determine

what patient characteristics predict response to opioid therapy,[806] however one cross-sectional study found greater benefit in those with worse baseline dyspnea and higher BMI.[807] The optimal formulation and administration route remain under discussion.[800,808]

Oxygen may offer some benefit even if the patient is not hypoxemic (SpO_2 > 92%) (**Figure 3.17**).[809] 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.[402,810] Refractory dyspnea may be more effectively managed with a multidisciplinary integrated palliative and respiratory care service.[811]

There is no evidence for a beneficial effect of benzodiazepines[812] and there are not enough data to recommend distractive auditory stimuli (music), relaxation, counseling and support, with or without breathing relaxation training, or psychotherapy.[813]

Nutritional support

Low BMI and particularly low fat-free mass is associated with worse outcomes in people with COPD.[814] 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.[815] 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 6MWD, respiratory muscle strength and health status.[816] A 12-month nutritional intervention in muscle wasted patients had no effect on physical capacity but physical activity was significantly higher.[817]

Panic, anxiety & depression

The causes of depression and anxiety symptoms in people with COPD are multifactorial and include behavioral, social and biological factors.[818] 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.[819]

Fatigue

Fatigue in people with COPD can be improved by self-management education, pulmonary rehabilitation, nutritional support and mind-body interventions.[820]

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.[821] Although mortality rates following hospitalization for an acute exacerbation are declining,[822] reported rates still vary from 23%[823] to 80%.[824] Progressive respiratory failure, cardiovascular diseases, malignancies and other diseases are the primary cause of death in people with COPD hospitalized for an exacerbation.[824] 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.[825] 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,

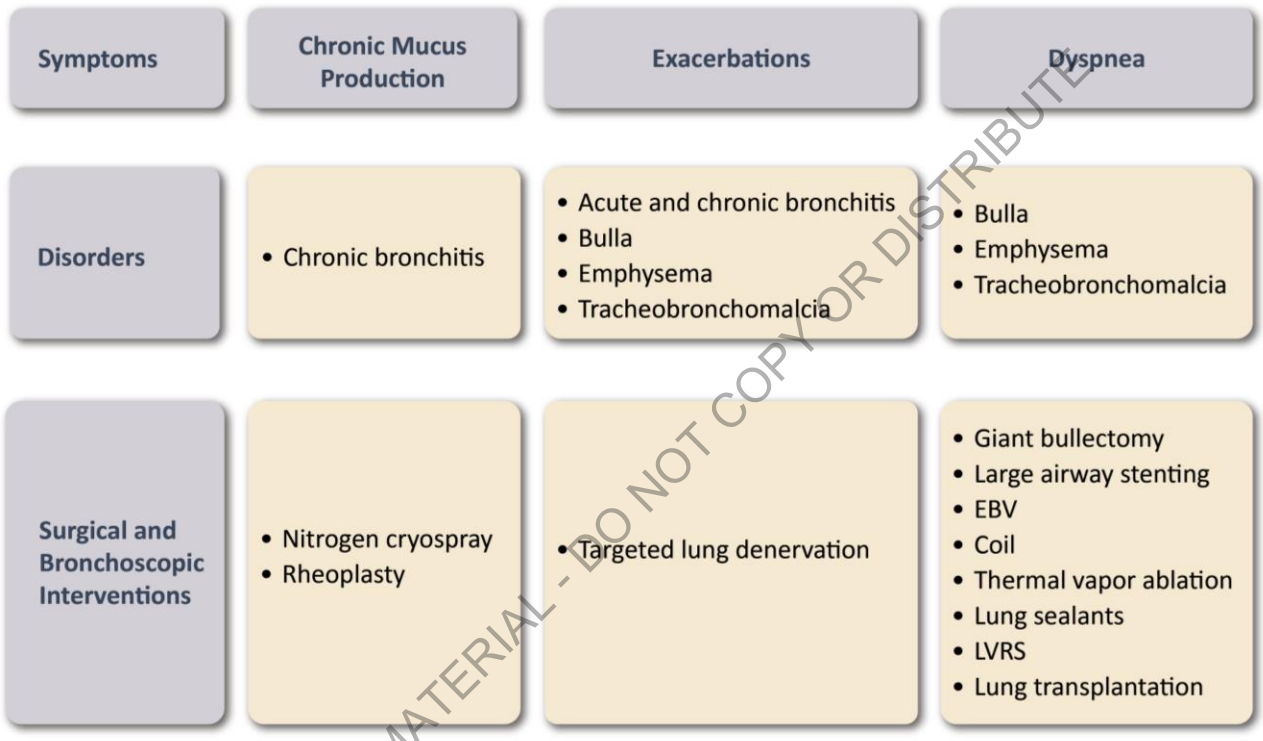
advance directives and place of death preferences.[826] At an individual level, prediction of 6-month survival in people with COPD is unreliable and therefore early discussion of these issues is important together with phased introduction of supportive care.[827] Hospitalization may be a trigger to initiate 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.[828] 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.[829,830]

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[831] 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).[793,794] 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.[792]

INTERVENTIONAL & SURGICAL TREATMENTS 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 3.21**).

Overview of Current and Proposed Surgical and Bronchoscopic Interventions for People with COPD Figure 3.21



Lung structural related therapies 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.

Key points for interventional therapy in stable COPD are summarized in **Figure 3.22**.

Interventional Therapy in Stable COPD

Figure 3.22

Lung Volume Reduction Surgery	• Lung volume reduction surgery improves survival in patients with severe emphysema who have an upper-lobe and low post-rehabilitation exercise capacity **(Evidence A)**
Bullectomy	• In selected patients, bullectomy is associated with decreased dyspnea, improved lung function and exercise tolerance **(Evidence C)**
Transplantation	• 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 ($PaCO_2$ > 50 mmHg); (2) pulmonary hypertension and/or cor pulmonale, despite oxygen therapy; or (3) FEV1 < 20% and either DLco < 20% or homogenous distribution of emphysema **(Evidence C)**
Bronchoscopic Interventions	• 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	• 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

Lung surgical treatments for patients with emphysema

Bullectomy

Giant bullectomy is a rare, but effective procedure for surgical resection of bulla that occupies more than 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.[832-834] Blood or thrombin instillation may be effective in those unfit for resection.[835-837]

Lung volume reduction surgery

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,[838] and increase lung elastic recoil pressure and density.[839] The structural changes that result from LVRS can significantly improve expiratory flow and chest wall, respiratory muscle and cardiac mechanics.[840,841] This results in improvements in FEV1, walking distance and quality of life.[842-845] LVRS can be performed unilaterally or bilaterally. In NETT, a RCT that

included patients with severe emphysema, bilateral LVRS improved survival in patients with upper-lobe emphysema and low post-rehabilitation exercise capacity.[789] 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.[846]

LVRS has been demonstrated to result in higher mortality than medical management in patients with severe emphysema who have FEV1 ≤ 20% predicted and either homogeneous emphysema on HRCT or a DLco ≤ 20% of predicted.[847] In addition to a lower DLco, a lower FEV1 and BMI values have also been reported to increase mortality.[848] Decreasing to a lower postoperative BODE is a predictor of improved survival following LVRS.[849] 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.[850] Identification of target zones using three-dimensional computed tomographic imaging is beneficial in selecting resectable target zones.[851] A prospective economic analysis in NETT indicated that LVRS is costly relative to healthcare programs that do not include surgery.[852]

Post NETT, experienced centers have reported substantial physiological and functional improvements with LVRS, accompanied by reduced morbidity and mortality.[853,854] However, the numbers of patients undergoing LVRS remain low worldwide.[854,855] 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.[856] 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.[857] To achieve successful outcomes, a multidisciplinary team is key to select potential patients for LVRS and coordinate postoperative care.[858]

Lung volume reduction surgery

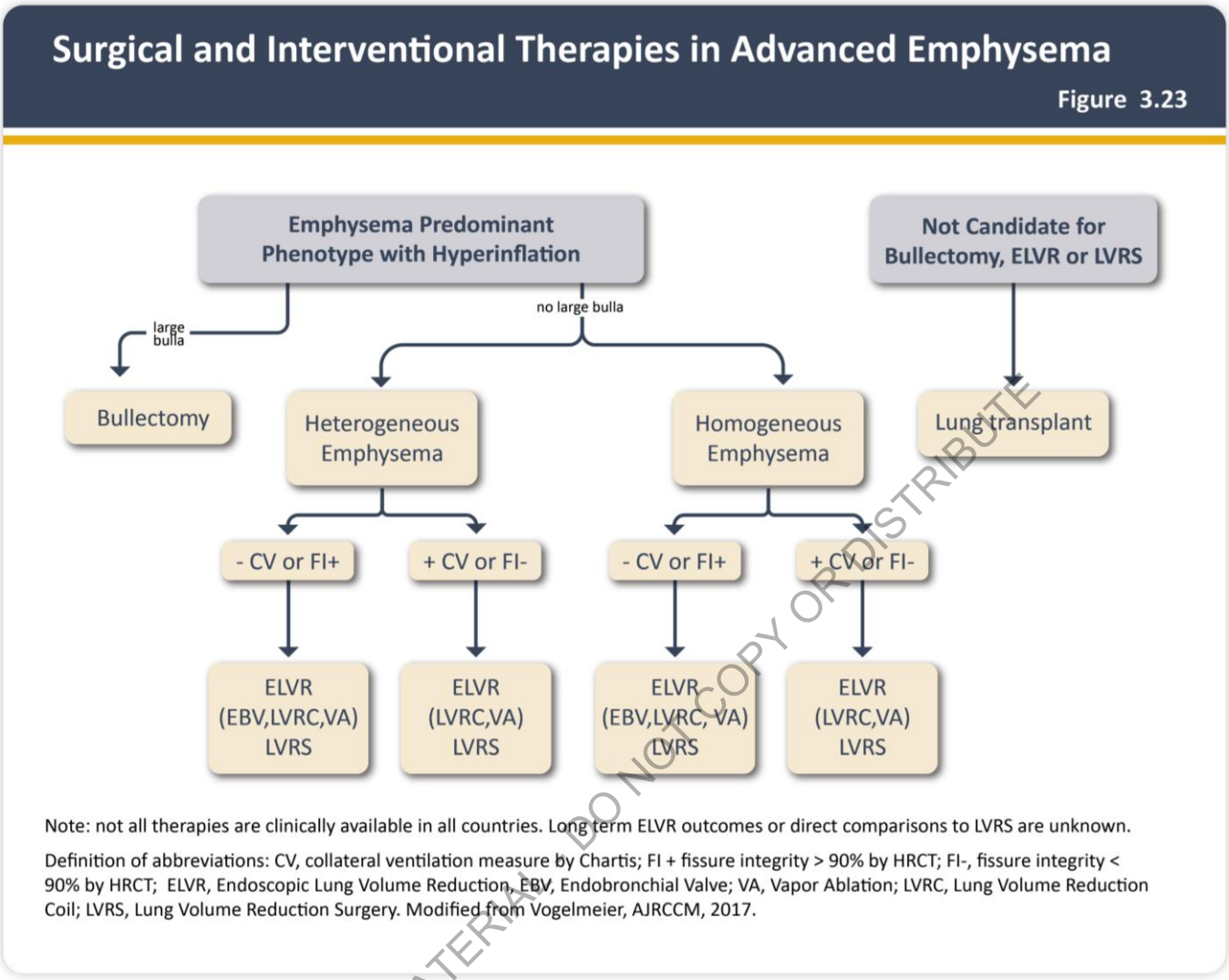
- In selected patients with heterogeneous or homogenous emphysema and significant hyperinflation refractory to optimized medical care, surgical or bronchoscopic modes of lung volume reduction (e.g., endobronchial one-way valves, lung coils or thermal ablation) may be considered.[859] Some of these therapies (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 COPD who have very severe airflow obstruction, and who do not have 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.[860] These include a variety of different bronchoscopic procedures to perform lung volume reduction (i.e., ELVR) including airway bypass stents, EBV, self-activating coils, sealants and thermal ablative techniques.[860] 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 (EBV, coil placement or thermal ablation) or surgical resection (LVRS) to treat hyperinflation in a patient with emphysema 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.[861] **Figure 3.23** provides an overview of the various interventional and surgical options for patients with emphysema.



Endobronchial one-way valves

EBV are the most well studied therapy of all the ELVR techniques. RCTs showed significant increases in FEV_1 and 6MWD 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.[528,862] Adverse effects in the endobronchial valve treatment group in both studies included pneumothorax, valve removal or valve replacement.[528] Pneumothorax was seen in 26.6% of subjects treated with the endobronchial valve usually within the first 72 hours of the procedure (76%).[862-864] But benefits have also been shown in patients with heterogeneous compared to those with homogenous emphysema in one study.[528]

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.[865] Pleural adhesions may also be a contributing factor to the development of a pneumothorax.[866] The occurrence of pneumothorax highlights the need for physicians performing this procedure to have expertise in the management of procedural complications.[865]

After the post-procedural period, patients treated with EBV tend to have a lower number of exacerbations and episodes of respiratory failure compared to usual care. A comparison of treatment benefits and complications

associated with EBV compared to LVRS show comparable benefits with endobronchial valve treatment but with fewer complications.[862] Additionally, ELVR has similar beneficial effects whether it is performed in the upper or lower lobes.[862,865]

Improved survival has been associated with post procedural atelectasis of the treated lobe post EBV.[867-869] Improved survival has also been reported in patients with severe hyperinflation undergoing EBV compared to a matched population not undergoing ELVR.[870]

When preferences for medical treatment for patients with severe emphysema are elicited, the majority chose treatments with EBV over LVRS or continued medial therapy.[871] 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.[862,872,873]

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, 6MWD or quality of life.[874]

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.[875]

Vapor ablation

In a prospective RCT, targeted thermal vapor 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.[861,876] 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 6MWD, lung function and health status in patients with advanced homogenous and heterogeneous emphysema. Studies reported an increase in 6MWD with coil treatment compared to control and smaller improvements in FEV_1, and quality of life measured by SGRQ.[877-879] 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.[880] Major complications included pneumonia, pneumothorax, hemoptysis and exacerbations occurring more frequently in the coil group.[878] 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.[878]

Sequential performance of LVRS or ELVR and 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 patients with advanced emphysema who are hyperinflated, 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.[881-883] 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.[884-889] The incidence of postoperative bleeding requiring re-exploration and renal dysfunction requiring dialysis or the use of extracorporeal membrane oxygenation may be higher in patients undergoing lung transplantation following LVRS.[890,891] Previous ELVR has been reported to have no impact on morbidity or survival post subsequent lung transplantation but may affect microbial colonization.[891,892]

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

Excessive dynamic airway collapse or tracheobronchomalacia is a disorder of the large airways where abnormal collapsibility occurs with expiration. Commons 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.[893] Airway stenting and tracheoplasty may be beneficial in select patients.[894,895]

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.[896] After treatment, rapid regeneration of normal epithelium occurs without scarring and may potentially treat chronic bronchitis.[897]

Another novel treatment for chronic bronchitis is rheoplasty,[898] which 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 RCTs are evaluating the efficacy of these therapies.[899,900]

Lung denervation

Targeted lung denervation intends to disrupt parasympathetic nerve transmission to and from the lungs.[901,902] 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.[902-905] A Phase III multicenter sham-controlled RCT reported that lung denervation did not reduce the annualized rate of moderate and severe exacerbations compared to sham but did show an improvement in dyspnea and less decline in FVC and FEV1 and increase in residual volume.[906] Post-hoc analyses identified a subgroup with greater hyperinflation (residual volume ≥ 175% pred) and less emphysema (≤ 20% low attenuation area −950 HU) who had improvements in FEV1, CAAT™, mMRC, and TDI, together with a reduction in moderate and severe exacerbations.[906] A further study is planned in that subgroup.

Lung transplantation

Over 1,000 patients with COPD annually undergo lung transplantation, or about 30.6% of all patients that undergo transplantation.[907] Since implementation of the LAS scoring system, the numbers of patients undergoing lung transplantation for COPD has been 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 $PaCO_2$ > 50 mmHg (6.6 kPa) and/or PaO_2 < 60 mmHg (8 kPa) and FEV1 < 25%.[908] They should be considered for listing for lung transplantation when: the BODE index is ≥ 7; FEV1 is < 15% to 20%; 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.[908] 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.[909]

Lung transplantation in patients with COPD has been predominately associated with an improvement in quality of life, although not an increase in survival except for patients with COPD who have severe AATD or those severely impaired with high BODE scores.[832,910-916] The median survival following lung transplantation for COPD is 5.9 years.[907] Over 70% of lung transplants conducted in patients with COPD are double lung transplants; the remainder are single lung transplants.[917] Bilateral lung transplantation leads to longer survival in patients with COPD especially in those < 60 years of age.[918,919]

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.[920] The most frequent complications in patients with COPD after lung transplantation are acute rejection, bronchiolitis obliterans, opportunistic infections and lymphoproliferative disease.[921]

CHAPTER 4: MANAGEMENT OF EXACERBATIONS

KEY POINTS:

- An exacerbation of COPD is an acute event with symptoms worsening over a few days (up to 14 days) and characterized by increased dyspnea and/or cough and sputum that may be accompanied by tachypnea and/or tachycardia. Exacerbations are often associated with increased local and systemic inflammation caused by airway infection, pollution, or other insults to the lungs.
- Although COPD exacerbations are most frequently caused by infections (viral, bacteria) or environmental pollutants, other conditions can mimic or worsen exacerbation-like symptoms. These include pneumonia, pulmonary embolism, acute heart failure, and pneumothorax. In many patients the exact cause of an exacerbation is unknown.
- Exacerbation severity is classified as mild, moderate or severe based on the clinical characteristics of the patient, according to the Rome proposal.
- Pharmacological therapy should be started as soon as possible to prevent both complications and subsequent events. It includes:
    - SABAs, with or without short-acting anticholinergics, are recommended as the initial bronchodilators to treat moderate/severe exacerbations.
    - Systemic corticosteroids are recommended for up to 5 days in patients with moderate/severe exacerbations.
    - Antibiotics are recommended for a total of 5 days in patients with purulent sputum, prior history of lung infections, etc.
    - Methylxanthines are not recommended due to increased side effect profiles.
- High flow oxygen systems and mechanical NIV are indicated for patients with COPD and acute respiratory failure because they improve gas exchange, reduce work of breathing and the need for intubation. They also decrease hospitalization duration and improve survival.
- Maintenance therapy with LABDs should be initiated as soon as possible. In patients with ≥ 1 moderate or severe exacerbation and elevated blood eosinophil levels, the addition of ICSs to a dual bronchodilator regimen should be considered at discharge.
- Exacerbation recovery time varies, taking up to 4-6 weeks, with some patients failing to return to their pre-exacerbation functional state.
- Following an exacerbation, the management of COPD and its comorbidities should be reviewed and appropriate measures for exacerbation prevention should be implemented (see **Chapter 3**).

DEFINITION

An exacerbation of COPD is an acute event with symptoms worsening over a few days (up to 14 days) and characterized by increased dyspnea and/or cough and sputum that 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.[291]

Impact

Exacerbations of COPD are important events because they negatively impact health status, worsen airflow obstruction,[486] disease progression, rates of hospitalization and readmission, and risk of death.[442,444,922-924] COPD exacerbations are associated with increased airway inflammation, increased mucus production and marked gas trapping.[289,925] These changes contribute to increased dyspnea that is the key symptom of an exacerbation. Other important symptoms include increased sputum purulence and volume, together with worsened cough, wheeze and difficulty sleeping due to symptoms.[926] Many exacerbations are not reported to healthcare professionals, and yet these events, although often shorter in duration, also have a significant impact on health status.[927,928] The WHO has defined a minimum set of interventions for the management of exacerbations that are of use in most settings.[929]

Assessing the patient and confirming the diagnosis

The diagnosis and assessment at the point of contact with a person with COPD can be confirmed by applying a systematic approach as proposed by the Rome classification of severity and outlined in **Figure 4.1**.

Exacerbations: Diagnosis and Assessment — Figure 4.1

1.	Complete a thorough clinical assessment for evidence of COPD and potential respiratory and non-respiratory conditions, including patient's symptoms, and signs of pneumonia, cardiovascular conditions, and pulmonary embolism.
2.	**Assess:** a. Symptoms, severity of dyspnea that can be determined by using a VAS, and documentation of the presence of cough. b. Signs (tachypnea, tachycardia), sputum volume and color, and respiratory distress (accessory muscle use).
3.	Perform additional investigations, if needed and available, to evaluate severity such as pulse oximetry, laboratory assessments such as blood eosinophils, CRP, viral and bacterial studies, and arterial blood gases.
4.	Evaluate for underlying conditions such as viral or bacterial infections, environmental or cardiovascular events that mimic the exacerbation.
5.	Consider appropriate place of care.

Abbreviations: COPD = chronic obstructive pulmonary disease; CRP = C-reactive protein; VAS = visual analog scale.

COPD exacerbation severity classification

Over the last two decades, the severity of an exacerbation has been classified *post hoc* primarily based on healthcare resource utilization and the treatment implemented.[467,492,681,790,930,931] This is probably adequate in clinical trials but useless at the point of care. We are **NOW** proposing that the severity of an exacerbation (as well as its treatment and

place of care) be determined based on the clinical characteristics of the patient. The Rome classification of exacerbation severity[291] is based on a thorough review of the available literature and a modified Delphi method to determine the variables and thresholds included. We propose that the severity of COPD exacerbations should be classified as mild, moderate or severe as summarized in **Figure 4.2**:

- **Mild**
  - Dyspnea VAS < 5
  - Respiratory rate < 24 breaths/min
  - Heart rate < 95 bpm
  - Resting SaO_2 ≥ 92% breathing ambient air (or patient's usual oxygen prescription) AND change ≤ 3% (when known)
  - CRP < 10 mg/L (if available)
- **Moderate** (meets at least three of five*)
  - Dyspnea VAS ≥ 5
  - Respiratory rate ≥ 24 breaths/min
  - Heart rate ≥ 95 bpm
  - Resting SaO_2 < 92% breathing ambient air (or patient's usual oxygen prescription) AND/OR change > 3% (when known)
  - CRP ≥ 10 mg/L (if available)

  *If obtained, ABG may show hypoxemia (PaO_2 70-80 mmHg)
- **Severe**
  - Dyspnea, respiratory rate, heart rate, SaO_2 and CRP same as moderate
  - If obtained, ABG may show hypoxemia (PaO_2 ≤ 60 mmHg) and/or hypercapnia and acidosis ($PaCO_2$ > 45 mmHg and pH < 7.35)

When evaluating a patient with COPD who is complaining of acute worsening of respiratory symptoms, it is desirable to systematically evaluate the severity of the event using clinical, physiological and laboratory variables that can reflect organ decompensation and potential outcomes (**Figure 4.2**).

In hospitalized patients, the severity of the exacerbation should be based on the patient's clinical signs, and we recommend the following classification:[932]

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

Respiratory failure: Respiratory rate: > 24 breaths per minute; heart rate > 95 bpm, using accessory respiratory muscles; appropriate mental status; hypoxemia improved with supplemental oxygen via Venturi mask > 35% FiO_2; hypercapnia i.e., $PaCO_2$ increased compared with baseline or elevated 50-60 mmHg.

Ventilatory Failure: Respiratory rate: > 24 breaths per minute; heart rate > 95 bpm, using accessory respiratory muscles; acute changes in mental status; hypoxemia not improved with supplemental oxygen via Venturi mask or requiring FiO_2 > 40%; hypercapnia i.e., $PaCO_2$ increased compared with baseline or elevated > 60 mmHg and the presence of acidosis (pH ≤ 7.25).

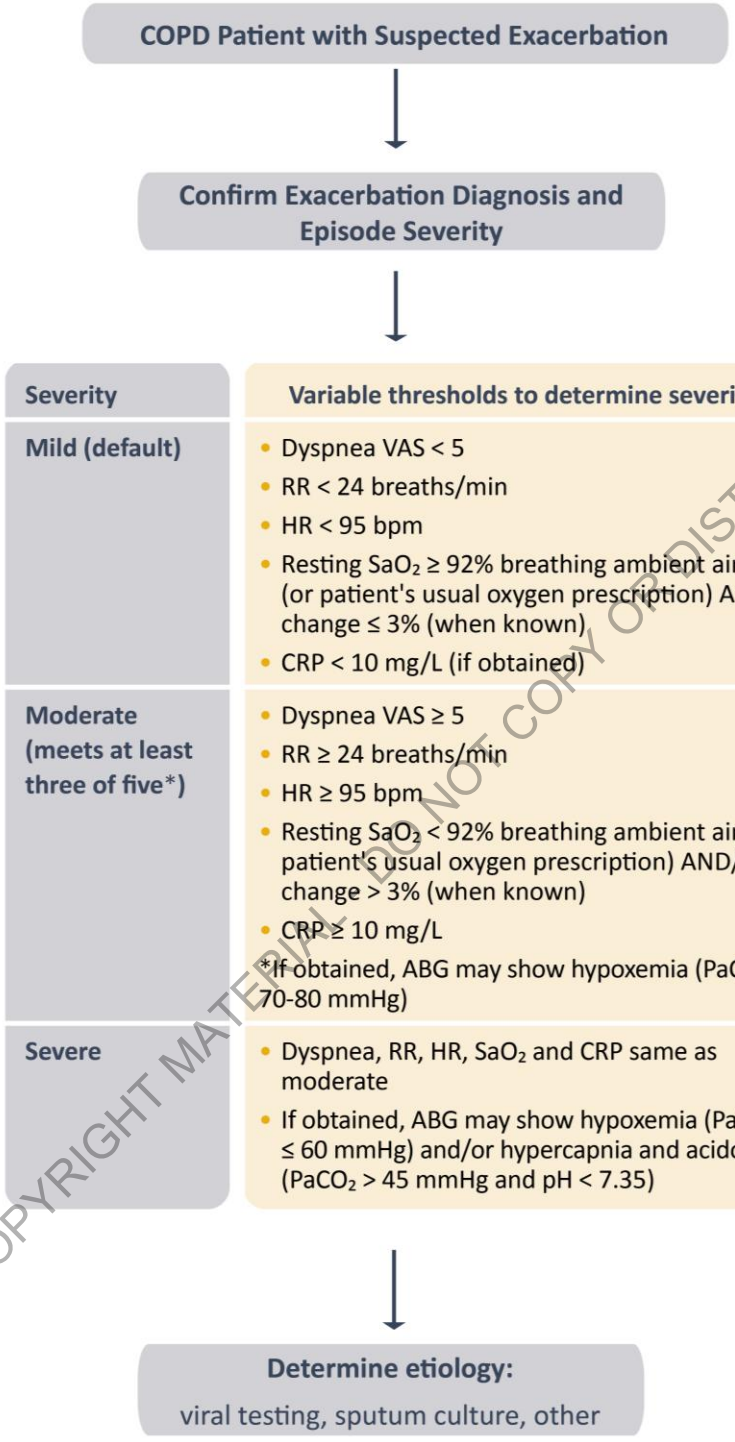
Several studies conducted in different countries have shown that the variables included in the Rome classification are routinely available in the hospital setting.[933,934] Importantly, these studies have shown that using the Rome classification 15-30% of people admitted for a COPD exacerbation classify as having a mild event, whereas using a

severity classification based on healthcare resource use they would have been classified as having had a severe event. Around 50% of those admitted had a moderate episode and close to 10% a severe episode.[933-936] Data suggest that severity of exacerbations using the Rome grading scheme correlates with prognosis, including need for intensive care admission and mortality.[933-937]

In settings where laboratory variables are not available, such as primary care, the severity of an exacerbation can be determined by quantification of dyspnea intensity using the VAS 0 to 10 dyspnea scale (where zero equates to not short of breath at all and 10 is the worst shortness of breath ever experienced), respiratory rate, heart rate and SaO_2 (**Figure 4.2**). Worsening of dyspnea in a patient with COPD, particularly if associated with cough, purulent sputum, and difficulty sleeping due to these symptoms, but no other symptoms or signs may be diagnosed as a COPD exacerbation. However, some patients may have worsening of respiratory symptoms, particularly dyspnea, but without other COPD exacerbation symptoms; this should prompt careful consideration of concomitant conditions.[487] Where available, measuring blood CRP level is also recommended.[938] To move from mild to moderate severity, 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 thresholds of included factors. It is proposed that prospective research will help determine a more specific marker of lung injury than the more generic CRP, as has been true for other organs and acute events.

Classification of the Severity of COPD Exacerbations

Figure 4.2

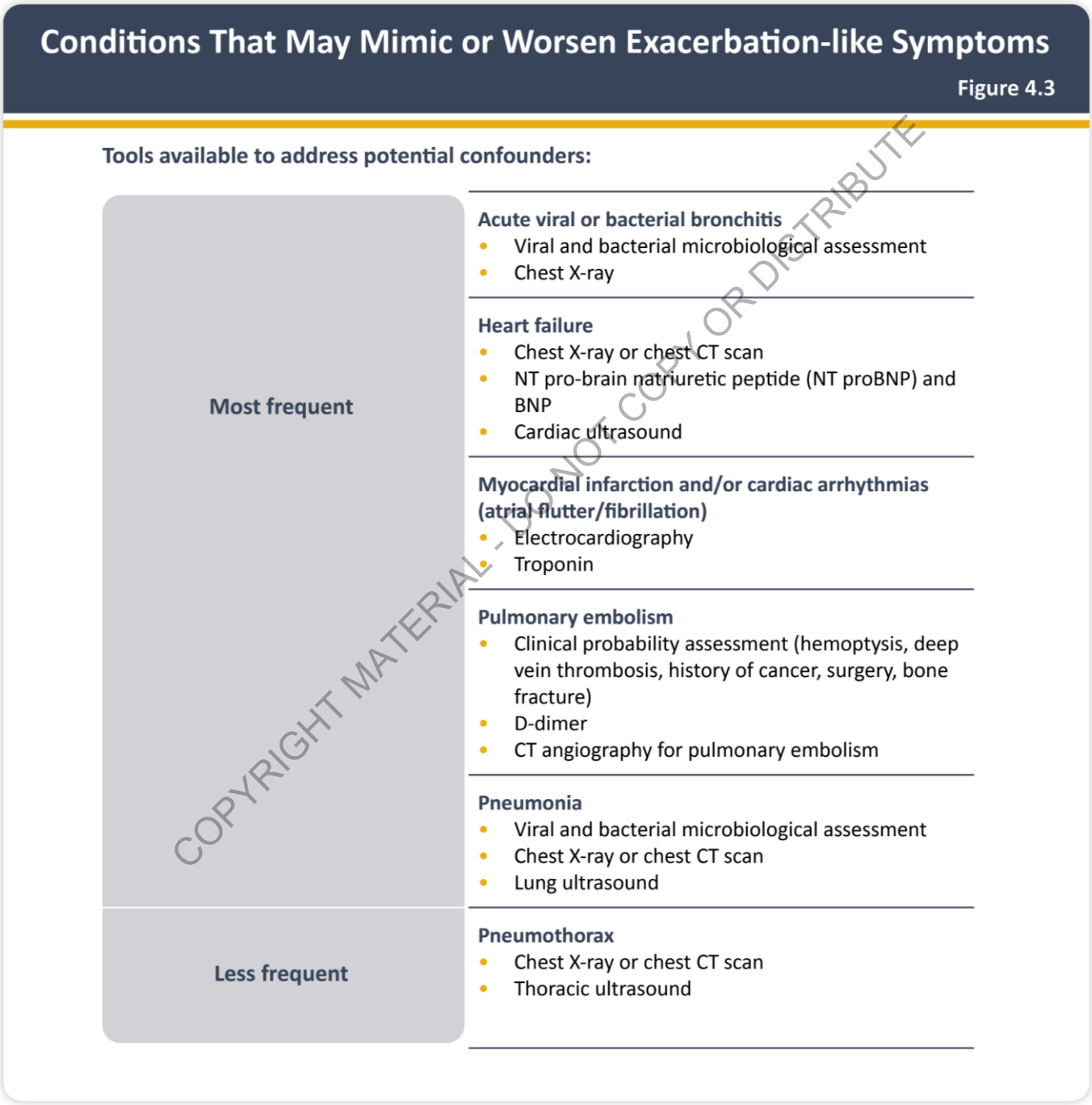


Adapted from: The Rome Proposal, Celli et al. (2021) Am J Respir Crit Care Med. 204(11): 1251-8.

Abbreviations: VAS visual analog dyspnea scale; RR respiratory rate; HR heart rate; SaO_2 oxygen saturation; CRP C-reactive protein; ABG arterial blood gases; PaO_2 arterial pressure of oxygen; $PaCO_2$ arterial pressure of carbon dioxide.

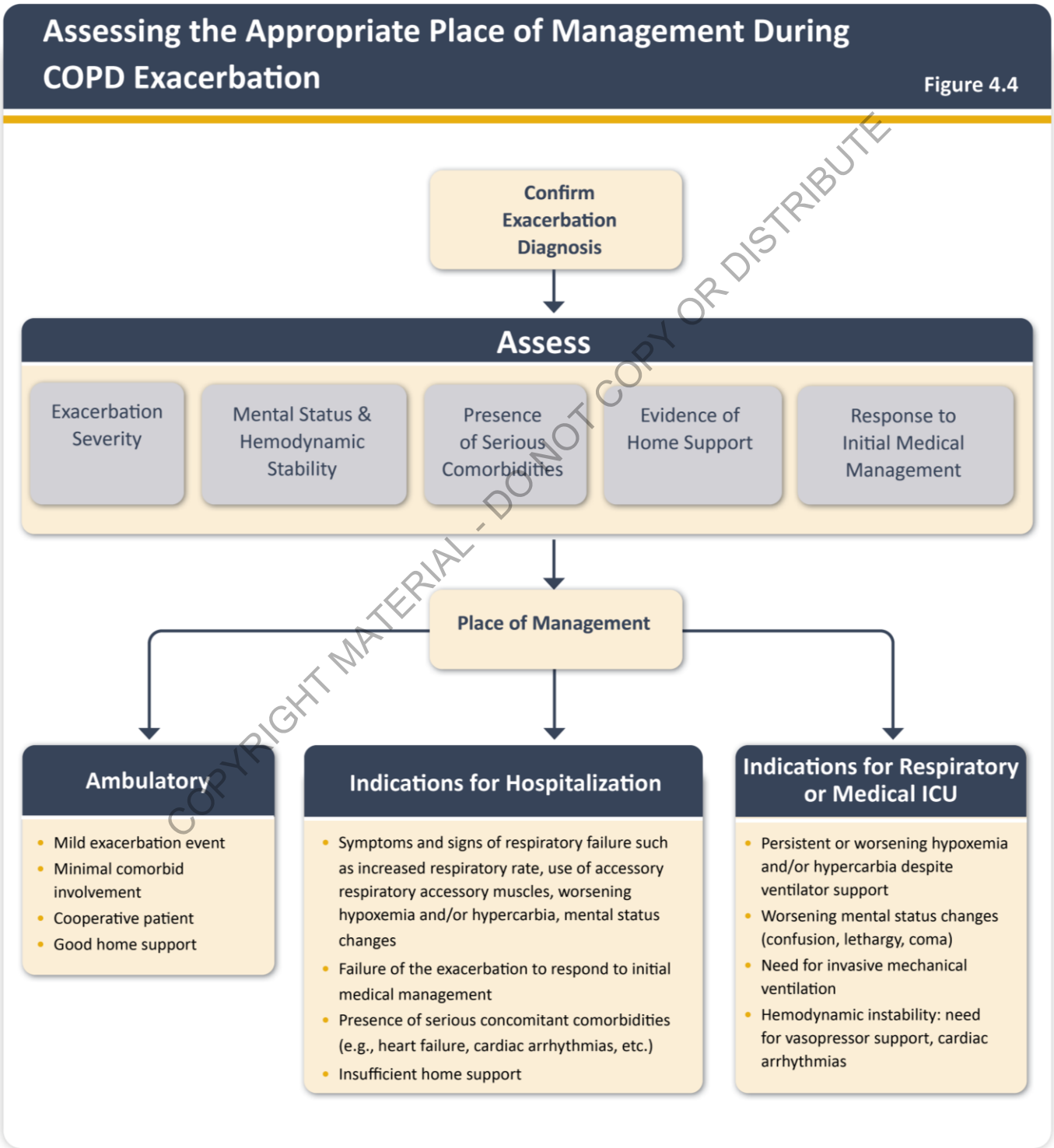
Conditions to be considered

Patients with COPD are at increased risk of respiratory viral infections;[939,940] bacterial infections;[941] pneumonia;[942-946] decompensated heart failure;[947,948] myocardial infarction and arrhythmias;[484,485,949] and pulmonary embolism.[950-952] These conditions may mimic or worsen exacerbations, particularly those requiring hospitalization, and are associated with increased risk of developing a fatal or non-fatal cardiovascular event such as heart failure, cardiac arrhythmias and/or stroke. Furthermore, the major adverse cardiovascular event risk remains elevated up to one year after the exacerbation.[484,485] In some patients, one or more conditions may contribute to the clinical presentation and should be addressed appropriately, as outlined in **Figure 4.3**.



Decision-making about the management setting

When deciding on the setting in which a patient with an exacerbation should be managed, it is important to determine not only the severity of the exacerbation *per se*, as detailed in the Rome proposal, if possible, but also assess how compromised the patient is. This assessment should include underlying COPD severity, presence and severity of comorbidities, mental status, and social and environmental factors, particularly the availability of home support. In practice, most exacerbations are managed on an outpatient basis, however even patients with a mild exacerbation may need hospital admission if there are other underlying problems. A guide to help assess the appropriate place of management is given in **Figure 4.4**.



In patients with exacerbations who have no signs of respiratory distress or indications for hospitalization (**Figure 4.4**) management can be ambulatory. Ambulatory patients should be closely followed up to ensure improvement, and they should be instructed to seek medical care if there is acute worsening of their condition. When a person having a COPD exacerbation comes to the ED, it is necessary to determine whether the exacerbation is life-threatening and consider whether the increased work of breathing or impaired gas exchange requires high flow oxygen or NIV. To determine the need for ventilator support (usually in the ED or hospital setting) blood gases should be measured. If high flow oxygen or ventilator support is required healthcare providers should consider admission to an area where proper monitoring and care by well-trained personnel can be provided. In less severe cases, the patient may be managed in the ED and if the clinical response is good, the patient may be discharged to be treated at home with clear instructions and a follow-up appointment.

If the patient is hospitalized, the severity of the exacerbation should be monitored based on their clinical signs including the variables mentioned in the Rome proposal and mental status changes. Particularly important is the monitoring of gas exchange variables. In this regard, the gold standard continues to be determination of ABGs[953,954] in more severe cases, while venous blood gases can be helpful in less severe COPD exacerbations.[955] The use of transcutaneous capnography[956,957] can be helpful in less severe cases, while oxygen saturation, a universally useful tool as the fifth vital sign, has been shown to be less accurate in individuals with darker skin tone.[958]

RISK FACTORS AND SYMPTOMS

Triggers

Given many exacerbations are not reported to healthcare professionals, people with COPD need to receive education about the importance of understanding exacerbation symptoms and when to seek professional healthcare.

Exacerbations are mainly triggered by respiratory viral infections, although bacterial infections and environmental factors such as ambient air pollution, excess heat and cold, wildfire smoke and dust-storms may also initiate and/or amplify these events.[602,959-962] 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.[963,964] A report from the UK showed RSV was associated with 8.7% of outpatient managed COPD exacerbations.[657] Exacerbations associated with viral infections are often more severe, last longer and precipitate more hospitalizations, as seen during winter. Short-term exposure to ambient NO_2, PM2.5, and PM10 is associated with increased hospitalizations, ED visits, and outpatient visits,[965] as well as increased mortality from COPD exacerbations.[48,966-968] A 2025 cohort study found that long term exposure to air pollution is also associated with increased risk of COPD exacerbations.[107]

Filamentous fungi, particularly Aspergillus species, may be identified in sputum samples of patients during moderate or severe exacerbations[969-971] although their clinical relevance remains unclear. Invasive pulmonary aspergillosis is rare (1.3-3.9%)[972] and more frequent in patients with more severe baseline airflow obstruction, recent use of broad-spectrum antibiotics or parenteral steroids, and hypoalbuminemia.[973] The diagnostic approach to invasive aspergillosis in this setting remains challenging.[974] Aspergillus sensitization is also a marker of increased risk of exacerbations.[975]

Symptoms

Exacerbations can be associated with increased dyspnea, difficulty breathing, fever and sputum production that, if purulent, may indicate bacterial infection.[926,939,963] There is evidence that viral infections are associated with a persistent, non-productive cough, worsening dyspnea and wheeze, with significant impact on quality of life.[976-978]

During a COPD exacerbation, increased symptoms are usually present for 7-10 days, but some events may last longer. At 8 weeks up to 20% of patients will not have recovered to their pre-exacerbation state.[979] COPD exacerbations contribute to disease progression,[980] which is more likely if recovery from exacerbations is slow.[981] Exacerbations can also cluster in time and once they occur there is increased likelihood of another event[445,982] (see **Chapter 2**).

Exacerbations in patients with COPD with biomass exposure are clinically similar to smoking-related COPD but markers of inflammation (T2) may be enhanced in these patients during exacerbations.[983]

Risk factors and scores for future events

Risk of occurrence

Several scores and factors can help predict COPD exacerbations. The most significant predictors include a history of previous exacerbations, impaired lung function (particularly FEV1), and the number of COPD maintenance medications. Other factors include female sex, higher daily reliever medication use, eosinophil count, and the presence of comorbidities, such as a history of gastro-esophageal reflux. However, the strongest predictor of future exacerbation frequency remains the number of exacerbations in the prior year.[445] This includes exacerbations prior to diagnosis, with even one exacerbation in the prior year increasing the risk of exacerbations in the next 12 months,[445,490,984,985] although the risk is greater if there have been two or more previous exacerbations. It is recognized that these patients form a moderately stable phenotype, even if some studies have shown that a significant proportion of patients change their exacerbation frequency especially with worsening FEV1.[986]

Other factors 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),[288] a greater percentage of emphysema or airway wall thickness[531] measured by chest CT imaging, dynamic hyperinflation,[987] the presence of chronic bronchitis,[173,988] high symptom burden (as measured by mMRC scale and CAAT™) and GERD.[989]

Risk of poor short-term outcomes

Several factors are associated with an increased risk of readmission, including age, male sex, markers of health status, disease burden (including previous exacerbation history), exacerbation severity (e.g., acidotic respiratory failure, need for mechanical ventilation, length of hospital stay), multimorbidity (e.g., CVDs, anxiety and depression), socio-familial context, and some biomarkers.[990-992] Receiving intubation with positive pressure ventilation or NIV are independent risk factors for rehospitalization and higher mortality.[993] In addition, predictive scores have been developed to predict the risk of readmission.[994] Deficiencies in management have also been identified in large-scale audits: the lack of healthcare resources such as respiratory specialists is associated with re-hospitalization and mortality.[995]

Vitamin D has an immune-modulating role and has been implicated in the pathophysiology of exacerbations.[996] 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.[996,997] 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.

Cohort studies have produced differing results regarding the ability of blood eosinophils to predict future exacerbation outcomes, reporting either no relationship[457] or a positive relationship.[458,459] Differences between studies are likely due to different exacerbation histories and ICS use. The presence of sputum eosinophilia has been related to susceptibility to viral infection.[939] There is insufficient evidence to recommend that blood eosinophils should be used to predict future exacerbation risk on an individual basis in patients with COPD. It has been suggested that exacerbations associated with an increase in sputum or blood eosinophils may be more responsive to systemic steroids[998] although more prospective trials are needed to test this hypothesis.[998] Recent prospective analysis of SPIROMICS suggests that serum IgG levels are associated with increased risk of exacerbation.[999]

Risk of poor long-term prognosis

Long-term prognosis following hospitalization for a COPD exacerbation is poor, with a five-year mortality rate of about 50%.[1000] Factors independently associated with poor outcome include older age, lower BMI, comorbidities (e.g., CVD or lung cancer), previous hospitalizations for COPD exacerbations, clinical severity of the index exacerbation, and need for LTOT at discharge.[1001-1003] 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 of mortality following an acute COPD exacerbation.[1004] COPD exacerbations increase the risk of adverse cardiovascular events, with heightened risk in the first 30 days persisting for up to 1–2 years.[1005] Mortality risk may be heightened during spells of cold weather.[1006]

A 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.[1007]

Scores

Several scoring systems have been developed to quantify the risk of future COPD exacerbations. The most used tools are SCOPEX (Score to Predict Short-Term Risk of COPD Exacerbations), which considers factors such as the number of COPD maintenance medications prior to the trial, higher average daily reliever use, a greater number of previous year exacerbations, lower FEV1/FVC ratio, and female sex. The score was validated to predict the likelihood of exacerbation within 6 months.[1008] CEX-HScore (CopdEX-Health Search Score) assesses the risk of COPD exacerbation, with a focus on the primary care setting and uses predictive factors that were developed using 16 determinants. The score showed fair accuracy for predicting exacerbations over a 6-month period.[1009] The DECAF Score (Dyspnea, Eosinopenia, Consolidation, Acidemia, and Atrial Fibrillation) was developed to identify in-hospital mortality in patients experiencing acute exacerbations.[1010] A modification of the DECAF score (mDECAF) replaces atrial fibrillation with history of exacerbations in the previous year. The main limitation of these scores is the lack of validation, poor sensitivity and specificity. GOLD does not recommend the routine use of any of these scores.

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.[1011] 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.[445,931,1012]

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 ED, if hypoxemic they should be started on controlled oxygen therapy and undergo assessment to determine whether the exacerbation is life-threatening and if increased work of breathing or impaired gas exchange requires consideration for NIV. 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 ED 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**. Key points for the management of all exacerbations are given in **Figure 4.6**.

Management of Severe but not Life-threatening Exacerbations*

Figure 4.5

Assess severity of symptoms, blood gases, chest radiograph

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) in patients with purulent oral secretions, prior positive sputum bacteria culture or requiring mechanical ventilation (invasive or noninvasive)

Consider high flow oxygen (HFNT) or noninvasive ventilation (NIV), obtain serial blood gas, venous blood gas and pulse oximetry measurements

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

Key Points for the Management of Exacerbations

Figure 4.6

- Short-acting inhaled beta$_2$-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 5 days **(Evidence A)**
- Antibiotics are indicated in patients with purulent sputum, prior positive sputum bacteria culture, or requiring mechanical ventilation (invasive or noninvasive) **(Evidence A)**
- Antibiotics, when indicated, can shorten recovery time, reduce the risk of early relapse, treatment failure, and hospitalization duration. Duration of therapy 5 days **(Evidence B)**
- High flow oxygen (HFNT) is the first mode of ventilation used in COPD patients with acute hypoxemic respiratory failure. For patients with hypercarbic respiratory failure or those who do not respond to HFNT, use non-invasive mechanical ventilation (NIV) unless absolutely contraindicated. NIV has been shown to: improve gas exchange, reduce breathing work and need for intubation, decrease hospitalization duration and improve survival **(Evidence A)**

PHARMACOLOGICAL TREATMENT

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

Bronchodilators

Although there is no high-quality evidence from RCTs, it is recommended that inhaled SABAs, with or without short-acting anticholinergics, are the initial bronchodilators for acute treatment of a COPD exacerbation.[1013,1014] A systematic review of the route of delivery of SABAs found no significant differences in FEV1 between using pMDIs (with or without a spacer device) or nebulizers to deliver the agent,[565,1015] although the latter may be an easier delivery method for sicker patients. If a nebulizer is chosen to deliver the bronchodilator agent, air-driven bronchodilator nebulization is preferable to oxygen-driven in acute exacerbations of COPD to avoid the potential risk of increasing the $PaCO_2$ associated with oxygen-driven bronchodilator administration.[1016] It is recommended that patients do not receive high doses of SABA due to possible side effects. Patients can receive one dose of nebulized medication every hour for 2-3 doses or use a pMDI 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 no clinical studies have evaluated the use of inhaled LABDs (either $beta_2$-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. In several countries nebulized LABDs are available, such as arformoterol, formoterol, or revefenacin. These medications have an onset of action similar to albuterol but have a longer duration of action. These nebulized solutions might be effective bronchodilators during exacerbations and could reduce the required frequency of treatments. However, there have not been any trials comparing nebulized LABA with nebulized SABA for COPD exacerbations, although this approach has been used in some hospital settings. One retrospective case-control study that compared hospitalized subjects treated with a nebulized LABA versus a nebulized SABA found that there was a reduction in 30-day readmissions with the LABA.[1017]

Intravenous methylxanthines (theophylline or aminophylline) **are not recommended** in these patients due to significant side effects.[1018,1019]

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,[1020-1023] the risk of early relapse, treatment failure,[1024] and the length of hospitalization.[1020,1022,1025] A dose of 40 mg prednisone-equivalent per day for 5 days is recommended.[1026] A systematic literature review concluded that a 5-day course of glucocorticoids is likely to be sufficient in patients with mild-to-moderate exacerbations, with the recognition that the quality of the evidence behind this recommendation is moderate.[1027] One observational study suggested that longer courses of oral glucocorticoids for COPD exacerbations are associated with an increased risk of pneumonia and mortality.[1028] Therapy with oral prednisolone is equally effective to intravenous administration.[1029] Nebulized budesonide alone may be a suitable alternative for treatment of exacerbations in some patients,[1021,1030,1031] and provides similar benefits to intravenous methylprednisolone, although the choice between these options may depend on local cost issues.[1032,1033] Even short bursts of glucocorticoids are associated with subsequent increased risk of pneumonia, sepsis and death[1034] and use should be confined to patients with significant exacerbations. Recent studies suggest that glucocorticoids are more efficacious when treating acute COPD exacerbations in patients based on blood eosinophil levels.[445,940,998,1035] A double-blind, placebo-controlled RCT (STARR2) of prednisolone therapy guided by blood eosinophil count during an acute COPD exacerbation suggested that prednisone could be safely avoided in some patients with COPD exacerbations and low eosinophil levels in primary care settings.[1036] However, there is a need for further prospective studies in hospitalized patients to validate these findings.

Antibiotics

Although the infectious agents in COPD exacerbations can be viral or bacterial,[964,1037] the use of antibiotics in exacerbations remains controversial. A Cochrane review concluded that there is a strong beneficial effect of antibiotic treatment during an exacerbation requiring intensive care, in terms of mortality and treatment failure.[1038] In other exacerbations requiring hospitalization the benefit is significant only when trials using antibiotics no longer in use are included.[1038] A large retrospective study showed that the administration of antibiotics in the first 2 hospital days was associated with improved outcomes compared with later initiation or no antibiotic treatment during the hospitalization.[1039] The benefit of using antibiotics in moderate, ambulatory exacerbations is less clear. In an RCT, the addition of doxycycline to oral corticosteroids in an outpatient setting did not prolong the time to next exacerbation.[1040] Systematic reviews of placebo-controlled studies have shown the benefits of antibiotic treatment in moderately or severely ill patients with COPD exacerbations with increased cough and sputum purulence.[1041,1042] These data are supported by more RCTs in patients with diagnoses of moderate COPD.[1043]

Identifying markers to help determine which patients will benefit from the use of antibiotics for the treatment of exacerbations is key. In general, there is evidence supporting the use of antibiotics when patients have clinical signs of a bacterial infection e.g., increased sputum purulence.[318,1044] Indeed, observed sputum purulence has 94.4% sensitivity and 52% specificity for high bacterial load.[318] Unfortunately, in the outpatient setting, sputum cultures are not feasible as they take at least 2 days and frequently do not give reliable results for technical reasons.

Several biomarkers of airway infection are being studied in exacerbations of COPD. Earlier studies of CRP reported contradictory findings.[1045,1046] One RCT found a marked reduction in antibiotic prescriptions without impaired outcomes in UK primary care outpatients with an exacerbation in whom antibiotics prescriptions were guided by point-of-care CRP testing.[1047] Another trial in patients hospitalized for exacerbations of COPD in The Netherlands found similar results (reduced antibiotic use with no increase in treatment failure).[1047] A double-blind, placebo-controlled study in exacerbations in patients with COPD who had mild to moderate airflow limitation and who were being managed in primary care showed that purulence of sputum and elevated point-of-care CRP were the two factors that identified patients with increased risk of failure without antibiotics.[1048]

Procalcitonin is an acute phase reactant that increases in response to bacterial infection and has been studied to determine the use of antibiotics in COPD exacerbations.[1049] The efficacy of this biomarker is controversial. Several studies, conducted mainly in the outpatient setting, suggested that procalcitonin-guided antibiotic treatment reduces antibiotic exposure and side effects with the same clinical efficacy.[1050-1052] 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.[1053] 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.[1054] Based on these conflicting results at this time we cannot recommend the use of procalcitonin-based protocols to make the decision on using antibiotics in patients with COPD exacerbations.[1055]

In summary, during an exacerbation antibiotics should be given to patients with COPD who:

- Have these at least two of these symptoms: increase in dyspnea, fever, sputum volume, and sputum purulence, if increased purulence of sputum is one of these symptoms
- Prior positive sputum culture during prior exacerbation
- Require mechanical ventilation (invasive or noninvasive).[926,964]

The choice of the antibiotic should be based on local bacterial resistance patterns. Usually, initial empirical treatment is an aminopenicillin with clavulanic acid, a macrolide, a tetracycline or, in selected patients, a quinolone. In patients

with frequent exacerbations, severe airflow obstruction,[1056,1057] and/or exacerbations requiring mechanical ventilation,[1058] 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 condition of the patient and pharmacokinetics of the antibiotic.

Shorter exposure to antibiotics may decrease the risk of developing antimicrobial resistance and complications associated with this therapy. A meta-analysis demonstrated that ≤ 5 days of antibiotic treatment had the same clinical and bacteriological efficacy to longer conventional treatment in outpatients with COPD exacerbations.[1059] The recommended length of antibiotic therapy is 5-7 days.[1060] We recommend a duration of ≤ 5 days of antibiotic treatment for outpatient treatment of COPD exacerbations.[1054,1059]

Other pharmacotherapy

Antioxidants

Mucolytics have been shown to have anti-inflammatory and antioxidant activity in addition to their classical mucolytic actions.[1061] Although mucolytics have been studied and used for COPD exacerbation prevention, there has been less investigation of mucolytics during acute exacerbations, even though the properties of mucolytics make them suitable for use during acute decompensations. Trials have shown that N-acetylcysteine is not effective in improving recovery of FEV1, although it reduces symptoms of cough and phlegm, and reduces inflammatory biomarkers during exacerbations.[1061,1062] Thus, N-acetylcysteine may be a useful adjunct to drug therapy in patients with difficulty clearing airway secretions. A meta-analysis of 24 studies and 2172 patients has shown with moderate certainty that mucolytics increase the rate of treatment success by 37%, while they also exert benefits on overall symptom scores, presence of cough at follow-up and ease of expectoration. Further adequately powered clinical trials are needed.[1063]

Adjunct therapies

Depending on the clinical condition of the patient, an appropriate fluid balance, use of diuretics when clinically indicated, anticoagulants, and the treatment of comorbidities and nutritional aspects should be considered. Hospitalized patients with COPD are at an increased risk of deep vein thrombosis and pulmonary embolism; up to 5.9% were found to have pulmonary embolism.[950,1064,1065] Prophylactic measures for thromboembolism should be instituted in these patients.[1066,1067] At all times, healthcare providers should strongly enforce the need for smoking cessation.

MANAGEMENT OF RESPIRATORY FAILURE

Oxygen therapy

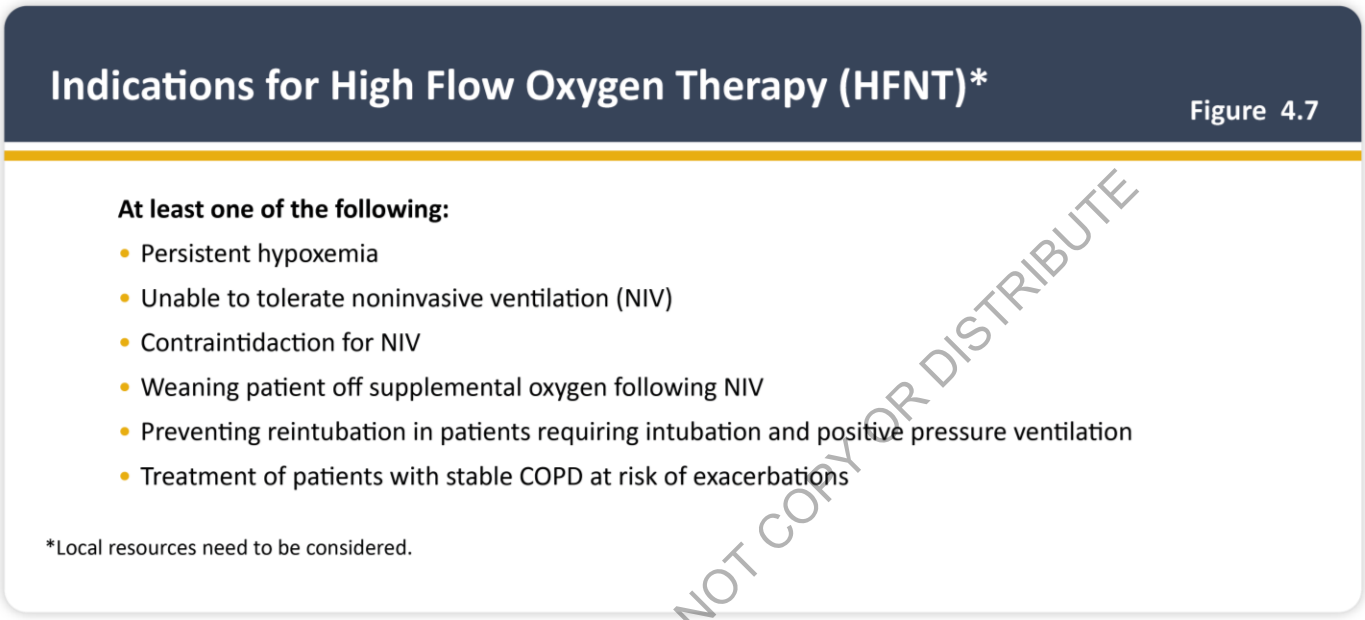
High-flow nasal therapy

Oxygen therapy has been considered first line respiratory support in patients suffering an exacerbation. However, in patients with COPD who remain hypoxemic despite the use of conventional oxygen therapy, hypercapnic, or unable to tolerate NIV, HFNT has been used to deliver heated and humidified air-oxygen blends from 10 to 60 lpm via specialized nasal cannulas.[1068-1070] In uncontrolled, observational and retrospective studies, HFNT is associated with a range of improvements in physiological measurements; decreased respiratory rate and effort, reduction in hypercapnia, and improvements in thoracoabdominal synchrony.[1071-1073]

HFNT has been utilized in the treatment of exacerbations in patients with COPD in three distinct scenarios: 1) treatment during hospitalized exacerbation, 2) to prevent reintubation in patients requiring intubation and positive

pressure ventilation during an exacerbation, and 3) treatment of patients with stable COPD who are at risk for exacerbations to prevent future moderate or severe exacerbations (**Figure 4.7**).

In a prospective RCT conducted in hospitalized hypoxemic exacerbations, patients who received HFNT developed less treatment failure that required switching to NIV, or intubation and mechanical ventilation than those who received conventional oxygen therapy.[1074] However, another prospective RCT in patients hospitalized with exacerbations reported no differences in the need for intubation or switch to NIV when comparing HFNT to conventional oxygen therapy.[1075] Furthermore, in subjects with a chronic hypercapnia those receiving HFNT had longer hospital stays and used less NIV compared to those receiving conventional oxygen therapy.[1076]



Several prospective RCTs have compared HFNT to NIV as first-line therapy in patients presenting with hospitalized exacerbations and respiratory acidosis. Patients who received HFNT had similar improvements in gas exchange at 12 hours and 5 days, hospitalization duration, and days of respiratory support to those receiving NIV, but patients who received HFNT had fewer complications and reported it more comfortable than NIV.[1077] A multicenter RCT of patients hospitalized with exacerbations reported HFNT to be non-inferior to NIV in lowering $PaCO_2$; however, approximately 30% of patients randomized to HFNT switched to NIV at 6 hours post-randomization due to a lack of improvement in gas exchange.[1077] In another prospective noninferiority RCT of patients hospitalized with exacerbations, the intubation rate was higher in the HFNT group compared to the NIV group; however, treatment switch rates, hospital length of stay, and 28-day mortality rates were similar between groups.[1078] In patients with hypercapnic respiratory failure, HFNT was noninferior to NIV for the primary outcome of endotracheal intubation or death within 7 days.[1079,1080]

HFNT has also been used post-extubation to prevent reintubation in patients hospitalized with exacerbation and acute respiratory failure that required intubation and mechanical ventilation. Small, single-centered trials have shown that HFNT is non-inferior to NIV in reducing cardon dioxide levels and respiratory rate, and HFNT was better tolerated than NIV post-extubation in patients with COPD after receiving positive pressure ventilation to treat acute on chronic respiratory failure.[1078,1081] The effect of post extubation HFNT vs. NIV on reintubation and development of post-extubation respiratory failure was evaluated in a large, prospective, multicenter RCT in high-risk patients, of whom approximately 18-22% had underlying COPD as the cause of respiratory failure.[1082] HFNT was non-inferior to NIV in preventing reintubation or post-extubation respiratory failure, but the rates of post-extubation respiratory failure and reintubation were high at 22% and 27%, respectively. In a subsequent study, post-extubation HFNT with NIV was again non-inferior to HFNT alone in patients at high risk of extubation failure (e.g., age > 65 years or underlying

cardiopulmonary disease; approximately 21-25% of subjects had underlying COPD),[1082] whereas in a further study in similar patients, the rates of reintubation (11.8% vs. 18.2%) were significantly lower in those who received HFNT and NIV vs. HFNT alone, as were the rates of post-extubation respiratory failure (21% vs. 29%).[1083] ERS Clinical Practice Guidelines currently recommend the use of NIV over HFNT for patients at high risk of extubation failure post-mechanical ventilation for exacerbations unless there are contraindications to NIV use. They also recommend the use of NIV over HFNT in patients hospitalized with exacerbations and hypercapnic respiratory failure.[1084]

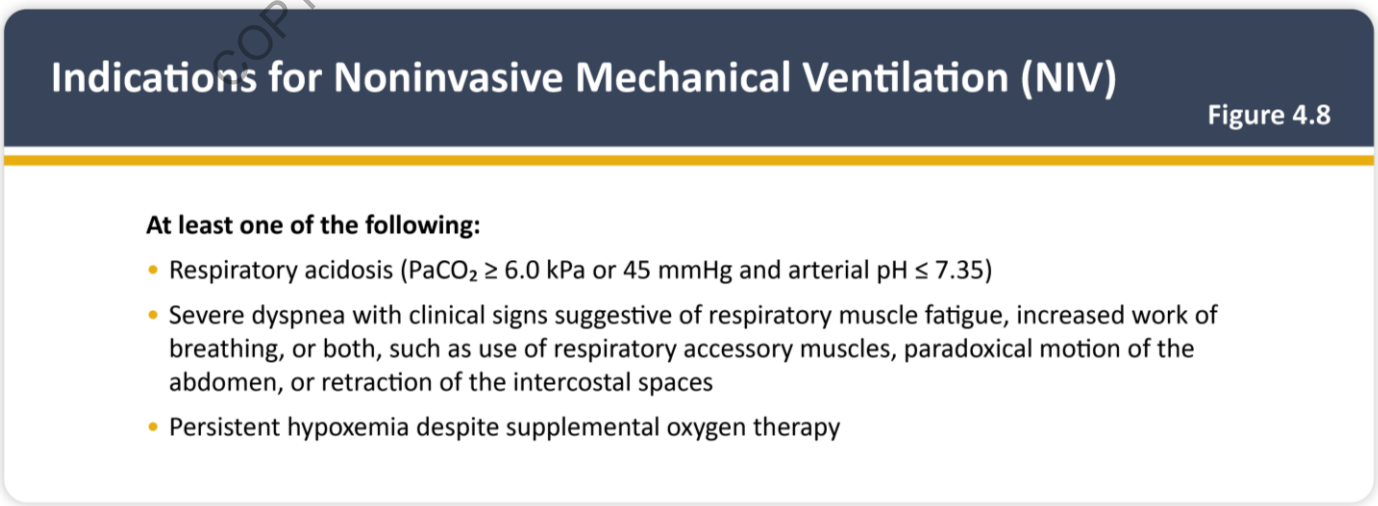
Chronic use of home HFNT in addition to LTOT has been reported to decrease the frequency of moderate and severe exacerbations in select patients with COPD in comparison to LTOT.[1085-1087] However, there was no impact on mortality, together with inconsistent effects on quality of life, gas exchange, lung function and 6MWD, potentially because baseline patient characteristics varied in terms of degree of airflow obstruction and severity of hypercapnia between studies. No obvious adverse effects were attributable to the use of chronic home HFNT. The home use of chronic nocturnal HFNT to prevent moderate or severe exacerbations of COPD is currently the focus of several large, multicenter international trials (NCT05204888, EpIC-HFT, HiLOT and HiFAE), which should provide results to definitively assess appropriate parameters of patient selection, the efficacy of home HFNT on patient outcomes, and the technical aspects of optimal application.

Ventilatory support

Some patients need immediate admission to a specialist respiratory care unit or ICU (**Figure 4.4**). In particular, the admission of patients with severe exacerbations to intermediate or specialist 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 (orotracheal tube or tracheostomy) ventilation. Respiratory stimulants are not recommended for acute respiratory failure.[1013]

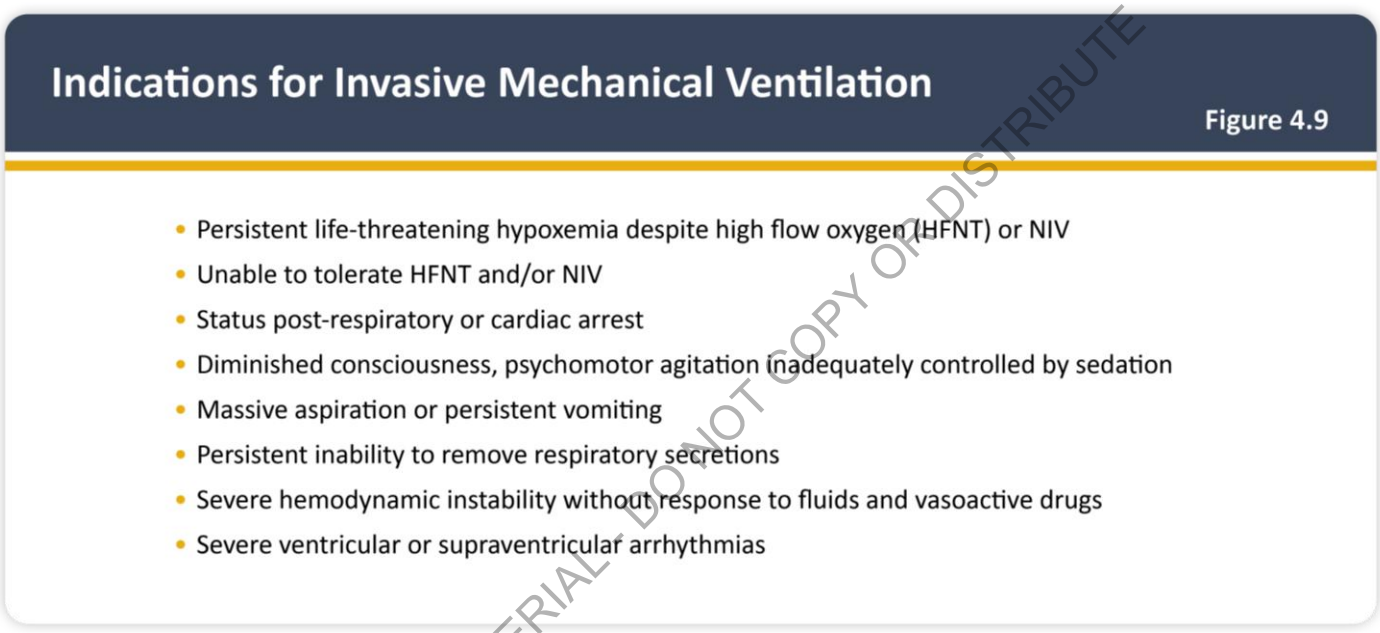
Noninvasive mechanical ventilation (NIV)

NIV is 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%,[1088-1092] and has been shown to improve oxygenation and acute respiratory acidosis, i.e., increasing pH and decreasing $PaCO_2$. It also decreases respiratory rate, work of breathing and severity of breathlessness, and also decreases complications such as ventilator associated pneumonia, and length of hospital stay. More importantly, mortality and intubation rates are reduced by this intervention.[1089,1093-1095] 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.[1096] The indications for NIV[1092] 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.[1097] 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.[1097] In patients who fail NIV as initial therapy and receive invasive ventilation as subsequent rescue therapy, morbidity, hospital length of stay and mortality are greater.[1090] 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.[1090] 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, the need for tracheostomy and consequential prolonged ventilation.

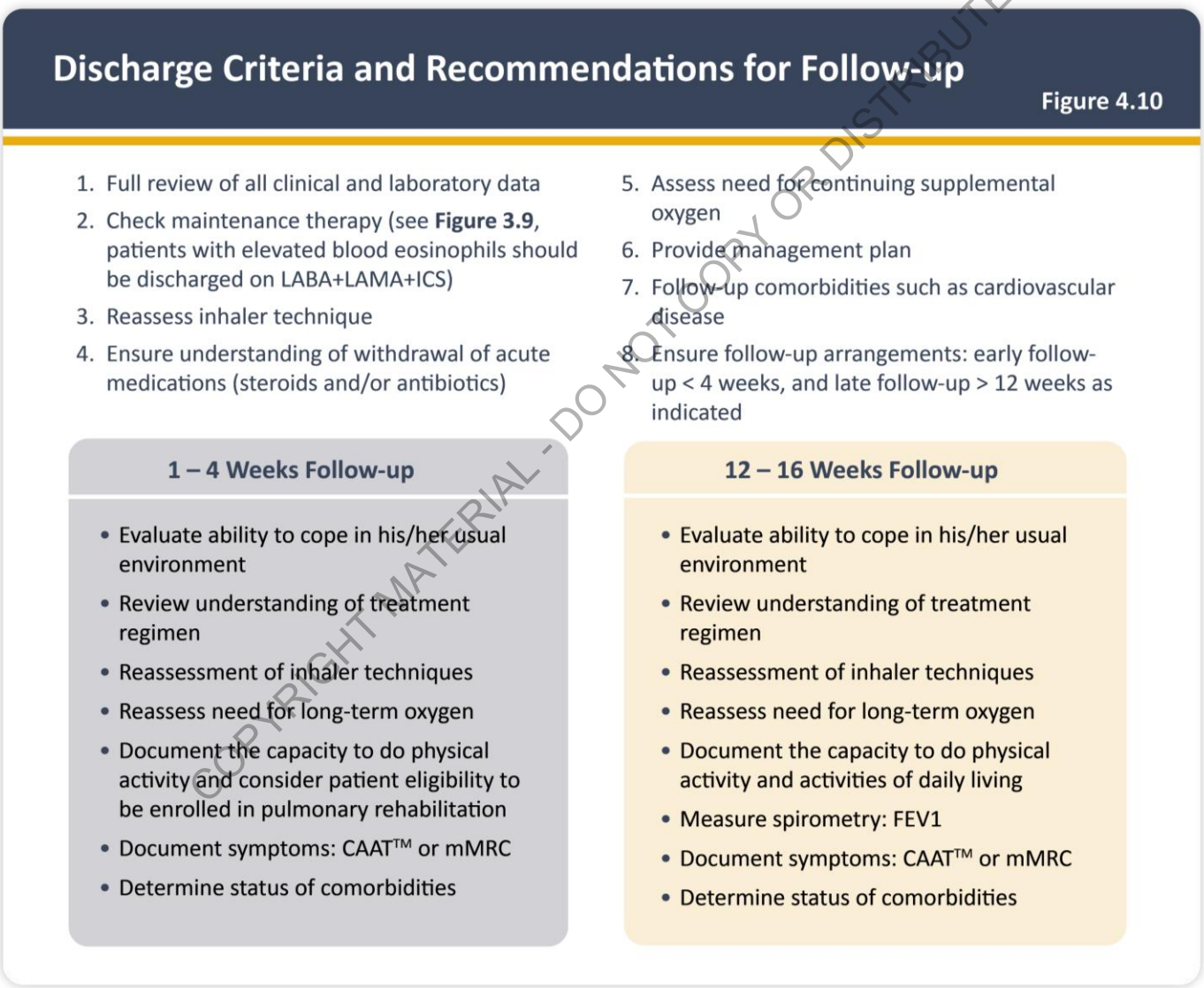


Acute mortality among patients with COPD and respiratory failure is lower than among patients ventilated for non-COPD causes.[1098] Despite this, patients who might otherwise survive are frequently denied admission to ICUs for intubation because of unwarranted prognostic pessimism.[1099] A large study of patients with COPD and acute respiratory failure reported in-hospital mortality of 17% to 49%.[1100] Further risk of mortality was reported over the next 30 days up to 12 months, particularly among those patients who had poor lung function before invasive ventilation (FEV1 < 30% predicted), had underlying cardiovascular disease, 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.[484,1101]

HOSPITAL DISCHARGE AND FOLLOW-UP

Readmissions occur in 30%-50% of patients within 30 days of discharge after hospitalization for COPD exacerbation, and are associated with increased mortality. Prevention of readmission is a major goal of post-discharge care, together with treatment optimization and stabilization of health status, prevention of comorbidity-related events, and prolongation of survival. Reaching these goals requires planning discharge properly in terms of both timing and post-discharge follow-up, and to implement appropriate long-term pharmacological and non-pharmacological therapy.

Early supported discharge and at-home programs have provided inconclusive results, despite trends towards a reduction of readmission and costs.[1102] The introduction of care bundles on hospital discharge that include education, optimization of medication, supervision and correction of inhaler technique, adherence reinforcement, the assessment and optimal management of comorbidities, pulmonary rehabilitation, supported self-management, early visit to specialists, telemonitoring and continued patient contact have also been investigated (**Figure 4.10**). Several observational studies analyzing retrospective claims for early (0 to 30 days) vs delayed (> 30 days) initiation of LABA+LAMA+ICS fixed combination following patients' first COPD exacerbation showed 20%-30% reduction in first moderate or severe COPD exacerbation and a reduction in re-hospitalizations.[1103-1105] A large real-world observational study of patients hospitalized for COPD exacerbation demonstrated that the maintenance therapy received at discharge impacted the future risk of exacerbation, readmission and mortality. It was also shown that most patients were discharged on inappropriate therapy. Only 17.5% of patients were prescribed triple therapy at discharge, or during the 2-week post-discharge period, with over one quarter of patients prescribed SABA only, or no inhaled medication at all.[1106]



The impact of transitioning from hospital to home on patient outcomes and readmissions is impacted by patient education and transitional care services.[1107] Early rehabilitation post hospital discharge (i.e., < 4 weeks) is associated with improved quality of life and increased exercise capacity and may be associated with decreased readmission rate and improved survival,[1108] although the evidence regarding these two outcomes is heterogeneous.[1109,1110]

Further, early follow-up (within 1 month) following discharge to review patient status and therapy should be undertaken when possible, as this has been related to fewer readmissions.[1110,1111] Lack of early follow-up may reflect both patient compliance, limited access to medical care, poor social and medical support, and/or the presence of more severe disease. Additional follow-up at 3 months is recommended to ensure a return to the stable clinical state and to 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. In addition, arterial oxygen saturation and blood gas assessment will more accurately determine the need for LTOT at prolonged follow-up compared to shortly after discharge.[1112]

CT assessment to determine the presence of bronchiectasis and emphysema should be done in patients with recurrent exacerbations and/or hospitalizations.[1113] A further detailed assessment of the presence and management of comorbidities should also be undertaken (**Figure 4.10**).

PREVENTION OF FURTHER EXACERBATIONS

After an acute exacerbation, appropriate measures for prevention of further exacerbations should be initiated (**Figure 4.10**). The use of a LABA+LAMA+ICS, smoking cessation, immunization against influenza, pneumonia, RSV and pulmonary rehabilitation have been shown to improve function and reduce subsequent COPD exacerbations.[635,1114-1116] The use of a LABA+LAMA+ICS fixed combination following hospitalization showed a significant reduction in first moderate or severe COPD exacerbation and in the rate of re-hospitalizations.[1103,1104,1117] The treatment interventions that significantly impact exacerbation risk and/or frequency are shown in **Figure 4.11** and **Chapter 3**.

Interventions that Reduce the Frequency of COPD Exacerbations

Figure 4.11

Intervention Class	Intervention
Bronchodilators	LABAs LAMAs LABA + LAMA
Corticosteroid-containing regimens	LABA + LAMA + ICS
Anti-inflammatory (non-steroid)	Roflumilast Dupilumab Mepolizumab
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 MULTIMORBIDITY

KEY POINTS:

- Patients with COPD often have other chronic conditions (multimorbidity) that increase the risk of poor outcomes.
- Multimorbidity is often underdiagnosed and undertreated, and should be actively searched for in each patient with COPD.
- The presence of those morbidities should not alter COPD treatment; comorbid disease should be treated as per usual standards, despite the presence of COPD.
- CVDs, particularly hypertension, ischemic heart disease, heart failure and atrial fibrillation, are common in COPD. The risk of a major cardiovascular event is significantly increased during and up to one year after a moderate or severe exacerbation.
- Lung cancer is a major cause of death in patients with COPD. An annual LDCT scan is recommended for lung cancer screening in patients with a smoking history, similar to recommendations for the general population. Screening for lung cancer in patients with COPD not associated with tobacco smoking is not recommended due to lack of evidence.
- Bronchiectasis is frequently present in patients with COPD, and when associated with infections impacts disease progression, exacerbations and risk of death.
- Depression/anxiety are frequent and important morbidities in COPD. They are often under-diagnosed and under-treated and are associated with poor health status and increased risk of death.
- In COPD, low BMI (< 21 kg/m^2) is associated with increased risk of death. Obesity (> 30 kg/m^2) is associated with metabolic syndrome and OSA. If OSA is present, CPAP treatment decreases risk of death.
- GERD is associated with an increased risk of exacerbations and poor health status.
- Multiple organ loss of tissue (MOLT) manifested by osteoporosis, sarcopenia, anemia and emphysema is associated with poor outcomes. Adequate nutrition, pulmonary rehabilitation and management of MOLT can improve outcomes.
- When COPD is part of a multimorbidity care plan, a goal should be simplicity of treatment, minimizing polypharmacy.

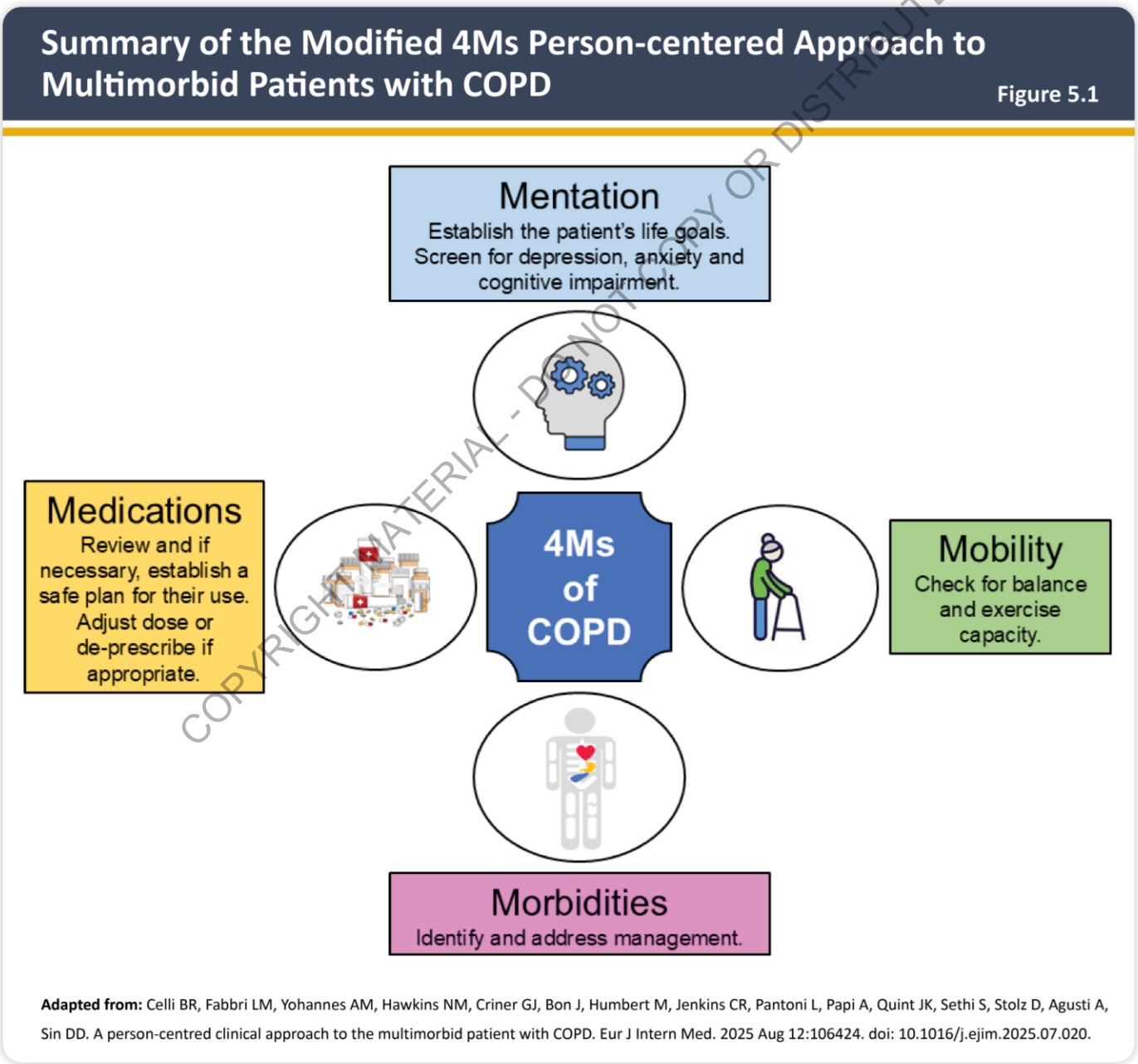
INTRODUCTION

Multimorbidity (defined as more than two additional chronic medical conditions) is common in patients with COPD.[292,468,469,478,1118-1123] Hypertension, ischemic heart disease (IHD), heart failure (HF), atrial fibrillation, lung cancer, depression and anxiety, bronchiectasis, GERD, morbid obesity, frailty, and malnutrition are among the most common morbid conditions in patients with COPD. These chronic conditions complicate the management of COPD and have a

significant impact on its prognosis. Providing specific recommendations for many of these conditions in the setting of COPD is challenging given the current state of evidence and the lack of guidelines addressing multimorbidity.

In patients with COPD, some of these morbidities arise independently of COPD. However, many are causally related, either sharing pathobiological pathways or one disease increasing the poor outcome risk of the other. This concept, known as "syndemics" represents a link between COPD and some of its comorbidities.[294,1124,1125] Importantly, comorbidities that are characterized by symptoms usually associated with COPD may be overlooked e.g., heart failure and lung cancer (breathlessness) or depression (fatigue and reduced physical activity).

Although COPD is negatively impacted by multiple comorbid diseases, COPD itself is also one of the most important conditions that adversely affects the outcomes of other disorders. For example, patients with congestive heart failure, ischemic heart disease,[1126] 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.[1127,1128]



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It is important to provide patients who have COPD with optimal evidence-based management for their respiratory disease. Any encounter between a healthcare practitioner and an individual with COPD offers an opportunity to manage not only their lung disease, but other prevalent morbidities.[471,1129] To maximize this opportunity, the Institute for Healthcare Improvement[1130] has proposed a systematic approach based on the '4Ms' for elderly patients with chronic non-communicable diseases: Mentation, Mobility, Medications, and Morbidities, all of which are important drivers of outcomes in this population.[1131,1132] In the context of patients with COPD, the 4Ms approach has been modified (**Figure 5.1**).[1133] Evaluating **Mentation** is important to define health goals,[1132] with a particular focus on depression and dementia[1134] as well as more severe psychiatric pathologies including bipolarity and schizophrenia. The patient should also be evaluated for **Mobility**, with particular attention to balance and frailty,[1135] and exercise capacity tested with the 6MWD test, an excellent predictor of survival in patients with COPD.[522,1136] It is important to review all **Medications** used by the patient, as more than 90% receive polypharmacy, inappropriate use of which results in poor clinical outcomes.[1137] Finally, **Morbidities,** the focus of this chapter, need to be identified, since appropriate diagnosis and management (in addition to specific treatment for COPD) improves outcomes. It is important to remember that in this population, active smoking should be considered a disease by itself,[1138] and needs to be addressed with a smoking cessation program.

COPD, FRAILTY AND MULTIMORBIDITY

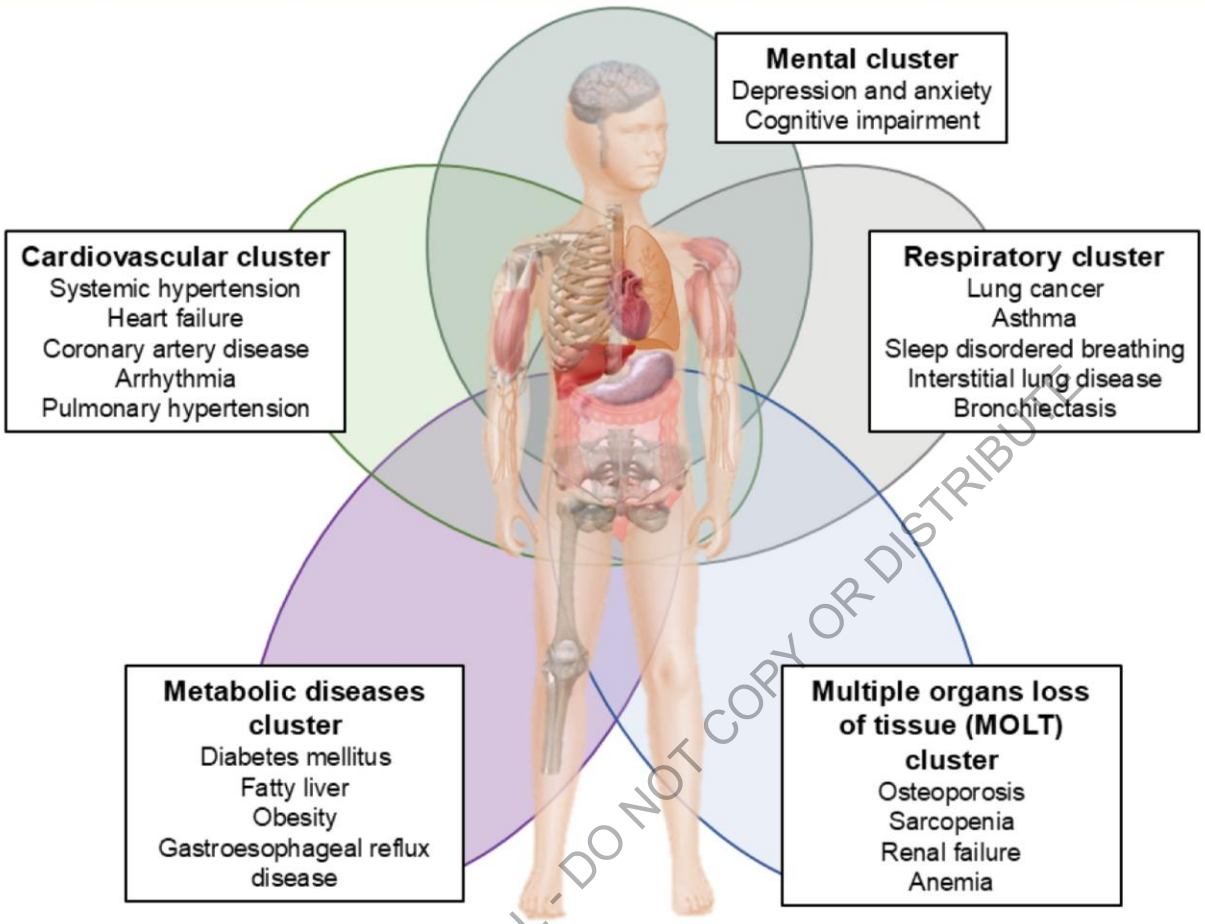
Frailty can be defined as a decline in multiple physiological systems, usually associated with aging. Practically, it can be determined by the presence of five components: weakness, slowness, exhaustion, low physical activity, and unintentional weight loss.[1139] Frailty is linked to conditions like cognitive impairment, cardiovascular disease, and with multimorbidity, compounding health risks.[1140] 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.[1141] A meta-analysis reported that frailty and pre-frailty were associated with all-cause mortality, acute exacerbation, and hospitalization in patients with COPD.[1142] Frailty is a predictor of outcomes in people with COPD.[1143] The ERS 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.[1144]

Once the general evaluation of Mentation, Medication and Mobility is complete, it is important to consider the most frequent morbidities potentially affecting the patient. These morbidities have been clustered by system organs using a modified Delphi methodology as shown in **Figure 5.2**.[1133]

Together with respiratory failure, some CVDs (arterial hypertension, heart failure, coronary artery disease, atrial fibrillation-flutter and pulmonary hypertension) and lung cancer are the most frequent causes of death in patients with COPD and therefore require close attention. However, other morbidities such as osteoporosis, depression, anxiety, sarcopenia, anemia, sleep-related disorders and renal failure negatively impact health-related quality of life, exacerbations and hospitalizations. Many are readily treatable and therefore, if identified, should be reviewed and monitored over time to optimize management. We recognize that the recommendations presented below may be insufficient for the management of all the morbidities patients with COPD may have and are not a substitute for the use of specific guidelines for the management of each individual comorbid condition. However, they contain practical information of use to healthcare providers caring for these patients.

Morbidity Clusters Frequently Present in Patients with COPD that Independently Impact Outcomes

Figure 5.2



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CARDIOVASCULAR DISEASES

Cardiovascular diseases are very frequent in patients with COPD that is caused by tobacco smoking, a shared risk factor for both organ systems. Several morbidities are of special importance and should be considered in all patients with COPD, namely: systemic arterial hypertension, heart failure, coronary artery disease, atrial fibrillation and pulmonary hypertension.[468,469,471,1124] In a large, real-world population of people with established CVDs, COPD was associated with a higher rate of cardiovascular events but patients with COPD were given less preventive therapy.[1145] The ESC guidelines recommend investigating cardiovascular risk factors in all patients with COPD.[1146]

Systemic hypertension

Close to 50% of patients with COPD have high blood pressure.[1122,1124] Uncontrolled hypertension is associated with reduced health-related quality of life and an increased risk of heart failure, myocardial infarction, and stroke.[1147] All patients should have their blood pressure measured at each medical evaluation, potentially complemented with home monitoring, with values > 130/80 mmHg abnormal and meriting treatment.[1147] Correcting poor diet, physical inactivity, and excessive alcohol consumption is crucial for hypertension control, either alone or with pharmacological

therapy.[1146]

The pharmacological treatment of COPD should be optimized because such treatment has not been associated with alterations in blood pressure levels. Systemic arterial hypertension should be managed according to guidelines.[1148,1149]

Heart failure

Heart failure is defined as a clinical syndrome (symptoms and signs) caused by a structural or functional cardiac abnormality corroborated by elevated natriuretic peptide levels or objective clinical or laboratory evidence of congestion. The prevalence of heart failure in patients with COPD ranges from 20–30%,[1150,1151] with annual incidence of 3–4%, although it is frequently under-diagnosed and should be proactively searched for since it is easily identified. The reduced (HFrEF) and preserved (HFpEF) ejection fraction phenotypes of heart failure occur with similar frequency (10% each) in patients with COPD. Close to 40% of patients with COPD who are mechanically ventilated due to hypercapnic respiratory failure have evidence of left ventricular dysfunction.[1152,1153] The presence of heart failure is an independent predictor of all-cause mortality.[1154]

International guidelines recommend the measurement of natriuretic peptides in patients with suspected heart failure, followed by echocardiography if abnormal. In patients with COPD, natriuretic peptides demonstrate high negative predictive values (0.80-0.98) to exclude left ventricular dysfunction in both stable state and during COPD exacerbations. However, they have relatively lower positive predictive values in patients with COPD than in the general population.[1155,1156]

Cardiovascular guidelines provide specific recommendations.[1155] For HFrEF this includes ACE inhibitors or angiotensin receptor blockers or sacubitril-valsartan, beta-blockers, mineralocorticoid receptor antagonists, and sodium-glucose transport protein 2 inhibitors. For HFpEF this includes sodium-glucose transport protein 2 inhibitors, sacubitril-valsartan and mineralocorticoid receptor antagonists. Treatment with β_1-blockers improves survival in heart failure and is recommended in patients who also have COPD. Selective β_1-blockers should be used only for approved cardiovascular indications and not for preventing exacerbations of COPD.[1157] Acute heart failure should be treated according to usual heart failure guidelines. Noninvasive ventilation added to conventional therapy improves outcomes for patients with heart failure with acute pulmonary edema.[1158]

Coronary artery disease

Coronary artery disease occurs in 10-20% of patients with COPD, and its presence is associated with increased morbidity and mortality of these patients.[1159,1160] Cardiovascular risk may be assessed by the global risk calculator that can be found on the US NHLBI website.[1161] The diagnosis of coronary artery disease is made in patients with different clinical presentations, including patients with symptoms (angina) or as a result of tests (ECG, high sensitivity troponin or coronary artery calcification seen in a CT scan).

In addition to assessing cardiovascular risk with conventional tools, screening using high sensitivity troponin at COPD diagnosis and at unexplained change in symptoms (dyspnea, chest pain or tightness, worsened exercise limitation) is recommended. Around 29-39% of patients with stable COPD have high sensitivity troponin values above the established general population with moderate cardiovascular risk threshold of 5-6 ng/L.[1162] When combined with ischemic resting ECG abnormalities the risk of all-cause mortality almost doubles compared to those with no cardiac biomarkers.[1163]

During, and for at least one year after an acute COPD exacerbation, there is an increased risk of cardiovascular events (death, myocardial infarction, stroke, arrhythmias, unstable angina, and transient ischemic attack).[1164] The risk is even higher if the exacerbation has resulted in hospitalization.[485,486,1165] The treatment of coronary artery disease should be according to guidelines irrespective of the presence of COPD and is best managed by a cardiologist. However, at a

regular visit with the COPD healthcare practitioner, a review of the treatment is warranted.

Arrhythmias

Cardiac arrhythmias are common in patients with COPD.[1166] Atrial fibrillation is frequent and associated with a lower FEV1,[1167] and concomitant COPD and atrial fibrillation is associated with more than a two-fold higher risk of all-cause mortality and of cardiovascular death compared with atrial fibrillation alone.[1168] Further, the risk of hospitalization for atrial fibrillation in the first 30 days after an exacerbation of COPD is increased when the exacerbation results in hospitalization.[1169] In patients with COPD 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.[1170]

For the diagnosis, it is recommended that an ECG is obtained at COPD diagnosis and at unexplained change in symptoms. Use of Holter monitoring may be indicated in patients with intermittent complaints of dizziness or fainting episodes because the prevalence of atrial fibrillation rises with extended monitoring duration.

The cornerstones of atrial fibrillation management are oral anticoagulation combined with rate or rhythm control strategies.[1171] There is no contraindication to any specific rate or rhythm control medication or strategy in patients with COPD, including beta-blockers. Catheter ablation should be considered for atrial fibrillation according to standard eligibility criteria. The presence of atrial fibrillation does not alter the treatment of COPD, as although bronchodilators have been previously described as potentially pro-arrhythmic agents;[1172,1173] available evidence suggests an overall acceptable safety profile for LABAs,[1174] anticholinergic drugs (and ICSs).[931,1175-1181] Nevertheless, caution is advised when using SABAs[1174,1182] and theophylline, which may precipitate atrial fibrillation and make control of the ventricular response rate difficult.[1183-1185]

Pulmonary hypertension

The presence of PH in patients with COPD is clinically relevant, as it is associated with increased healthcare resource utilization, more hospitalizations and a poor prognosis.[287]

PH is defined by an elevated mPAP > 20 mmHg, as assessed by right heart catheterization;[1186,1187] 25-30% of all patients with COPD present with mildly elevated mPAP.[1186-1188] PH is classified in five distinct groups, based on their different pathophysiological mechanisms, clinical presentation and therapeutic management: PAH (group 1), PH associated with left heart disease (group 2), PH associated with lung diseases and/or hypoxia (group 3), chronic thromboembolic PH (group 4) and PH associated with unclear and/or multifactorial mechanisms (group 5). All groups of PH can be diagnosed in patients with COPD.[285] Indeed, COPD may contribute to pulmonary vascular disease.

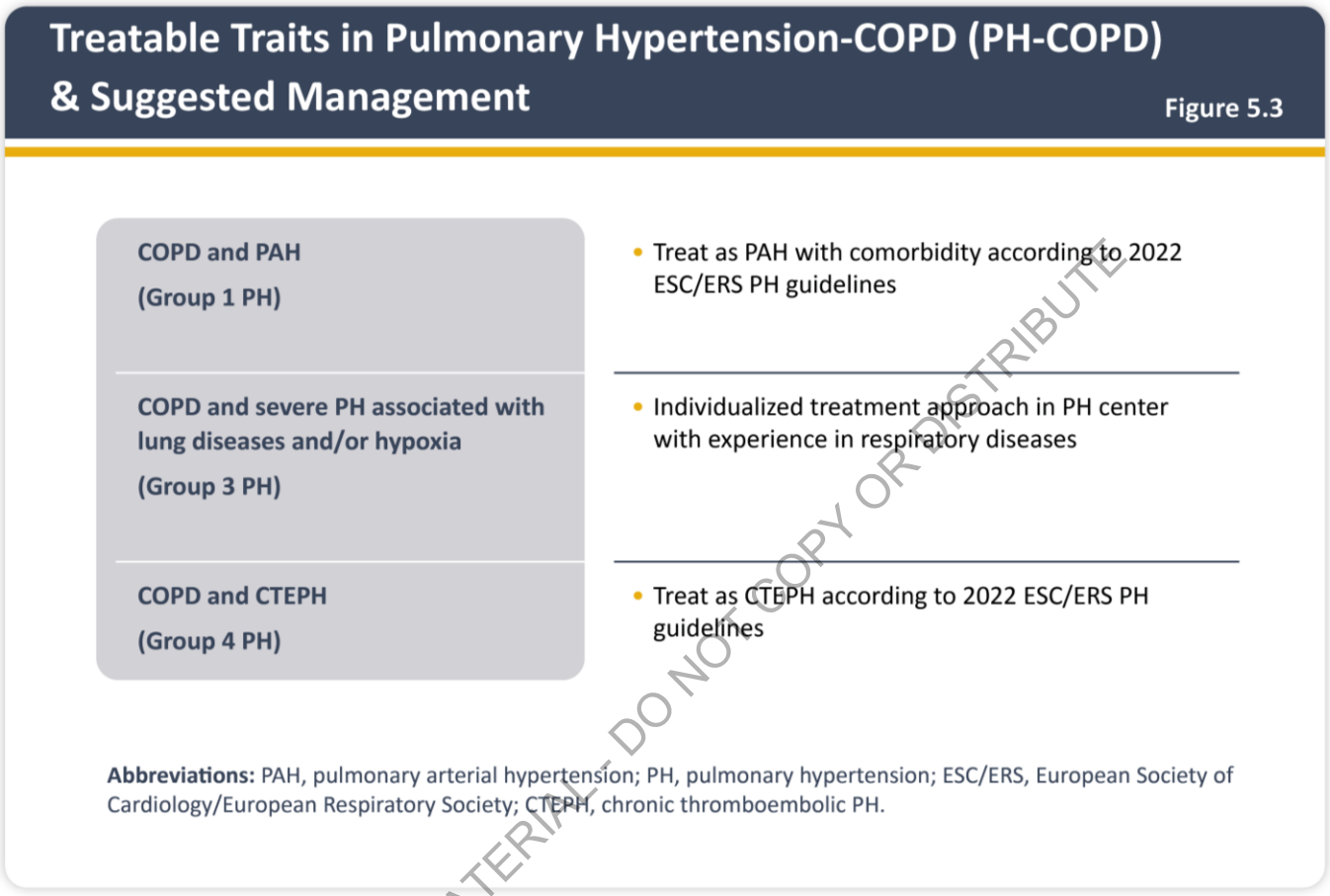
A diagnosis of PH in a patient with COPD requires a careful analysis of the possible mechanisms leading to elevated mPAP. This is critical in order to identify treatable traits of PH-COPD. For example, chronic thromboembolic PH is a treatable cause of PH occurring more frequently in patients above the age of 40 years, and can be detected in patients with COPD.[1189]

A subgroup (5%) of patients with COPD have severe PH.[1186,1187,1190] The 2022 ESC/ERS PH guidelines define severe PH-COPD by an increased peripheral vascular resistance > 5 Wood Units.[1186,1187,1191] The severity of PH is an independent predictor of prognosis,[287] 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 circulatory exercise limitation. For this group of patients the term “pulmonary vascular phenotype” has been suggested.[285] Pulmonary pressure increases during a COPD exacerbation, but its role is still uncertain.[1192]

Echocardiography is the best non-invasive tool to estimate the probability and severity of PH.[287,1186,1187] In addition, elevated N-terminal pro B-type natriuretic peptide and an increased ratio of the diameter of the pulmonary artery and

the aorta on HRCT 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.[288]

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 5.3**). Long-term oxygen therapy is recommended in hypoxemic patients.



In patients with non-severe PH-COPD the use of PAH medications is not recommended. Patients with severe PH-COPD require an individualized approach.[1186,1187] Further well-designed RCTs should be encouraged to advise for or against the use of PAH medications in PH-COPD.[1193]

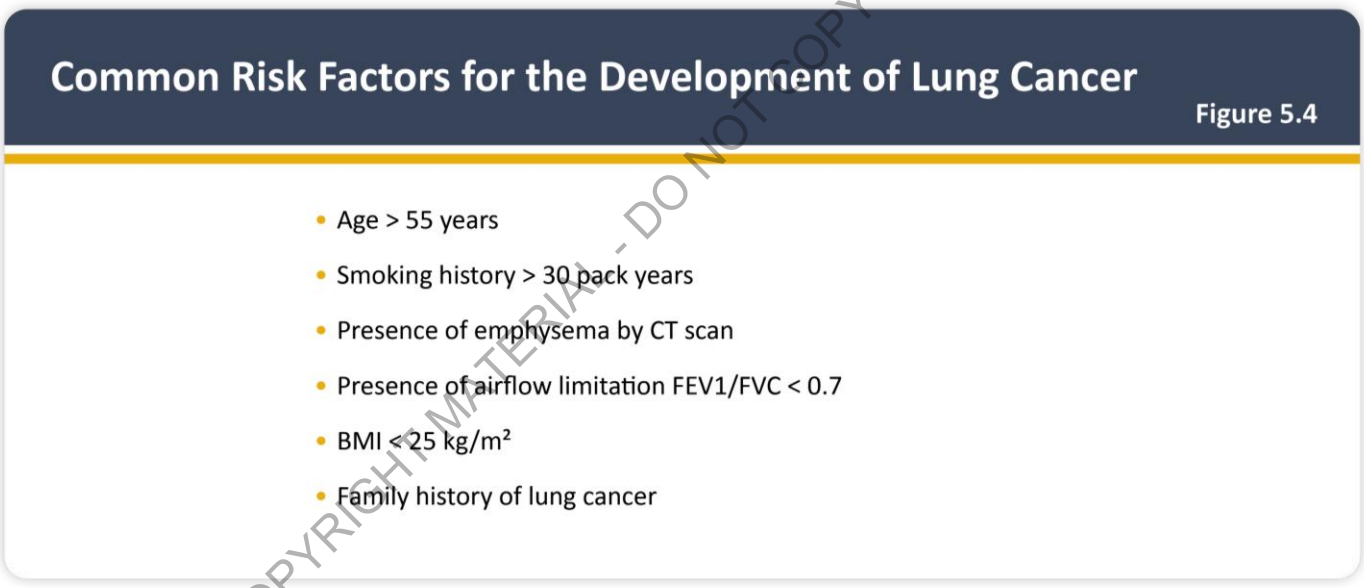
Peripheral artery disease

PAD is commonly associated with atherosclerotic heart disease and may have significant implications for functional activity as well as health-related quality of life in people with COPD.[1194] In a large cohort of patients with COPD of all degrees of severity, 8.8% were diagnosed with PAD – a prevalence that is higher than in non-COPD controls (1.8%).[1194]

Patients with COPD and PAD reported worse functional capacity and health status compared to those without PAD. The management of PAD depends on its severity, with surgery to be considered in patients with severe limitations.[1195]

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 combined, causing an estimated 1.6 million deaths worldwide each year.[1196] Unfortunately, the great majority of lung cancers are diagnosed at an advanced stage, resulting in poor overall survival.[1197] Therefore, primary and secondary prevention and early detection are important to improve survival. The association between COPD and lung cancer has been systematically confirmed in several epidemiological and observational cohort studies.[1124,1198-1201] These two diseases appear to share more than tobacco smoke exposure as their common origin (**Figure 5.4**). 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.[1202-1204] Whether the spirometric severity of airflow obstruction is directly or inversely associated with a greater risk for lung cancer development remains controversial.[1200,1205] The association between lung cancer and the 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.[1206,1207] The best preventive measures for lung cancer (as for COPD) are smoking prevention and cessation.[1208]



Several studies involving the use of low-dose chest CT screening have shown improved survival.[400,1209,1210] The USPSTF updated its recommendation for lung cancer screening in 2021,[1211] based on a systematic review that examined the accuracy of screening for lung cancer, and that considered the benefits and harms associated with lung cancer screening. USPSTF also commissioned collaborative modeling studies from the National Cancer Institute 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 low-dose CT in adults aged 50-80 years who have a 20-pack year smoking history and currently smoke, or who quit smoking within the past 15 years. They recommend stopping screening once either the 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 modelling 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.[1211-1215] COPD has also been reported to be an independent risk factor for lung cancer incidence in never smokers,[1216,1217] with

risk factors including biomass fuel exposure, second-hand smoke, radon exposure, air pollution, a family history of lung cancer, and asbestos exposure. However, 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 for these individuals since the possible harms of screening seem to outweigh the possible benefit of finding early lung cancer.[1218] Although the USPSTF recommendations are supported by several major medical societies, important questions still 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.[399,1219]

The implementation of a screening program, where available, could be useful, but has to be implemented in the appropriate environment to avoid over-diagnosis, increased morbidity and mortality due to needless diagnostic procedures for benign abnormalities, and anxiety and incomplete follow-up.[1220] However, one Danish study suggested that being part of a lung cancer screening program significantly promotes smoking abstinence,[1221] 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.[1208] Smoking cessation interventions as part of CT scan screening programs could be of use.

Inhaled corticosteroids and lung cancer incidence

ICSs are recommended in selected people with COPD, although their potential impact on the development of lung cancer has been the subject of conflicting reports.[1222-1224] Based on the available data, ICSs do not appear to increase or decrease the risk of lung cancer – although this is pending studies adequately planned to clarify these important questions.

Asthma

Patients with asthma have a high risk of developing COPD, even after adjusting for smoking status.[160] Furthermore, airflow limitation that persists after bronchodilator administration may be present in 5-21% of patients with asthma.[1225,1226] Patients with comorbid asthma and COPD have increased dyspnea, worse health-related quality of life, an increased risk of exacerbation and hospitalization, greater lung function decline, and a reduced life expectancy compared to those with COPD alone.[1227-1230] In patients with COPD, the coexistence of asthma should be considered in those with a family history of asthma, previous childhood diagnosis of asthma/bronchitis, wheezing, atopic manifestations, childhood respiratory infections, and use of inhaled medications.[1231]

Bronchodilator responsiveness and blood eosinophil levels do not differentiate between asthma, COPD, or comorbid asthma and COPD, even though blood eosinophil and fractional exhaled nitric oxide levels tend to be higher in those with comorbid asthma and COPD.[1232,1233] We recommend the close examination of a lung CT, as patients with comorbid asthma and COPD tend to have greater airway thickness and less emphysema than those with COPD alone. Furthermore, mucus plugging is more prevalent in patients with asthma or comorbid asthma and COPD than COPD alone, and the extent of mucus plugging is associated with increased mortality.[187,190,1234]

All asthma preventive measures and treatments should be employed, particularly maintenance ICS, if asthma is identified in a patient with COPD. Some patients with COPD and T2 inflammation without a diagnosis of asthma benefit from biologic therapy.[681,691,1235]

Pulmonary tuberculosis

Pulmonary TB and COPD are two prevalent respiratory diseases in LMICs. Increasing evidence has shown that a history of pulmonary TB is associated with the development of chronic airflow obstruction,[215,1236] while patients with COPD have a three times increased risk of developing active TB compared with the general population.[1237] Pulmonary TB can cause permanent structural abnormalities in both the airways and lung parenchyma, such as calcification,

cavitation, traction bronchiectasis, and fibrosis, leading to post-TB lung damage. Besides, TB may induce a particular form of inflammatory response with small airway and perivascular involvement which may further contribute to gas trapping, airflow limitation, and impaired diffusion capacity.[213,1238] Given these pathophysiological features, TB-associated COPD is increasingly recognized as a distinct cause of COPD. Cigarette smoking and *Mycobacterium tuberculosis* infection may act synergistically to exacerbate lung destruction, and patients with TB who smoke often present with more severe disease, increased cavitation, delayed response to anti-TB therapy, and worse outcomes.

The use of ICS, especially at higher doses, may increase the risk of TB reactivation or development in patients with COPD,[1239,1240] and in patients with underlying risk factors, such as those living in TB-endemic regions, patients with radiologic sequelae of TB, and patients who are immunocompromised or have comorbidities such as diabetes or low bodyweight.[1241,1242] In such settings, ICS should be used with caution and active TB must be excluded before initiation of this therapy. Patients should be closely monitored during treatment.

Bronchiectasis

With increasing use of CT in the assessment of COPD, previously unrecognized bronchiectasis is often being identified,[1243] although it is unclear at present whether a diagnosis based on radiological criteria has the same impact as a clinical diagnosis of bronchiectasis. The prevalence of bronchiectasis in patients with COPD has been reported in several studies with varied results ranging from 20-69%.[315,1244] Bronchiectasis is probably caused by an interplay between chronic airways infection and inflammation in COPD.[1245] A continuum may exist between chronic bacterial infection without radiological changes and overt radiological bronchiectasis.[534,1246] Comorbid bronchiectasis in COPD tends to be cylindrical or tubular, bilateral and lower lobe dominant, and is associated with increased exacerbation frequency, increased risk of pneumonia, airflow obstruction, and mortality.[314,1247,1248] If bronchiectasis is diagnosed (usually with imaging), tests to determine etiology should be individualized, such as immunoglobulin deficiency, cystic fibrosis transmembrane conductance regulator mutation, ciliary dysfunction, and fungal or mycobacterial infection.

In patients with COPD and bronchiectasis, ICS use should be carefully evaluated because such individuals are prone to pneumonia and nontuberculous mycobacteria infections.[1249] A blood eosinophil threshold of 300 cells/µL could be used to support ICS use, although if lower respiratory tract infections are frequent, ICS cessation should be considered. Macrolide therapy may benefit both the COPD and bronchiectasis by reducing exacerbations. Measures to enhance secretion clearance and chronic inhaled antibiotics can prevent exacerbations.[1250] Sputum culture is indicated, because its results may help guide antibiotic therapy. The anti-inflammatory dipeptidyl peptidase-1 inhibitor brensocatib, which has been evaluated in bronchiectasis and approved by the FDA, might also be effective in patients with combined bronchiectasis and COPD.[1251]

Interstitial lung disease / interstitial lung abnormalities

ILDs are conditions hallmarked by fibrotic changes of the lung.[1252-1254] COPD and ILDs may coexist as they share common risks (e.g., older age, male sex, and occupational and toxic inhaled exposures). Patients with ILDs typically report dyspnea as their main symptom due to similar mechanisms as COPD despite marked differences in respiratory mechanics.[1255,1256] When patients with comorbid ILDs and COPD experience an acute exacerbation it may be due to either disease, with important implications for treatment and prognosis.[1257] ILAs, an imaging finding of early ILDs that occurs in 7-10% of patients with COPD, are associated with worsening dyspnea, health-related quality of life and exercise capacity, and increased mortality risk.[246] A smaller subset of patients may present with combined pulmonary fibrosis (usually in lower lobes) and emphysema in the upper zones, with lung function tests that indicate a marked reduction in diffusing capacity but lung volumes within the normal range.[1258]

A careful examination of thoracic imaging, preferably chest HRCT, may help exclude the presence of ILAs or ILDs. Lung function testing at diagnosis and sequential measurements help define disease progression. Patients with combined COPD and ILD require a multidisciplinary approach, involving specialists in COPD, ILD, pathology and radiology.

Although there are no specific trials of anti-fibrotic treatments in patients with COPD and ILDs, we recommend intermittent follow-up, including assessment of DLco every 6-12 months to define disease progression. In this context, patients with some emphysema (< 30%) and pulmonary fibrosis treated with antifibrotics have a lung function decline similar to treated patients with pulmonary fibrosis without COPD.[1259]

Obstructive sleep apnea

OSA is a sleep disorder hallmarked by repeated episodes of upper airway closure that affects 9-26% of the US adult population.[1260] Both COPD and OSA frequently coexist, particularly in obese men and obese post-menopausal women.[1261-1263]

Patients with both COPD and OSA have a worse prognosis compared with either condition alone.[1264] During sleep, they experience more frequent episodes of oxygen desaturation and have more total sleep time with hypoxemia and hypercapnia than patients who have OSA without COPD.[1265] Their apneic events involve more profound hypoxemia and more cardiac arrhythmias,[1266] and they are more likely to develop daytime pulmonary hypertension[1267,1268] than patients with just OSA or COPD alone.

If there is a clinical suspicion of OSA (e.g., obesity, snoring, daytime somnolence, hypertension) a formal sleep study is indicated.

For patients with COPD and OSA, a program should be implemented that includes weight loss for obese patients, reduced alcohol intake, and sleep hygiene interventions. CPAP or bi-level positive airway pressure should be initiated in patients with COPD and sleep disordered breathing as it improves health-related quality of life and decreases the risk of death.[762] Further, in patients with COPD and OSA, CPAP has been reported to reduce all-cause hospitalizations, emergency room visits, moderate and severe exacerbations and associated healthcare costs.[762,1271] Weight reduction medications, such as glucagon-like peptide receptor agonists could help in selected obese patients.[1272,1273]

MENTAL CONDITIONS

Anxiety, depression and psychosis

Anxiety and depression are important and underdiagnosed morbidities in patients with COPD,[327,1274-1276] and both are associated with poor prognosis.[1275,1277] The prevalence of anxiety alone and combined anxiety and depression is similar in men and women with COPD (all approximately 34%), whereas depression alone is more common in men than women (61% versus 39%). Furthermore, younger age is associated with more severe symptoms of depression and anxiety.[88,327,1276,1278] COPD is very common in patients with other psychiatric illnesses, particularly schizophrenia,[1279-1281] and people with COPD are twice as likely to commit suicide as those without COPD.[1282]

Untreated depression and anxiety are associated with social isolation, increased healthcare utilization, premature mortality, and increased disease burden for patients and their caregivers. Depression, anxiety and psychosis (including schizophrenia and substance abuse, both alcohol and drugs) are independently associated with elevated 30-day readmission rates in patients with COPD, and are important determinants of death in younger patients with COPD.[1281,1283-1286] People with severe mental illness tend to receive medical care intermittently, often with a lack of continuity of care and infrequent use of primary and preventive services. Physical symptoms may be viewed as "psychosomatic" leading to under-diagnosis. People with COPD and schizophrenia are less likely to receive adequate general medical care, including investigation and treatment, in line with guidelines.[1281]

The Patient Health Questionnaire-2 for depression, with scores less than three suggesting no important

depression,[1287] and the Generalized Anxiety Disorder-2 for anxiety, with the same score threshold,[1288] can be used as screening tools to detect clinically significant depression or anxiety.

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.[1289,1290] Combining pulmonary rehabilitation and cognitive behavioral therapy are effective in alleviating anxiety and depressive symptoms.[1291,1292] Anti-depressant drug therapy needs to be managed with caution, and patients with severe depression and suicidal ideation or attempts must be referred promptly for specialist treatment.

Cognitive impairment and dementia

Cognitive impairment is common in people with COPD,[1293] with an estimated average prevalence of 32%,[1294] although prevalence and severity vary by the type of assessment,[1295] and extensive neuropsychological testing suggests that up to 56% of patients with COPD may have cognitive impairment.[1296,1297] Longitudinal studies suggest a greater risk of developing cognitive impairment in patients with COPD that is diagnosed in midlife,[1293,1298] and associate COPD with the development of dementia.[1299] In a systematic review, age-matched patients with COPD had a 24% increased risk of dementia and a 30% elevated risk of cognitive impairment compared to individuals without COPD, with no differences by sex, although the risk of both increased with age.[1300]

Cognitive impairment has been associated with impairment in basic activities of daily living,[1301,1302] and variably associated with impaired health status.[1303,1304] The coexistence of cognitive impairment and COPD is associated with an increased risk of hospitalization, longer hospital stay during acute exacerbation hospitalization, worse health-related quality of life, and increased risk of death.[1301,1302,1305,1306]

Patients with cognitive impairment are more likely to make errors when using inhalers.[1301] The relatively easy to use Mini Mental State Examination can help screen for cognitive impairment,[1307] with the Montreal Cognitive Assessment test being a potential alternative.[1308]

Patients with COPD who have mild cognitive impairment should be enrolled in pulmonary rehabilitation programs with or without cognitive training.[1309] Addressing potential underlying risk factors such as sleep deprivation, hypoxemia, frequent exacerbations and atherosclerosis is important. Patients with dementia should be referred to mental healthcare specialists for further neuropsychological assessment and treatment.

METABOLIC DISEASE

Diabetes mellitus

Studies have shown that metabolic syndrome and manifest diabetes are frequent in patients with COPD.[468,1310] Type 2 DM is present in approximately 20% of patients with COPD, increasing morbidity and mortality, and complicating the management of both.[1311] Type 2 DM is associated with a restrictive lung function profile, independent of race, age, sex, country of origin, bodyweight, smoking history, or history of lung disease,[1312,1313] although insulin resistance is associated with an increased risk of COPD in women but not in men.[1314] When patients are treated with systemic corticosteroids during exacerbations, hyperglycemia worsens, enhancing the risk of infection and prolonging the duration of the episode. ICS, especially in high doses, are associated with worsening DM control and increased risk of glaucoma and cataracts.[1315]

Measurement of hemoglobin A1c and fasting blood glucose for patients who have not had these tests in more than a year can help verify a diagnosis and monitor disease control. COPD should be treated as usual, although efforts should

be made not to use systemic corticosteroids. If indicated, they should be used at the lowest possible dose for the shortest possible time. The use of novel DM therapies such as glucagon-like peptide agonists and sodium-glucose cotransporter-2 inhibitors are promising, but further trials in COPD specific populations are needed before clear recommendations can be made.[1316,1317]

Obesity

The relationship between weight and COPD outcomes is complex. Extensive data in multiple cohorts show that there is increased mortality risk at BMI extremes,[1003,1318-1320] such that values < 21 kg/m^2 or > 30 kg/m^2 contribute to a poor prognosis. Obesity is associated with airflow limitation, increased symptoms such as dyspnea, and an elevated risk of cardiovascular complications, although it appears protective for COPD progression and respiratory-related mortality. Very obese patients with COPD are more likely to decompensate and require non-invasive or mechanical ventilation, and have a higher tracheostomy rate and odds of being discharged on domiciliary oxygen.[1321] However, a low BMI also carries a poor prognosis, being a phenotype of COPD with a higher mortality risk than patients of normal weight. Thus, the most beneficial BMI for patients with COPD appears to be one that is within the 'normal' or 'overweight' categories.

BMI should be measured at all visits, and changes monitored over time. Optimization of BMI includes lifestyle management implementing regular exercise, adequate nutrition to attain and maintain BMI 21-30 kg/m^2. The recent introduction of weight control medications with important beneficial systemic effects should be considered by providers knowledgeable of their use.[1322]

Gastroesophageal reflux

GERD is an independent risk factor for COPD exacerbations, and is associated with worse health status in patients with COPD,[445,1323,1324] although the mechanisms responsible for the increased risk of exacerbations are not yet fully established.

GERD should be minimized through weight loss (if obese) and avoiding late-night meals or specific food and drink that might aggravate reflux. In addition, a semi-recumbent sleeping posture may be helpful, and an empiric trial of a proton-pump inhibitor may improve GERD symptoms and decrease the risk of exacerbation,[1325] In patients with severe reflux and in whom conservative therapy has failed, surgical fundoplication has been effective.[1326,1327]

Liver steatosis

NAFLD, also known as metabolic dysfunction-associated steatotic liver disease, affects 30-60% of patients with COPD,[1328] linked through common risk factors (e.g., chronic inflammation, obesity, inactivity) or causal mechanisms such as hypoxemia. It can be detected using low-dose chest CT,[529,1329] and although most cases are benign, 20-30% can progress to MASH (metabolic dysfunction-associated steatohepatitis), which can in turn progress to liver cirrhosis and hepatocellular carcinoma.[1330] Although NAFLD prevalence is slightly increased in patients with COPD it does not seem to worsen the prognosis of COPD.[1331]

Liver function testing and checking the CT for evidence of NAFLD can help establish the diagnosis. These patients should be advised to lose weight, exercise regularly, control risk factors such as hyperglycemia, hypertension and hypercholesterolemia, and avoid alcohol. Resmetirom, a thyroid hormone receptor β-agonist, has been approved in some countries for the treatment of metabolic dysfunction-associated steatohepatitis,[1332,1333] while glucagon-like peptide-1 receptor agonists may also be of use in this disease.

DISEASES WITH MULTIPLE ORGANS LOSS OF TISSUE

The term 'multiple organs loss of tissue' (MOLT) has been proposed for patients with emphysema, low BMI, osteoporosis and sarcopenia.[1334] These characteristics frequently co-occur in patients with COPD, and are associated with poor exercise capacity, compromised health-related quality of life, and an increased risk of exacerbations, hospitalizations and mortality.

Osteoporosis

Osteoporosis is an important and common comorbidity in patients with COPD,[469,1125] which is often under-diagnosed[1335] and is associated with poor health status and prognosis. The prevalence may be as high as 30% in women and 18% in men, with the prevalence increased by the presence of COPD.[1336] Osteoporosis is often associated with emphysema,[1337] decreased BMI[1338] and low fat-free mass.[1339] Low bone mineral density and fractures are common in people with COPD even after adjustment for steroid use, age, pack-years of smoking, current smoking, and exacerbations.[1340,1341] Systemic corticosteroids significantly increase the risk of osteoporosis, and repeated courses for COPD exacerbations should be avoided if possible. An association between ICS use and fractures has been found in pharmaco-epidemiological studies;[1342] however, these studies have not fully taken severity of COPD or exacerbations and their treatment into consideration.

Clinically, chest CT scans can help identify individuals with low bone mineral density and muscle mass who should undergo more detailed assessment. Dual energy X-ray absorptiometry scanning can establish bone mineral density with excellent precision.

COPD should be treated as usual despite the presence of osteoporosis. Given the complicated landscape of anabolic and antiresorptive agents for the treatment of osteoporosis, these patients should be managed by providers familiar with the treatments or referred to an osteoporosis specialist.[1343]

Renal failure

The prevalence of renal failure, defined as GFR < 60 mL/min/1.73 m^2, is three-times higher in patients with COPD than in matched controls (approximately 7% in patients aged < 65 years; 17-20% in those > 70 years).[1344,1345] Because sarcopenia is frequent in patients with COPD, serum creatinine levels may be normal in patients with renal failure. Low estimated GFR values are associated with decreased health-related quality of life and 6MWD, and increased hospitalizations and mortality.[1346] Importantly, glomeruli number and size are decreased in patients with COPD, who also frequently have microalbuminuria.[1347,1348]

Estimated GFR should be measured, and the use of medication should be checked, since patients with COPD frequently receive potentially nephrotoxic drugs, such as non-steroidal anti-inflammatory drugs, or treatments that are eliminated via the kidney. Furthermore, many patients with COPD receive an ACE inhibitor, angiotensin II receptor blocker or β-blocker that can decrease erythropoietin production. With renal failure, it is important to adjust medications that can injure the kidney or where renal elimination of the drugs may result in relevant side effects.[1349]

Anemia

Anemia is frequent in people with COPD, with a reported prevalence of 7.5-34%.[1350] Those with combined COPD and anemia are generally older, have more frequent cardiometabolic comorbidities, greater dyspnea, worse health-related quality of life and airflow obstruction, reduced exercise capacity, an increased risk of severe exacerbations and higher mortality than patients with COPD alone.[1350-1356]

Anemia due to chronic disease is the most common type seen in COPD, followed by iron deficiency anemia,[1357,1358]

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, ACE inhibitors, angiotensin II receptor inhibitors, renal dysfunction, and androgens.[1359-1367]

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 the correction of anemia 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

Smoking causes an increase in carboxyhemoglobin, thereby increasing red blood cell mass and the risk of secondary polycythemia in patients with COPD.[1368,1369] Indeed, secondary polycythemia has long been recognized as a common comorbidity in COPD, with a reported prevalence of 6-10.2% in patients with COPD in an outpatients department (when defined as hemoglobin ≥ 17g/dL in males and ≥ 15g/dL in females),[1352,1354,1370] and 9.2% of men and 3.5% of women in the COPDGene cohort.[1371]

Male sex, current smoking, living at high altitude (e.g., Denver, Colorado, USA), impaired DLco, and severe hypoxemia are associated with an increased risk for secondary polycythemia, whereas LTOT use is associated with a decreased risk.[1371,1372] The coexistence of OSA is also associated with an increased risk of polycythemia in patients with COPD.[1373]

Secondary polycythemia in COPD may be associated with PH,[1374,1375] venous thromboembolism,[1375] and increased mortality.[1376,1377] 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 patients with 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.

POSTOPERATIVE RISK OF COPD ON GENERAL AND THORACIC SURGERY OUTCOMES

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 patients with COPD.[1378] 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.[1014,1379,1380]

The risk of postoperative pulmonary complications in patients with COPD 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.[1380] 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%.[874] These data suggest that intubation and/or simple airway manipulation may increase the risk of exacerbation in select patients with COPD.

To prevent postoperative pulmonary complications, patients with COPD who are clinically symptomatic and/or have limited exercise capacity should be treated medically intensively before surgery, with all the measures already well established for such 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.

Resection for lung cancer treatment

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.[1381,1382] Patients with COPD who are 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.[1381,1382]

The risk of postoperative complications from lung resection appears to be increased in patients with decreased predicted postoperative pulmonary function (FEV_1 or DLco < 30-40% predicted) or exercise capacity (peak VO_2 < 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.

OTHER CONSIDERATIONS

Periodontitis and dental hygiene

The association between COPD and periodontitis has been mainly reported in the dental literature, although whether this reflects common causative factors such as age, smoking, and socioeconomic circumstances remains speculative. Both conditions have a common (neutrophilic) relationship; whether this reflects cause or effect is difficult to elucidate,[1383] although one study suggested a shared pathophysiology between periodontitis and COPD, with similar aberrant neutrophil function, especially when associated with AATD.[1384]

The risk of developing periodontitis is proportional to COPD control, with prevalence increasing with the number of emergency department visits for COPD.[1385] High antibody levels to common periodontal pathogens is associated with fewer exacerbations of COPD.[1386] In a recent systematic review, low to moderate quality evidence suggests that periodontal treatment is associated with slower lung function decline, reduced frequency of exacerbations, and less healthcare resource use in patients with COPD and chronic periodontitis.[1387] 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.

Vitamin D deficiency

Patients with COPD may have low vitamin D levels due to reduced sunlight exposure (COPD symptoms keep patients indoors) and poor dietary intake. In addition, long-term use of corticosteroids impairs vitamin D absorption and some studies have shown that very low vitamin D levels are linked to increased risk of lung infections, which can trigger exacerbations and worsen COPD.[1388] A meta-analysis of RCTs found that vitamin D supplementation significantly reduced moderate/severe exacerbations in patients with very low baseline levels (< 25 nmol/L).[996] Thus, consider

checking for vitamin D deficiency in people with COPD, particularly if the patient has a history of frequent exacerbations.

Guide to the practical tools available to evaluate and monitor multimorbid patients with COPD

A useful grouping of testing that could be used to evaluate multimorbid patients with COPD is presented in **Figures 5.5** and **5.6**. Although not all need to be used in every patient, a systematic approach considering these tools could help organize care in complex cases.[1133]

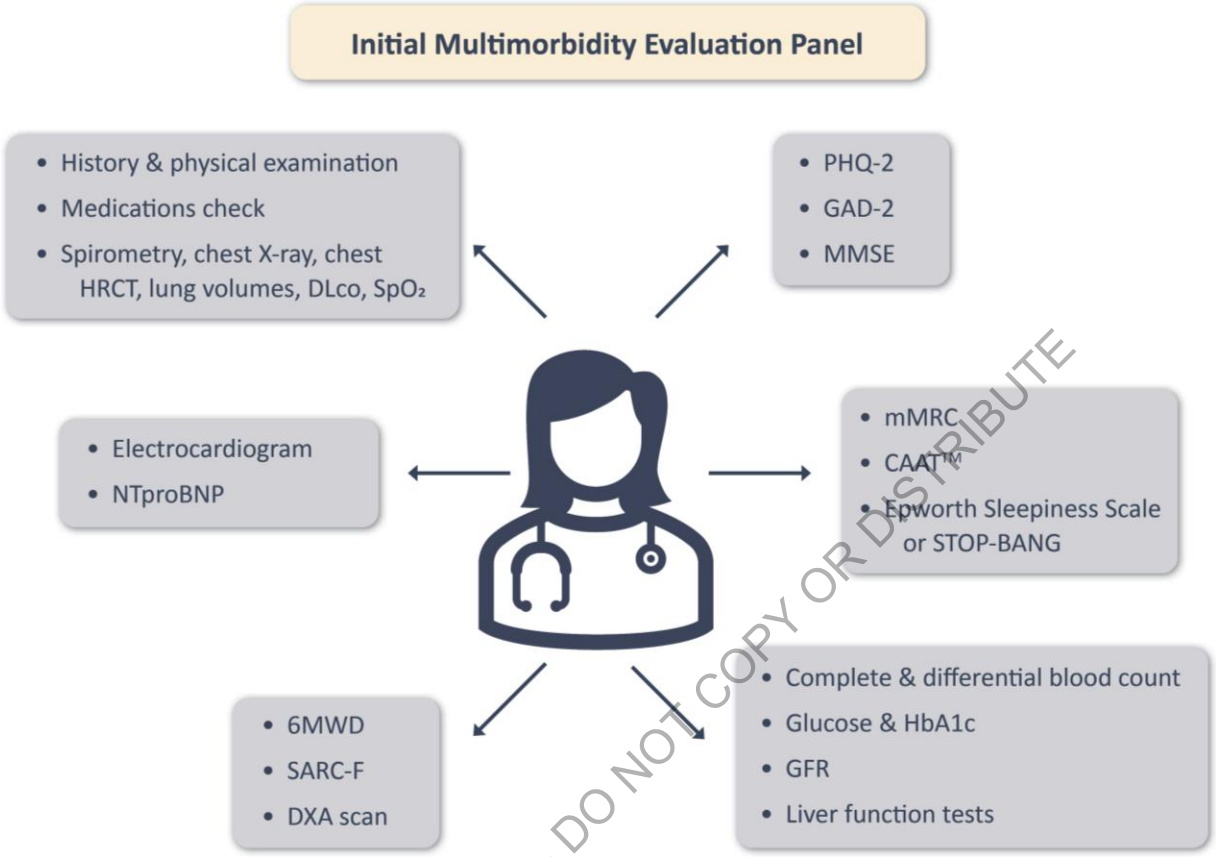
COPD as part of multimorbidity

As expected, multimorbid 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. GOLD does not aim to turn the specialist into a generalist, but we propose that healthcare providers managing patients with COPD should integrate clinical information to help maximize the interaction with the patient to the benefit of the latter. A proactive, holistic rather than a siloed approach can decrease the fragmented care so prevalent in today's healthcare systems. Simple and practical clinical tools are available to most clinicians that help identify and grade the severity of the most important morbidities affecting individual patients, and that determine whether the problem is being properly addressed. If it is not, either treat it according to best practice or help direct the patient to the appropriate specialist care and resources to achieve optimal management. As a rule, there is no evidence that COPD should be treated differently when part of multimorbidity; however, it should be kept in mind that most evidence comes from trials in people with COPD as the only significant disease.[470]

Finally, treatments should be kept simple in the light of the unbearable polypharmacy that these patients are often exposed to. It is likely that a holistic approach in the management of patients with COPD might help reverse the effects of different diseases on overall health, prevent exacerbations, improve health-related quality of life and hopefully reduce hospitalizations and the risk of death.

Potential Complementary Approach for the Detection of Frequent Morbidities in all Patients with COPD – Initial Evaluation

Figure 5.5

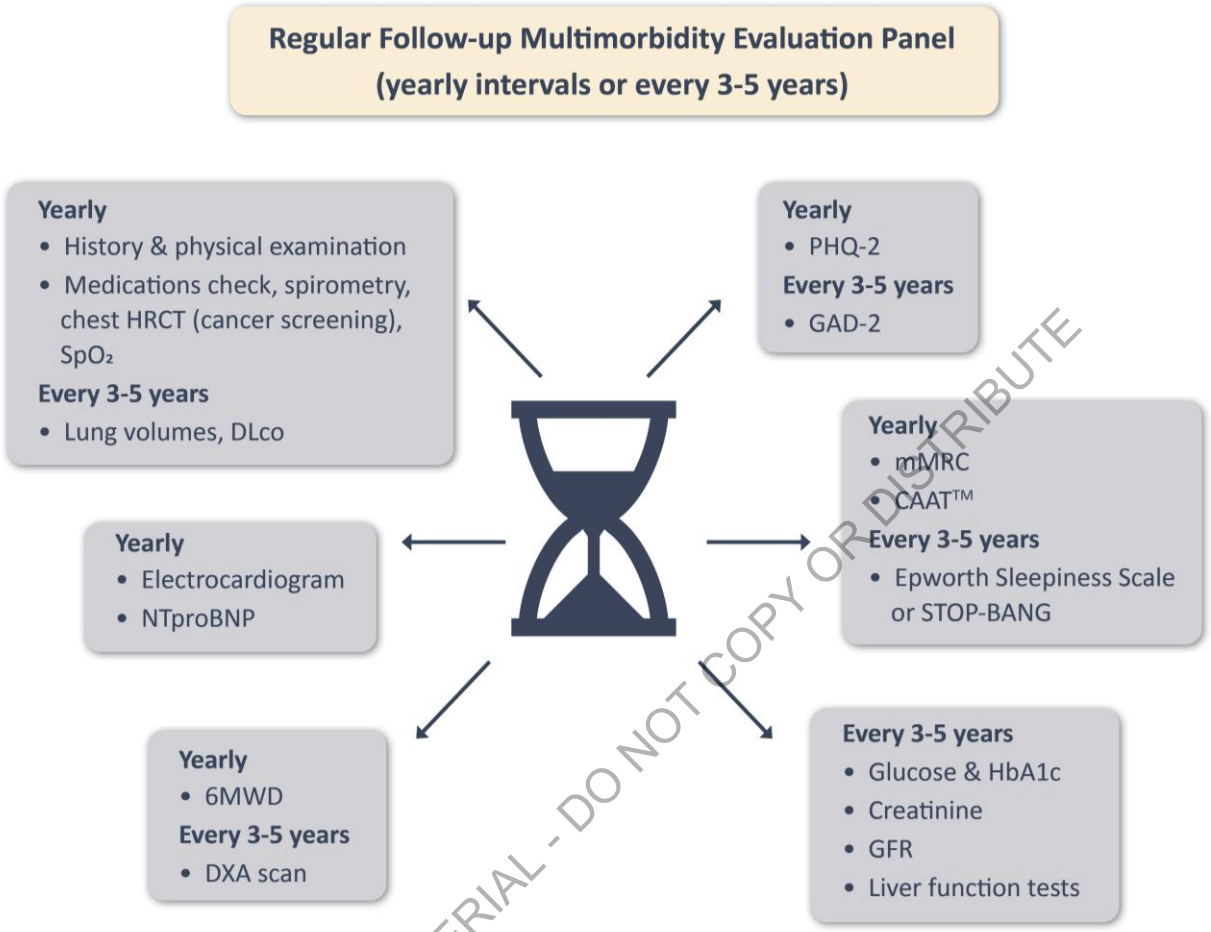


Abbreviations: HRCT, high-resolution computerized tomography; DLco, diffusing capacity for carbon monoxide; SpO_2, oxygen saturation; SARC-F, Strength, Assistance walking, Rising from chair, Climbing stairs and Falls; DXA, dual energy X-ray absorptiometry; mMRC, modified Medical Research Council dyspnea scale; CAAT™, Chronic Airways Assessment Test; GFR, glomerular filtration rate; NTproBNP, N-terminal prohormone of brain natriuretic peptide; 6MWD, 6-minute walking distance test; HbA1c, glycated hemoglobin A1c test; PHQ-2, Patient Health Questionnaire-2; GAD-2, Generalized Anxiety Disorder-2; MMSE, Mini Mental State Examination.

Adapted from: Celli BR, Fabbri LM, Yohannes AM, Hawkins NM, Criner GJ, Bon J, Humbert M, Jenkins CR, Pantoni L, Papi A, Quint JK, Sethi S, Stolz D, Agusti A, Sin DD. A person-centred clinical approach to the multimorbid patient with COPD. Eur J Intern Med. 2025 Aug 12:106424. doi: 10.1016/j.ejim.2025.07.020.

Potential Complementary Approach for the Detection of Frequent Morbidities in all Patients with COPD – Regular Follow-up

Figure 5.6



Abbreviations: HRCT, high-resolution computerized tomography; DLco, diffusing capacity for carbon monoxide; SpO_2, oxygen saturation; SARC-F, Strength, Assistance walking, Rising from chair, Climbing stairs and Falls; DXA, dual energy X-ray absorptiometry; mMRC, modified Medical Research Council dyspnea scale; CAAT™, Chronic Airways Assessment Test; GFR, glomerular filtration rate; NTproBNP, N-terminal prohormone of brain natriuretic peptide; 6MWD, 6-minute walking distance test; HbA1c, glycated hemoglobin A1c test; Patient Health Questionnaire-2; GAD-2, Generalized Anxiety Disorder-2.

Adapted from: Celli BR, Fabbri LM, Yohannes AM, Hawkins NM, Criner GJ, Bon J, Humbert M, Jenkins CR, Pantoni L, Papi A, Quint JK, Sethi S, Stolz D, Agusti A, Sin DD. A person-centred clinical approach to the multimorbid patient with COPD. Eur J Intern Med. 2025 Aug 12:106424. doi: 10.1016/j.ejim.2025.07.020.

CHAPTER 6: ARTIFICIAL INTELLIGENCE AND EMERGING TECHNOLOGIES IN COPD

KEY POINTS:

- Artificial intelligence can help in the diagnosis, assessment, clinical management, and prediction of prognosis of COPD.
- Yet, AI comes with risks and limitations that need careful consideration before deployment in clinical practice.
- Telehealth includes virtual, hybrid virtual and in-person care models.
- Telehealth may offer improved healthcare access, outcomes, and affordability.
- Pulmonary rehabilitation and self-management may be delivered virtually.
- Evidence is still emerging regarding the effectiveness of virtual compared to in-person delivery.

ARTIFICAL INTELLIGENCE IN COPD

The term artificial intelligence refers to a set of rules (algorithms) that enable computers to learn, analyze data and make decisions based on that knowledge.[1389,1390] **Figure 6.1** shows a list of common "*AI models*" which differ in the way they are trained and analyze data.[1391] AI comes with risks and limitations that need careful consideration before deployment in clinical practice (**Figure 6.2**).[1392] Below we discuss briefly some areas where AI can be helpful in COPD and we refer the interested reader to a recent manuscript that extends these concepts further.[1393]

Diagnosis

Underdiagnosis, misdiagnosis and late diagnosis are very prevalent in COPD.[382,1394,1395] They are clinically relevant because underdiagnosis implies no treatment, misdiagnosis can lead to wrong treatment, and late diagnosis likely supposes less effective treatment. AI can help address these three domains.

Underdiagnosis

AI can potentially help identify individuals at risk in electronic health records, both in primary and specialized care. This can also be done in the community, as shown in Canada.[386] There may even be the opportunity to identify undiagnosed patients with COPD in lung cancer screening programs.[386,1396] However, currently the quality and interoperability of the data included in the EHR, together with the legal framework on data access and medical devices, may limit its practical implementation.

Misdiagnosis

AI based interpretation strategies can reduce misdiagnosis by providing automated interpretations and diagnostic suggestions.[1397-1399] Likewise, AI may be able to extract novel, hidden, high-dimensional features from the flow-volume spirometry loops.[1398,1400]

Principal AI Models

Figure 6.1

Machine Learning (ML)	• Algorithms learn patterns from data without being explicitly programmed
Supervised Learning	• Training a model with labelled data (input + known output)
Unsupervised Learning	• Training without labels to find hidden patterns or clusters
Reinforcement Learning (RL)	• Training by trial and error, guided by rewards or penalties
Deep Learning (DL)	• ML approach using neural networks with many layers to automatically extract features
Neural Network (NN)	• A computational system inspired by the brain, made of interconnected nodes ("neurons").
Natural Language Processing (NLP)	• AI field focused on analyzing and generating human language from medical text
Large Language Models (LLMs)	• Very large NLP models trained on massive text corpora for versatile language tasks
Foundation Models	• Very large models trained on diverse data that can be adapted (fine-tuned) to many tasks
Generative AI	• Models that can create new data (text, images, molecules) based on learned patterns

Late diagnosis

The diagnosis of COPD is often established (if it is at all) in the 7th decade. By then the disease is frequently far advanced and less responsive to treatment.[1401] As discussed above, AI can facilitate earlier diagnosis by searching EHRs.[1402,1403] Further, several studies used AI to predict lung function trajectories and risk of COPD in individuals in the general population requiring intervention.[1404,1405]

AI-assisted diagnostic alternatives to spirometry

There are several AI-assisted novel diagnostic alternatives to spirometry being explored in relatively small populations, so they require validation in larger cohorts:[1406]

- Analysis of respiratory sound attributes[1407]
- Analysis of voice features[1408]
- Oscillometry (FOT, IOS, AOS)[1409]
- Motion sensors[1410]
- E-nose signals / volatile organic compounds (VOC)[1411,1412]
- Photoplethysmography[1413]

- Chest computed tomography (CT)[296,1414-1416]
- Electrical Impedance Tomography (EIT)[1414]

Potential Risks and Mitigation Strategies of AI in Medicine

Figure 6.2

	Potential Risks	Mitigation Strategies
Clinical Risks	• Misdiagnosis, overreliance on AI, biased outcomes	• Rigorous validation, human oversight, bias testing
Data-Related Risks	• Poor data quality, biased training data, privacy breaches	• Data cleaning, diverse datasets, strong security protocols
Technical Limitations	• Black-box models, poor generalizability, data drift	• Use interpretable models, retraining, external validation
Ethical & Legal Risks	• Unclear accountability, informed consent issues, inequity	• Clear liability frameworks, transparent patient communication, equitable access
Operational Challenges	• Workflow integration problems, regulatory complexity, high maintenance costs	• User-centered design, regulatory alignment, ongoing monitoring and funding

Heterogeneity of COPD

COPD is a heterogeneous disease, and clinical management can be improved if a personalized and precise approach to care is used. Biomarkers can potentially be used to address this heterogeneity.

Imaging biomarkers

The use of AI imaging is the most developed AI platform currently utilized in COPD. AI can be used to quantify the extent and the pattern of emphysema and to analyze fissure integrity, mucus plugs, bronchiectasis and/or pulmonary vessels.[1417] Likewise, using AI-assisted analysis of nodules may avoid overuse of invasive procedures and a more accurate and rapid classification of patients at risk of lung cancer.[1418]

Biologic biomarkers

Several studies used AI on omics data to identify biologic biomarkers of potential use in COPD.[1419-1421] Most of them require validation in large cohorts with longitudinal data[1422] but clearly pave the way for a better characterization of COPD patients and, potentially, the identification of novel therapeutic targets.

Multimodal models

Multimodal models that integrate biological and imaging data may offer better insights into COPD risk and progression. Emerging foundation models (**Figure 6.1**) such as *Merlin* extends this concept further by integrating imaging and text but also structured clinical and laboratory data.[1418,1423] This highlights the potential of AI to address the complex, multi-domain nature of COPD risk stratification and management.

Management guidelines, multimorbidity and AI

The concept of evidence based medicine (EBM) has been widely adopted by the medical community since its proposal, back in 1992.[1424] As a result, a large number of evidence-based clinical practice guidelines are now available. Yet, to be fully and appropriately implemented in clinical practice, any clinical practice guideline needs to be read, memorized and applied wisely by the practicing physician. Many patients with chronic diseases, including COPD, often suffer from other diseases.[294] So, many different guidelines need to be considered in everyday practice.[1133] This is an herculean process where AI can be of great help, since algorithms could be embedded in current EHR systems to summarize the current clinical status of the multimorbid patient who has been seen by different (often many) specialties and/or to advise the practicing physicians of potential problems with the management of that patient (e.g., polypharmacy, inappropriate treatment of a multimorbid disease, tests missing, vaccination needed and others). As a side note, in order to get AI collecting the appropriate information included in the EHRs, the use of acronyms (which often vary between specialties and even between physicians) should be banned. An alternative, already in place in some institutions, is that the conversation between the patient and the doctor is continuously recorded ("keyboard zero"). Then, AI can produce a summary of the visit (without acronyms) for the doctor (and the patient using a user-friendly, not technical language) that, after being approved by the attending physician, can be stored in the EHR and printed or sent e.g., via e-mail, text message, SMS, WhatsApp etc) to the patient. As a side effect, this keyboard zero strategy is likely to improve eye contact (and empathy) with the patient. Finally, given that guidelines are written by "human consensus based on best available evidence by experts in the field", they constitute an invaluable source of input data for AI, and should continue to be produced by "human expert consensus".

Remote patient monitoring

When combined with wearable sensor technologies, AI can also allow RPM by facilitating transmission of patient-reported outcomes and physiological data directly to healthcare professionals. Yet, there is still limited evidence that RPM in COPD impacts on relevant clinical outcomes.[1425] A key issue in this setting is how healthcare systems will be able to efficiently review this data and respond to it.[1426]

On the other hand, given that inhaled therapy is a cornerstone of COPD treatment and that adherence and correct inhalation is often poor, the potential of digital smart inhalers to improve adherence and inhaler technique is large.[1426-1428] Likewise, AI-supported home rehabilitation is a potential alternative when face to face programs are not available.[1429]

Finally, AI can be potentially used at the home of the patient. A chatbot is a computer program designed to simulate conversation with human users, either through text or voice, to provide information, answer questions, or complete tasks. If appropriately trained and validated, a chatbot in the home of the patient can potentially be the first interface to contact the healthcare system[1430] and answer questions the patient may have about her/his health at home and recommend specific actions, including automatically seeking healthcare, either remotely or in person.[1431]

Prognosis

In a systematic review and meta-analysis Smith *et al* concluded that there is still limited evidence that conventional machine learning and deep learning prognostic models demonstrate superior performance to pre-existing disease severity scores in COPD patients.[1432] Likewise, AI can also help identifying patients at higher risk of exacerbations.[1421]

Most of these studies require validation in large cohorts with longitudinal data[1422] but clearly pave the way for a better assessment of risk in COPD patients.[1433]

TELEHEALTH, REMOTE MONITORING AND FOLLOW-UP

The COVID-19 pandemic dramatically changed how outpatient care is delivered in healthcare 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.[1434] However, incorporation of virtual care into ambulatory care should be based on evidence.

A Cochrane review[1435] on telehealth for remote monitoring and consultations for patients with COPD included three main different models that have been studied in RCTs:[1435]

- 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 five RCTs that transferred data and allowed review by health professionals in real time (synchronous).[1435] 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 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 patients with COPD, whether in-person, by phone or in a virtual/online setting, in **Appendix 2** 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 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 healthcare 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.

DELIVERY OF PULMONARY REHABILITATION: 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 was established as the gold-standard in a 2021 Cochrane review.[1436] 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).[736]

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.

DELIVERY OF SELF-MANAGEMENT: IN-PERSON VERSUS VIRTUAL

A 2022 Cochrane review reported that a self-management intervention both improved quality of life and reduced hospital admissions.[1437] 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 a 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.[1438]

APPENDICES

APPENDIX 1 - ABBREVIATIONS

6MWD, 6-minute walking distance
AATD, α-1 antitrypsin deficiency
ABG, arterial blood gas
ACE, angiotensin converting enzyme
AI, artificial intelligence
ATS, American Thoracic Society
BAI, breath-actuated metered-dose inhaler
BD, bronchodilator
BMI, body mass index
BODE, Body mass index, Obstruction, Dyspnea, and Exercise
BOLD, Burden of Obstructive Lung Diseases
CAT™, COPD Assessment Test
CAAT™, Chronic Airways Assessment Test
CAPTURE, COPD Assessment in Primary Care to Identify Undiagnosed Respiratory Disease and Exacerbation Risk
CCQ©, Clinical COPD Questionnaire
CDC, US Centers for Disease Control
CDQ, COPD Diagnostic Questionnaire
CI, confidence interval
CISNET, Cancer Intervention and Surveillance Modeling Network
COPD, chronic obstructive pulmonary disease
COPD-PS, COPD Population Screener
COVID-19, coronavirus disease 2019
CPAP, continuous positive airway pressure
CRP, C-reactive protein
CRQ, Chronic Respiratory Questionnaire
CT, computed tomography
CVD, cardiovascular disease
DALY, disability-adjusted life years
DLco, carbon monoxide diffusing capacity of the lungs
DM, diabetes mellitus
DNA, deoxyribonucleic acid
DPI, dry powder inhaler
ED, emergency department
EBV, endobronchial one-way valves
ECG, electrocardiogram
EHR, electronic health record
ELVR, endoscopic lung volume reduction
ERS, European Respiratory Society
ESC, European Society of Cardiology
EU, European Union
EVALI, e-cigarette or vaping product use-associated lung injury
FDA, US Food and Drug Administration
FEV1, forced expiratory volume in 1 second
FiO_2, fraction of inspired oxygen
FVC, forced vital capacity
GBD, Global Burden of Disease
GERD, gastroesophageal reflux disease
GETomics, gene(G)-environment(E) interactions occurring over the lifetime(T) of the individual
GFR, glomerular filtration rate
GLI, Global Lung Initiative
GOLD, Global Initiative for Chronic Obstructive Lung Disease
HADS, Hospital Anxiety and Depression Scale
HFNT, high-flow nasal therapy
HFpEF, heart failure with preserved ejection fraction
HICs, high-income countries
HIV, human immunodeficiency virus
HMICs, high- and middle-income countries
HRCT, high-resolution computed tomography
ICD, International Statistical Classification of Diseases and Related Health Problems
ICS, inhaled corticosteroid
ICU, intensive care unit
ILA, interstitial lung abnormalities
ILD, interstitial lung disease
Ig, immunoglobulin
IL, interleukin
IRR, incidence rate ratio
LABA, long-acting $beta_2$-agonist
LABD, long-acting bronchodilator
LAMA, long-acting muscarinic antagonist
LAS, lung allocation severity
LDCT, low-dose computed tomography
LFQ, Lung Function Questionnaire
LICs, low-income countries
LLN, lower limit of normal
LMICs, low- and middle-income countries
LTOT, long-term oxygen therapy
LVRS, lung volume reduction surgery
mMRC scale, modified Medical Research Council

dyspnea scale
MOLT, multiple organ loss of tissue
mPAP, mean pulmonary arterial pressure
NAFLD, non-alcoholic fatty liver disease
NETT, National Emphysema Treatment Trial
NHLBI, National Heart, Lung, and Blood Institute
NIH, National Institutes of Health
NIV, noninvasive ventilation
NPPV, noninvasive positive pressure ventilation
NS, not statistically significant
OSA, obstructive sleep apnea
$PaCO_2$ partial pressure of carbon dioxide
PAD, peripheral artery disease
PAH, pulmonary arterial hypertension
PaO_2 partial pressure of oxygen
PCV, pneumococcal conjugate vaccine
PDE, phosphodiesterase
PEF, peak expiratory flow
PH, pulmonary hypertension
PLATINO, Project for the Investigation of Obstructive Lung Disease
PM2.5 or PM10, particulate matter of 2.5 or 10 µm or less in diameter
pMDI, pressurized metered-dose inhaler
PPSV, pneumococcal polysaccharide vaccine
PRIME-MD, Primary Care Evaluation of Mental Disorders
PRISm, preserved ratio impaired spirometry
PROs, patient reported outcomes
PUMA, PUMA COPD questionnaire
RCT, randomized controlled trial
RPM, remote patient monitoring
RSV, respiratory syncytial virus
SABA, short-acting $beta_2$-agonist
SABD, short acting bronchodilator
SaO_2, oxygen saturation of arterial blood
SARS-CoV-2, severe acute respiratory syndrome coronavirus 2
SE, standard error
SGRQ, St. George's Respiratory Questionnaire
SMI, soft mist inhaler
T2, type 2 (referring to inflammation)
TB, pulmonary tuberculosis
TDI, Translational Dyspnea Index
UK, United Kingdom
USPSTF, United States Preventative Service Task Force
US, United States of America
VAS, visual analog scale
V_A/Q, ventilation-perfusion
VHC, valved holding chamber
WHO, World Health Organization

APPENDIX 2 - 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: □ no □ yes, color: Regular cough □ no □ yes

Recent change in symptoms □ no □ yes If yes, since when: □ Sputum color: □ Sputum volume ↑ = ↓ □ Dyspnea ↑ = ↓ □ Fatigue ↑ = ↓ □ Cough ↑ = ↓ □ Other □ Signs of hypercapnia **CAAT™: /40**	*Maintenance medication and adherence*: □ SABA □ LABA+LAMA □ LABA □ LABA+ICS □ LAMA □ LABA+LAMA+ICS □Other: *Non pharmacological Rx*: O2: CPAP: BIPAP :

2. AIRBORNE VIRUS – If patient is feeling unwell, check other symptoms: □ Fever____ □ Sore throat □ Anosmia □ Others_____

Contact with someone positive for airborne virus? □ no □ yes Tested for airborne virus? □ no □ yes If yes □ positive □ negative

3. WRITTEN ACTION PLAN – no □ yes □

Instruction and any additional treatment: _____

Last time it has been used (date):

4. RECENT ADMISSIONS AND EMERGENCY VISITS

Hospital/ED	Where	Date	Length	Reason (Dx)

Comments:

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	

Comments and what patient should prioritize based on his/her needs:

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 – Airborne virus**
    a. Assess whether the patient has any symptoms of airborne virus infection 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 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.[1434] 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 ED visits**
    a. Write down recent admissions and ED 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).

APPENDIX 3 – 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[571,573,575,1439,1440] 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.[575,1441,1442] 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.[1443] 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.[1444-1448] 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 although preliminary evidence suggests that e-cigarette use could be associated with COPD.[1449,1450]

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.[1451-1454] 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.[1455]

The CDC and FDA investigated an outbreak of EVALI. Laboratory data showed that vitamin E acetate, an additive in some THC-containing e-cigarettes, was strongly linked to the EVALI outbreak.[1456] 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 recognized features of COPD.[1457-1461] These data are summarized in a review by Gotts and colleagues,[1462] 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.[1451-1454] 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.[1463] 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.[1464]

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.[1465] 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.[1466]

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.[565] Prolonged abstinence rates in the pharmacotherapy groups ranged from 14% to 27%, and in the placebo group from 5% to 9%.[565]

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%).[1467] Varenicline and bupropion showed similar efficacy, however, the group receiving varenicline compared with bupropion smoked more cigarettes per day.[1467]

Maintenance therapy for 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.[931,1468-1471] However, a systematic review combining data from nine studies demonstrated a reduction in the rate of FEV1 decline of 5.0 mL/year in active treatment arms compared with placebo arms.[1472] The difference between long-acting bronchodilator containing treatment arms and placebo arms was 4.9 mL/year. The difference between ICS 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 A3.1**. 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.[929]

Bronchodilators

Bronchodilators are medications that increase FEV1 and/or change other spirometric variables (**Figure A3.2**). 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,[1473,1474] 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.[1475,1476]

Bronchodilator dose-response (FEV1 change) curves are relatively flat with all classes of bronchodilators.[1477-1483] Increasing the dose of either a beta$_2$-agonist or an anticholinergic by an order of magnitude, especially when given by a nebulizer, appears to provide subjective benefit in acute episodes[1484] but is not necessarily helpful in stable disease.[1485] Bronchodilator medications in COPD are most often given on a regular basis to prevent or reduce symptoms. Toxicity is also dose-related (**Figure A3.1**). Use of short-acting bronchodilators on a regular basis is not generally recommended.

Beta$_2$-agonists

The principal action of beta$_2$-agonists is to relax airway smooth muscle by stimulating beta$_2$-adrenergic receptors, which increases cyclic AMP and produces functional antagonism to bronchoconstriction. There are short-acting (SABA) and long-acting (LABA) beta$_2$-agonists. The effect of SABAs usually wears off within 4 to 6 hours.[1479,1480] Regular and as-needed use of SABAs improve FEV1 and symptoms.[1486] LABAs show duration of action of 12 or more hours and do not preclude additional benefit from as-needed SABA therapy.[1487]

Formoterol and salmeterol are twice-daily LABAs that significantly improve FEV1 and lung volumes, dyspnea, health status, exacerbation rate and number of hospitalizations,[1488] but have no effect on mortality or rate of decline of lung function. Indacaterol is a once daily LABA that improves breathlessness,[1489,1490] health status[1490] and exacerbation rate.[1490] Some patients experience cough following the inhalation of indacaterol. Olodaterol and vilanterol are additional once daily LABAs that improve lung function and symptoms.[1491,1492]

Adverse effects

Stimulation of beta$_2$-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 beta$_2$-agonists, regardless of route of administration. Although hypokalemia can occur, especially when treatment is combined with thiazide diuretics,[1493] and oxygen consumption can be increased under resting conditions in patients with chronic heart failure,[1494] these metabolic effects decrease over time (i.e., show tachyphylaxis). Mild falls in PaO_2 can occur after administration of both SABAs and LABAs[1495] but the clinical significance of these changes is uncertain. Despite prior concerns related to the use of beta$_2$-agonists in the management of asthma, no association between beta$_2$-agonist use and loss of lung function or increased mortality has been reported in COPD.[1488,1496,1497]

Antimuscarinic drugs

Antimuscarinic drugs block the bronchoconstrictor effects of acetylcholine on M3 muscarinic receptors expressed in airway smooth muscle.[1498] SAMAs, namely ipratropium and oxitropium, also block the inhibitory neuronal receptor M2, which potentially can cause vagally induced bronchoconstriction.[1499] 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.[1498]

A systematic review of RCTs concluded that ipratropium, a short acting muscarinic antagonist, alone provided small benefits over short-acting beta$_2$-agonist in terms of lung function, health status and requirement for oral steroids.[1500] 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).[1498,1501] LAMA treatments improve symptoms, including cough and sputum and health status.[1498,1502,1503] They also improve the effectiveness of pulmonary rehabilitation[1504,1505] and reduce exacerbations and related hospitalizations.[1502] Clinical trials have shown a greater effect on exacerbation rates for LAMA treatment (tiotropium) versus LABA treatment.[1506,1507]

Maintenance Medications in COPD*

Figure A3.1

Generic Drug Name	Inhaler Type	Nebulizer	Oral/Injectable Delivery	Duration of Action
BETA$_2$-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
Oxitropium 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
Revefenacin		✓		24 hours
Combination Short-Acting Beta$_2$-Agonist Plus Anticholinergic in One Device (SABA+SAMA)				
Fenoterol/ipratropium	SMI	✓		6-8 hours
Salbutamol/ipratropium	SMI, MDI	✓		variable
Combination Long-Acting Beta$_2$-Agonist Plus Anticholinergic in One Device (LABA+LAMA)				
Formoterol/aclidinium	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 Beta$_2$-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
Mepolizumab			injectable	4 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.

Bronchodilators in Stable COPD

Figure A3.2

- 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
- Ensifentrine 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)**

Adverse effects

Inhaled anticholinergic drugs are poorly absorbed which limits the troublesome systemic effects observed with atropine.[1498,1508] 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.[1499,1509] Although occasional urinary symptoms have been reported, there are no data to prove a true causal relationship.[1510] Some patients using ipratropium report a bitter, metallic taste. An unexpected small increase in cardiovascular events in those patients with COPD regularly treated with ipratropium bromide has been reported.[1511,1512] In a large, long-term clinical trial in patients with COPD, tiotropium added to other standard therapies had no effect on cardiovascular risk.[931] Although there were some initial concerns regarding the safety of tiotropium delivery via the Respimat® inhaler,[1513] 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.[1175] 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.[1514-1516]

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.[1517-1519] 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,[1517] 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.[1520] Addition of theophylline to salmeterol produces a greater improvement in FEV1 and breathlessness than salmeterol alone.[1521,1522] Earlier studies reported contradictory evidence regarding the effect of low-dose theophylline on exacerbation rates.[1523,1524] A study that investigated the effectiveness of adding low-dose theophylline to ICS in patients with COPD who were at increased risk of exacerbation showed no difference compared with placebo in the number of COPD exacerbations over a one-year period.[1525] A large placebo-controlled trial in patients with COPD who had moderate to very severe airflow obstruction (FEV1 < 70%) showed no effect of oral theophylline alone or in combination with prednisolone 5 mg daily on exacerbations of COPD.[1526]

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.[1518,1520] 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.[1527,1528] Combinations of SABAs and SAMAs are superior compared to either medication alone in improving FEV1 and symptoms.[1529] Treatment with formoterol and tiotropium in *separate inhalers* has a bigger impact on FEV1 than either component alone.[1530] There are numerous combinations of a LABA and LAMA in a *single inhaler* available (**Figure A3.1**). These combinations improve lung function compared to placebo;[1527] 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.[1531] Single inhalers improve adherence to treatment[1532] and are more cost-effective.[1533] In studies where PROs are the primary endpoint or in pooled analyses, combination bronchodilators have a greater impact on PROs compared to monotherapies.[1534-1537] 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.[1538] 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.[677] The LABA+LAMA

combination demonstrated favorable improvements compared with the monotherapies for the majority of outcomes irrespective of baseline health-related quality of life.[1539] 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 patients with COPD [1540] (**Figure A3.2**). These findings have been shown in people across different ethnic groups (Asian as well as European).[1541]

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.[1542] 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.[1543] 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.[1544] 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.[467] 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.[1545]

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 A3.3**).

Inhaled corticosteroids

General considerations

In vitro evidence suggests that COPD-associated inflammation has limited responsiveness to corticosteroids. Moreover, some drugs including beta$_2$-agonists, theophylline or macrolides may partially facilitate corticosteroid sensitivity in COPD.[1546,1547] 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.[1544] 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.[467,1548]

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.[1549] 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.[1549] 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.[790] However, an increase in mortality was not observed in patients with COPD who were treated with fluticasone furoate in the SUMMIT trial.[1181] In patients with COPD who had moderate airflow obstruction, 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.[1550] A number of studies have investigated whether there is a relationship between ICS treatment and risk of lung cancer with conflicting results.[1551]

Anti-Inflammatory Maintenance Therapy

Figure A3.3

Inhaled Corticosteroids	• 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 suggesta 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
Oral Glucocorticoids	• Long-term use of oral glucocorticoids has numerous side effects **(Evidence A)** with no evidence of benefits **(Evidence C)**
PDE Inhibitors	• In patients with chronic bronchitis, severe to very severe COPD and a history of exacerbations: ▪ Roflumilast improves lung function and reduces moderate and severe exacerbations **(Evidence A)** • Ensifentrine improves lung function **(Evidence A)** but an effect on exacerbations has not been evaluated in patients at increased exacerbation risk
Antibiotics	• 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)**
Mucoregulators & Antioxidant Agents	• Regular treatment with mucolytics such as erdosteine, carbocysteine and N-acetylcysteine reduces the risk of exacerbations in select populations **(Evidence B)** • Antioxidant mucolytics are recommended only in selected patients **(Evidence A)**

Biologics	• In patients with moderate to severe COPD with a history of exacerbations despite triple therapy and higher blood eosinophils (≥ 300 cells/µL):
	  ▪ Dupilumab reduces exacerbations, improves lung function and quality of life in patients with chronic bronchitis **(Evidence A)**
	  ▪ Mepolizumab reduces exacerbations in patients with and without chronic bronchitis **(Evidence A)**

Other Anti-Inflammatory Agents	• 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$_2$-agonist (LABA+ICS)

In patients with COPD who have moderate to very severe airflow obstruction and a history of exacerbations, an ICS combined with a LABA is more effective than either component alone in improving lung function, health status and reducing exacerbations.[1552,1553] 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.[790,1181]

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.[462-467] 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.[453] Data modeling indicates that ICS containing regimens have little or no effect at a blood eosinophil count < 100 cells/µL,[462] 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,[252,257,1554] notably haemophilus, and increased bacterial infections and pneumonia.[1555] 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;[462,463,465] 2) pre-specified analyses comparing triple therapy versus LABA+LAMA or LAMA;[464,466,467] and 3) other analyses comparing LABA+ICS versus LABA+LAMA[1556] or studying ICS withdrawal.[692,693,1557]

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).[464,467,1544] 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 long-acting bronchodilators are shown in **Figure 3.10**.[555]

Adverse effects

There is high quality evidence from RCTs that ICS use modifies the airway microbiome[1558] and is associated with higher prevalence of oral candidiasis, hoarse voice, skin bruising and pneumonia.[1549] This excess risk has been confirmed in ICS studies using fluticasone furoate, even at low doses.[1559] Patients at higher risk of pneumonia include those who currently smoke, are aged ≥ 55 years, have a history of prior exacerbations or pneumonia, a BMI < 25 kg/m^2, a poor mMRC dyspnea grade and/or severe airflow obstruction.[1560,1561] Independent of ICS use, there is evidence that a blood eosinophil count < 2% increases the risk of developing pneumonia.[1562] In studies of patients with COPD who had moderate airflow obstruction, ICS by itself or in combination with a LABA did not increase the risk of pneumonia.[1181,1561]

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.[1470,1559,1563-1565] Results of observational studies suggest that ICS treatment could also be associated with increased risk of

diabetes/poor control of diabetes,[1315] cataracts,[1566] and mycobacterial infection.[1567] An increased risk of tuberculosis has been found in both observational studies and a meta-analysis of RCTs.[1239,1241,1568] In the absence of RCT data on these issues, it is not possible to draw firm conclusions.[1569] ICS and lung cancer incidence is discussed in **Chapter 5**.

Triple therapy (LABA+LAMA+ICS)

The step up in inhaled treatment to LABA plus LAMA plus ICS (triple therapy) can occur by various approaches[1570] and has been shown to improve lung function, patient reported outcomes and reduce exacerbations when compared to LAMA alone, LABA+LAMA and LABA+ICS.[464,466,467,1571-1578] 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.[1579]

A *post-hoc* pooled analysis of three triple therapy RCTs in patients with COPD who had 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.[1580] Two large one-year RCTs (IMPACT and ETHOS) were reviewed 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.[492,1581]

Oral glucocorticoids

Oral glucocorticoids have numerous side effects, including steroid myopathy[1582] which can contribute to muscle weakness, decreased functionality, and respiratory failure. 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.[1583] Conversely, prospective studies on the long-term effects of oral glucocorticoids in stable COPD are limited.[1584,1585] 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 inhibitors

The principal action of PDE4 inhibitors is to reduce inflammation by inhibiting the breakdown of intracellular cyclic AMP.[1586] 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 airflow obstruction, and a history of exacerbations.[1587] The effects on lung function are also seen when roflumilast is added to long-acting bronchodilators,[1588] and in patients who are not controlled on fixed-dose LABA+ICS combinations.[687] The beneficial effects of roflumilast have been reported to be greater in patients with a prior history of hospitalization for an acute exacerbation.[689] There has been no study directly comparing roflumilast with an ICS.

Adverse effects

Roflumilast has more adverse effects than inhaled medications for COPD.[1589] 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,[1590,1591] 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.[1592] Later studies have shown that regular use of some antibiotics may reduce exacerbation rate.[1593,1594]

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.[685,1595,1596] Azithromycin use was associated with an increased incidence of bacterial resistance, prolongation of QTc interval, and impaired hearing tests.[685] A *post-hoc* analysis suggests lesser benefit in active smokers.[686] 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.[1597] Long-term doxycycline did not reduce exacerbations, although there may be responder subgroups.[1598]

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

In patients with COPD who are not receiving ICS, regular treatment with mucolytics such as carbocysteine and N-acetylcysteine may reduce exacerbations and modestly improve health status.[1599-1602] Long-term treatment of mild to moderate COPD with high-dose N-acetylcysteine (600 mg twice daily) neither significantly reduced the annual rate of total exacerbations nor improved lung function.[1603] 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.[1604]

Phosphodiesterase-3 and -4 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 guanosine monophosphate levels, causes smooth muscle relaxation.[1605] In parallel Phase III RCTs, ensifentrine, delivered via standard jet nebulizer, significantly improved lung function[1605] 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.[453,681-683] Studies did not find safety or tolerability issues.[1606] Ensifentrine is currently only available in the US.

Biologic therapy

Dupilumab is a fully human monoclonal antibody that blocks the shared receptor component for IL-4 and IL-13. In two large, phase III, 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, from GOLD 2-3, and blood eosinophil count of ≥ 300 cells/µL who received dupilumab had fewer exacerbations, better lung function and improved health status over 52 weeks (**Figure 3.11**).[681,682]

Mepolizumab is a humanized monoclonal antibody that targets IL-5. Across three phase III, double-blind, randomized, placebo-controlled trials, patients with COPD, 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, from GOLD 2-4, with and without chronic bronchitis, and blood eosinophil count of ≥ 300 cells/µL who received mepolizumab for 52 to 104 weeks and had fewer moderate or severe exacerbations and a reduction in exacerbations leading to ED visits or hospitalizations (**Figure 3.11**).[690,691]

Benralizumab is a humanized monoclonal antibody directed against the alpha chain of the IL-5 receptor. Two phase III, double-blind, randomized, placebo-controlled trials, of patients with COPD, a history of two or more moderate exacerbations or one or more severe exacerbation(s) in the last year despite treatment with LABA+ICS, LABA+LAMA or LABA+LAMA+ICS, from GOLD 2-4, found that add-on benralizumab was not associated with a lower annualized rate of COPD exacerbations.[1607]

Other drugs with potential to reduce exacerbations

Nedocromil and leukotriene modifiers have not been tested adequately in patients with COPD and the available evidence does not support their use. [1608,1609]

There was no evidence of benefit, and some evidence of harm, including malignancy and pneumonia, following treatment with an anti-tumor necrosis factor-alpha antibody (infliximab) in patients with COPD.[1610]

A recent Cochrane meta-analysis did not show sufficient evidence to support the use of immunostimulants.[1611]

An RCT of the selective β_1 receptor blocker metoprolol in patients with COPD who had moderate or severe airflow obstruction, and 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.[1157,1612] 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.[1613] 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.[1614]

There is no evidence that supplementation with vitamin D has a positive impact on exacerbations in unselected patients.[1615] In a meta-analysis vitamin D supplementation reduced exacerbation rates in patients with low baseline vitamin D levels,[996] but a more recent study has shown no effect.[997]

Adherence to inhaled COPD medications

Adherence is defined as the process by which a person takes their medication as prescribed by a healthcare provider.[1616] 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.[1617-1627]

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 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.[1628] Most studies included were conducted in high-income countries and many used pharmacy claims data to assess adherence.[1628] Self-reported non-adherence to COPD medication varies between 28% and 74% (mean 50.9%) in HICs[1619,1628,1629] and between 46% and 93% (mean 61.7%) in LMICs.[1630-1633] 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.[1634,1635]

Adherence is a complex concept, influenced by multiple factors including social/environmental, person-related and treatment-related factors.[1636] Several studies have explored the variables associated with medication adherence in

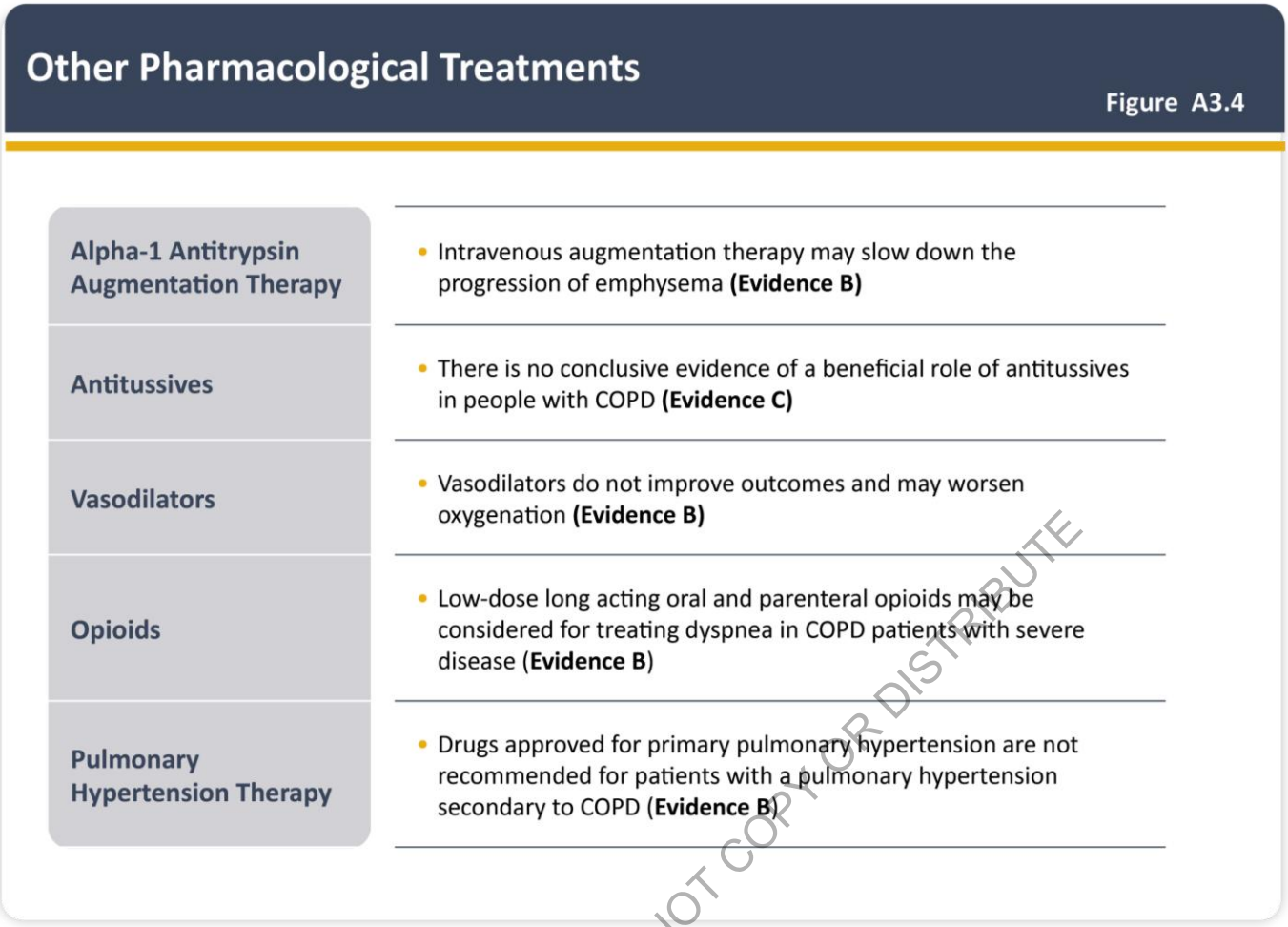
people with COPD.[1628,1630] Factors such as the presence of co-morbidities, in particular depression, smoking status, schooling level, disease severity, and drug regimen factors such as dosage complexity, polypharmacy and side effects of therapy, are the main factors associated with low adherence.[1627,1628,1630,1631,1637,1638] In addition, socioeconomic factors, including unemployment, low-income status, immigration status, living alone and poor medication availability[102] have been shown to negatively influence inhaled medication adherence and to be related to the non-use of medication.[1637,1639,1640]

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.[710,1641]

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.[732,1628] 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.[1435,1642] Involving a person in establishing an individually tailored treatment plan has been shown to improve adherence.[1643] 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 A3.4**.



Alpha-1 antitrypsin augmentation therapy

The logical approach to minimize the development and progression of lung disease in patients with AATD 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[1644] and that this reduction is most effective for patients with FEV1 35% to 49% predicted.[1645] 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 focused 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 COPD in heterozygotes for the Z gene[57,58] 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.[1646-1648] 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.[1649] 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.[1649]

The indication for augmentation therapy is emphysema although there are no fixed criteria for diagnosis or confirmation. The evidence for augmentation therapy efficacy varies according to the outcome studied.[1650] Intravenous augmentation therapy has been recommended for individuals with AATD and an FEV1 ≤ 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,[1651] although recent studies comparing mortality in patients with AATD-associated COPD and severe airflow obstruction have observed a survival advantage of augmentation.[1652] 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.[1653]

Vasodilators

Vasodilators have not been properly assessed in patients with COPD who have 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.[1654] Studies have shown that sildenafil does not improve the results of rehabilitation in people with COPD and moderately increases pulmonary artery pressure.[1655] Tadalafil does not appear improve exercise capacity or health status in patients with COPD who have mild pulmonary hypertension.[1656]

Management of mucus hypersecretion

Treatment goals for patients with chronic bronchitis 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.[1657] Smoking cessation may decrease airway injury by limiting immune mechanisms that cause persistent inflammation and abnormal epithelial cell gene expression.[1658]

Mucus clearance treatments that promote mechanical movement through the airway such as oscillating positive expiratory pressure therapy may improve mucus mobilization, symptoms and quality of life in people with COPD who produce sputum daily or most days.[1659,1660] 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.[1661-1665]

LAMAs, predominantly tiotropium and aclidinium, can improve sputum production and decrease cough in patients with COPD who have moderate to severe airflow obstruction.[1666-1669] Triple therapy with dual LABDs combined with an ICS 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.[1600] 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.[1600] Recombinant human DNase has similarly shown lack of benefit in mucopurulent patients with COPD.[1670,1671] New classes of mucolytics agents are being developed.[1672] In a small double-blind placebo-controlled study, patients randomized to receive a cystic fibrosis transmembrane

conductance regulator potentiator icenticaftor had improvements in FEV1 and sputum bacterial colonization compared to placebo.[1673] 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.[896,903,905,1674]

APPENDIX 4 – 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."[671] 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.[671]

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 health-related quality of life, a lower probability of respiratory-related hospital admissions, and no excess respiratory-related and all-cause mortality risks.[1437] 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.[1675,1676] 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 invention 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[1677] and the PIC-COPD,[1678] 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.[1437]

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 healthcare service utilization compared with usual care.[1679]

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.[1680] 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.[1681]

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.[1682-1684] Besides, delivering integrated interventions by telemedicine did not show a significant effect.[1685,1686] 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.

A study on the impact of credentialed pharmacist-led home medicines review (targeting treatable traits e.g., medication adherence and action plans for managing exacerbations) on health outcomes in primary care patients with COPD reported improved treatment adherence, quality of life, and less depression and anxiety. Credentialed pharmacists can work alongside general practitioners to optimize COPD management.[1687]

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 patients with COPD.[1688] This leads to a downward spiral of inactivity which predisposes patients to reduced quality of life, increased rates of hospitalization and mortality.[1689-1691] As such, there has been tremendous interest in implementing behavior-targeted interventions with the aim of improving physical activity[1692] and these should be encouraged.[1689] 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.[1429] The use of an internet-mediated intervention may benefit people with COPD with low baseline self-efficacy to increase physical activity.[1693] 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.[1694] 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.[1695] 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.[1696] In a meta-analysis Ba Duan Jin exercise has also been shown to have a positive improvement effect on lung function and 6MWD in COPD patients.[1697]

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 patients with COPD.[1698] A combination of constant load or interval training with strength training provides better outcomes than either method alone.[1699]

Where possible, endurance exercise training to 60-80% of the symptom-limited maximum work or heart rate is preferred,[1700] or to a Borg-rated dyspnea or fatigue score of 4 to 6 (moderate to severe).[1701] 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.[1702,1703] 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 patients with COPD.[1704] 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,[1505] since both LAMAs and LABAs have shown reduced resting and dynamic hyperinflation. These changes contribute to better training effects.[1473,1705] Adding strength training to aerobic training is effective in improving strength, but does not improve health status or exercise tolerance.[1706] Upper extremities exercise training improves arm strength and endurance, and results in improved functional capacity for upper extremity activities.[1707] Exercise capacity may also be improved by whole-body vibration training.[1708]

Inspiratory muscle training increases strength of inspiratory muscles,[1709] 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.[1710-1712]

Pulmonary rehabilitation

The benefits to patients with COPD from pulmonary rehabilitation are considerable (**Figure A4.1**), and rehabilitation has been shown to be the most effective therapeutic strategy to improve shortness of breath, health status, exercise tolerance and sleep quality.[1713,1714] 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.[1715,1716]

Exercise-induced oxygen desaturation can be seen in a significant minority of patients with COPD and has been associated with impaired quality of life, exacerbation risk, and mortality.[1717] A large RCT did not suggest clinical improvement with LTOT for patients without resting hypoxemia but exertional desaturation.[1718] When needed, 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,[1719] but most evidence was limited by low study quality. A large RCT,[755] with blinding of participants, trainers and assessors, demonstrated that patients with COPD 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 COPD who have severe airflow obstruction, are on LTOT, and 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. Such humidified air-oxygen treatment may reduce respiratory muscle load and respiratory rate, while increasing expiratory time.[1720] In an RCT, the delivery of humidified air-oxygen 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.[1721] However, a greater improvement in the 6MWD test was observed with humidified air-oxygen. A similar small trial suggested an improved walking distance.[1722] The proportion of patients reaching the minimal clinically important difference in endurance time and 6MWD was also significantly higher with humidified air-oxygen. 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 A4.1

Pulmonary Rehabilitation	• 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)** • Pulmonary rehabilitation leads to an improvement in sleep quality **(Evidence C)**
Education and Self-Management	• 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	• Integrative care and telehealth have no demonstrated benefit at this time **(Evidence B)**
Physical Activity	• Physical activity is a strong predictor of mortality **(Evidence A)**. People with COPD should be encouraged to increase their level of physical activity. Programs that use effective behavioral change techniques, including the use of step counters, have been shown to increase physical activity in the short term.

There are data from large RCTs regarding the effectiveness of pulmonary rehabilitation after hospitalization for an acute exacerbation. 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.[779,1723] 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[782] and fewer rehospitalizations at one year.[1724] Furthermore, in a meta-analysis pulmonary rehabilitation initiated before hospital discharge with endurance training alone was found to reduce readmission rate and improve 6MWT distance.[1725] One study has reported that initiating pulmonary rehabilitation before the patient's discharge may compromise survival through unknown mechanisms.[1726] Pulmonary rehabilitation ranks as one of the most cost-effective treatment strategies.[739]

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.[1727] 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 COPD who have moderate to severe airflow obstruction.[1728] A major barrier to full participation is access, which is particularly limited by geography, culture, finances, transport and other logistics.[497,674,796,1729]

Pulmonary rehabilitation can be conducted at a range of sites.[674] Community-based and home-based programs have been shown to be as effective as hospital-based programs in randomized controlled trials,[1730,1731] as long as the frequency and intensity are equivalent.[1732] 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[1730] or a walking program[1731] could be considered as alternative to traditional hospital pulmonary rehabilitation training programs. There is also evidence that standardized home-based pulmonary rehabilitation programs improve dyspnea in patients with COPD.[1733] 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.[1734] Another challenge is that the benefits of pulmonary 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.[742,1735] Pulmonary rehabilitation may help reduce anxiety and depression symptoms.[1292]

Tele-rehabilitation

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

Tele-rehabilitation has been proposed as an alternative to the traditional approaches. This became even more relevant in the COVID-19 pandemic era where in-person pulmonary rehabilitation was not 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 was analyzed in a Cochrane review.[1436]

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 pulmonary rehabilitation 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[1736] and accurately prescribing exercise capacity.[1737]

Promoting physical activity is also central to the recommendations that should be given to every patient with COPD regardless of disease severity. Promoting physical activity using smartphone apps is gaining popularity although at present data on effectiveness are lacking.[164]

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 pulmonary rehabilitation). 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 pulmonary rehabilitation 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.[326,1738-1742] Malnutrition has been reported in 30-60% of patients hospitalized with COPD;[1743] up to 50% of people with COPD weigh less than 90% of ideal bodyweight.[1744] 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.[1745,1746] The severity of airflow obstruction correlates with the presence of malnutrition[1747] since ventilator inefficiency increases daily energy requirements.[1748] 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.[1749-1751]

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 bodyweight, quality of life, respiratory muscle strength and 6MWD.[815,1743] However, nutritional support has not been consistently shown to improve lung function.[815,1752-1754] Multimodality treatment that incorporates rehabilitation with nutritional support and protein supplementation may improve fat free mass, BMI and exercise performance.[1755] Among malnourished, hospitalized people with COPD, a protein enriched supplementation decreased mortality and improved handgrip strength, bodyweight and nutritional biomarkers 90 days post hospital discharge.[1756]

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