European Respiratory Society and European Society of Thoracic Surgeons clinical practice guideline on fitness for curative intent treatment of lung cancer

Alessandro Brunelli [1,50], Georgia Hardavella [2,50], Rudolf M. Huber [3,50], Thierry Berghmans [4], Armin Frille [5], Maria Rodriguez [6,7], Ilona Tietzova [8,9,10], Lieven Depypere [11], Riccardo Asteggiano [12,13], Tim Batchelor [14], Adrien Costantini [15], Dirk De Ruysscher [16,17,18], Valerie Durieux [19], Corinne Faivre-Finn [20,21], Mark K. Ferguson [22], Daniel Langer [23], Nandor Marczin [24,25,26], Blin Nagavci [27], Nuria Novoa [28], Cecilia Pompili [29], Janette Rawlinson [30,31], Annemiek Snoeckx [32], Thomy Tonia [33], Wouter H. van Geffen [34], Clare Williams [35], Edward J. Caruana [36], Pinar Akin Kabalak [37], Ulrich Mansmann [38], Vincent Fallet [39], Diego Kauffmann-Guerrero [40], Marianne Paesmans [41], Amani Al Tawil [42], Nora Alhannoush [43,44,45], Andrew W. Creamer [46], Ismini Kourouni [47] and Torsten Gerriet Blum [48,49]

[1]Department of Thoracic Surgery, St James's University Hospital, Leeds, UK. [2]4th–9th Department of Respiratory Medicine, "Sotiria" Athens' Chest Diseases Hospital, Athens, Greece. [3]Division of Respiratory Medicine and Thoracic Oncology, Department of Medicine V, Ludwig-Maximilians-University of Munich, Thoracic Oncology Centre Munich, German Centre for Lung Research (DZL CPC-M), Munich, Germany. [4]Thoracic Oncology Functional Unit, Institut Jules Bordet, Hôpital Universitaire de Bruxelles, Université Libre de Bruxelles, Brussels, Belgium. [5]Department of Medicine II (Oncology, Gastroenterology, Hepatology and Respiratory Medicine), University of Leipzig Medical Center, Leipzig, Germany. [6]Thoracic Surgery Department, Clínica Universidad de Navarra, Madrid, Spain. [7]Cancer Center Clinica Universidad de Navarra (CCUN), Pamplona, Spain. [8]First Department of Tuberculosis and Respiratory Diseases, General University Hospital in Prague and First Faculty of Medicine, Charles University, Prague, Czech Republic. [9]Department of Respiratory Medicine, Thomayer University Hospital and First Faculty of Medicine, Charles University, Prague, Czech Republic. [10]Department of Palliative Medicine, General University Hospital in Prague and First Faculty of Medicine, Charles University, Prague, Czech Republic. [11]Department of Thoracic Surgery, University Hospitals Leuven, Leuven, Belgium. [12]Internal Medicine, Department of Medicine and Surgery, University of Insubria, Varese, Italy. [13]LARC – Laboratorio Analisi e Ricerca Clinica Turin, Turin, Italy. [14]St Bartholomew's Hospital, London, UK. [15]Respiratory Diseases and Thoracic Oncology Department, Hôpital Ambroise Pare Assistance Publique-Hôpitaux de Paris (AP-HP), Boulogne-Billancourt, France. [16]GROW – Research Institute for Oncology and Developmental Biology, Maastricht University, Maastricht, The Netherlands. [17]Department of Radiation Oncology (Maastro), Maastricht, The Netherlands. [18]Department of Radiotherapy, Erasmus MC Cancer Institute, University Medical Center, Rotterdam, The Netherlands. [19]Bibliothèque des Sciences de la Santé, Université Libre de Bruxelles, Brussels, Belgium. [20]Clinical Oncology, The Christie NHS Foundation Trust, Manchester, UK. [21]Division of Cancer Sciences, University of Manchester, Manchester, UK. [22]Division of Thoracic Surgery, Department of Surgery, University of Chicago, Chicago, IL, USA. [23]KU Leuven, Faculty of Movement and Rehabilitation Sciences, Department of Rehabilitation Sciences, Research Group for Rehabilitation in Internal Disorders, Leuven, Belgium. [24]Department of Anaesthesia, Royal Brompton Hospital, Royal Brompton and Harefield Hospitals, Part of Guy's and St Thomas' NHS Foundation Trust, London, UK. [25]Division of Anaesthetics, Pain Medicine and Intensive Care, Department of Surgery and Cancer, Imperial College London, London, UK. [26]Department of Anaesthesia and Intensive Care, Semmelweis University Budapest, Budapest, Hungary. [27]Institute for Evidence in Medicine, Faculty of Medicine and Medical Center, University of Freiburg, Freiburg, Germany. [28]Department of Thoracic Surgery, University Hospital Puerta de Hierro-Majadahonda, Madrid, Spain. [29]Institute for Clinical and Applied Health Research, University of Hull, Hull, UK. [30]Lung Cancer Patient Advisory Group, European Lung Foundation, Sheffield, UK. [31]British Thoracic Oncology Group Steering Committee, Leicester, UK. [32]Department of Radiology, Antwerp University Hospital and University of Antwerp, Antwerp, Belgium. [33]Institute of Social and Preventive Medicine, University of Bern, Bern, Switzerland. [34]Department of Respiratory Medicine, Medical Center Leeuwarden, Leeuwarden, The Netherlands. [35]European Lung Foundation, Sheffield, UK. [36]Department of Thoracic Surgery, Glenfield Hospital, University Hospitals Leicester, Leicester, UK. [37]Department of Chest Diseases, University of Health Sciences, Ankara Atatürk Sanatorium Training and Research Hospital, Ankara, Turkey. [38]Department of Medical Information Sciences, Biometry and Epidemiology, Medical Faculty, Ludwig Maximilians University, Munich, Germany. [39]Hopital Tenon Assistance Publique-Hôpitaux de Paris (AP-HP), Paris, France. [40]Department of Medicine V, University Hospital, LMU Munich, Member of the German Center for Lung Research (DZL), Munich, Germany. [41]Statistics Department, Institut Jules Bordet, Hôpital Universitaire de Bruxelles, Brussels, Belgium. [42]Institute for Medical Information Processing, Biometry, and Epidemiology (IBE), Faculty of Medicine, Ludwig-Maximilians-Universität München, Munich, Germany. [43]Division of Anaesthetics, Pain Medicine and Intensive Care, Imperial College London, London, UK. [44]Anesthesia Technology Department, Imam Abdulrahman bin Faisal University, Jubail, Saudi Arabia. [45]Department of Anaesthesia and Critical Care, Royal Brompton and Harefield Hospitals, Guy's and St Thomas' NHS Foundation Trust, London, UK. [46]UCL Respiratory, University College London, London, UK. [47]Division of Pulmonary, Critical Care and Sleep Medicine, Case Western Reserve University (MetroHealth Medical Center), Cleveland, OH, USA. [48]Lungenklinik Heckeshorn, Helios Klinikum Emil von Behring, Berlin, Germany. [49]Medical School Berlin, Berlin, Germany. [50]Co-chairs.

Corresponding author: Alessandro Brunelli (alexit_2000@yahoo.com)

Shareable abstract (@ERSpublications)
This multidisciplinary panel of lung cancer experts from different specialties has generated practical and up-to-date recommendations to assess patients' fitness for curative intent treatment for lung cancer https://bit.ly/4m57e3s

Cite this article as: Brunelli A, Hardavella G, Huber RM, *et al*. European Respiratory Society and European Society of Thoracic Surgeons clinical practice guideline on fitness for curative intent treatment of lung cancer. *Eur Respir J* 2025; 66: 2500156 [DOI: 10.1183/13993003.00156-2025].

Received: 23 Jan 2025
Accepted: 1 Aug 2025

Abstract

A multidisciplinary panel of lung cancer experts with a special interest in functional evaluation of lung cancer patients, and lung cancer patient representatives, has been facilitated by the European Society of Thoracic Surgeons and the European Respiratory Society to provide healthcare professionals with practical and up-to-date recommendations for the assessment of patients' fitness for curative intent treatments for lung cancer. The panel formulated four PICO (population, intervention, comparison and outcomes) questions and seven complementary narrative questions. Both types of questions were assigned to groups of at least two experts. A medical librarian conducted the literature searches, and the authors selected relevant studies based on predefined inclusion criteria. Risk of bias was assessed using the QUIPS (Quality in Prognosis Studies) tool. Data were summarised and the certainty of evidence was assessed with GRADE (Grading of Recommendations, Assessment, Development and Evaluations) and the Evidence to Decisions framework was used to formulate recommendations. A series of multidisciplinary recommendations was formulated about the utilisation of pulmonary function tests, split lung function values, exercise tests, cardiologic testing, and the role of prehabilitation, sublobar resections, risk scores and comorbidities in selecting patients for curative intent treatment.

Introduction

Patient fitness is a critical factor influencing curative intent treatment of lung cancer. In 2009 the European Respiratory Society (ERS) and the European Society of Thoracic Surgeons (ESTS) published guidelines on fitness for radical therapy in lung cancer patients, which focused mainly on surgical treatment due to the paucity of other published evidence on other oncological treatments [1]. In the meantime, there has been significant progress in all lung cancer treatment modalities. Perioperative outcomes after thoracic surgery have improved due to the widespread use of minimally invasive techniques and lung sparing resections which reduce surgical trauma without compromising oncological quality. In this direction, enhanced recovery programmes have been introduced to streamline and improve perioperative care with the aim of reducing hospital stay and further improving clinical outcomes [2–8]. Radiotherapy has also progressed with the application of intensity-modulated radiotherapy and stereotactic body radiotherapy (SBRT) in selected cases of early stage lung cancer [9]. The development of immune checkpoint inhibitors and targeted therapies has led to a substantially more integrated systemic treatment with surgery and radiotherapy [10–12]. All this progress is underpinned by patient empowerment. Its role in informed and shared decision-making has become increasingly important and should therefore be considered when discussing risk and benefit of a curative intent treatment. These developments contribute to a better prognosis but their combined use and interchangeability in the treatment sequence pose additional risks for side-effects, and therefore appropriate patient assessment and selection is required for any single/multimodality treatment.

Following the publication of the ERS/ESTS guidelines in 2009 [1] and the American College of Chest Physicians (ACCP) guidelines published in 2013 [13], no further guidelines on this topic have been published, except for a consensus document from an American Association for Thoracic Surgery expert panel which addressed the assessment of high-risk patients for lobectomy in stage I non-small cell lung cancer (NSCLC) [14].

The implementation of all novel oncological/surgical approaches in clinical practice needs to be linked with updated guidance on fitness assessment prior to treatment. Therefore, ERS and ESTS agreed to produce a new guideline addressing this unmet need. Compared to the previous guidelines published in 2009, a more robust methodology was applied, the scope of the guidelines was expanded to non-surgical treatments and newly published evidence has been included.

Methods

This section provides a summary of the applied methodology. Supplement A gives detailed information on the methodological process (section A1) as well as the PICO (population, intervention, comparison and outcomes) and narrative questions (section A2).

Scope and purpose of the document

This joint guideline was developed by the ERS and the ESTS. It follows the previous guideline from 2009 [1]. The objective of this guideline is to provide guidance on fitness evaluation and functional work-up in candidates for curative intent treatment for early stage lung cancer. This document is intended to be used by all specialists contributing to the lung cancer pathway.

Composition of the task force panel

This task force consisted of a multidisciplinary team of experts from different countries, led and chaired by A. Brunelli, G. Hardavella and R.M. Huber. The panel consisted of experts in the fields of respiratory medicine, radiation and medical oncology, thoracic surgery, cardiology, radiology, anaesthesiology and physiotherapy. In addition to ERS and ESTS, the following organisations were contacted to select experts in their respective specialty: European Society of Cardiology (Riccardo Asteggiano); European Society of Anaesthesiology and Intensive Care and European Association of Cardiothoracic Anaesthesiology and Intensive Care (Nandor Marczin); and European Society for Radiotherapy and Oncology (Corinne Faivre-Finn and Dirk De Ruysscher). The panel included also patient representatives from the lung cancer patient advisory group of the European Lung Foundation (ELF), who had voting rights and participated as active panel members. The task force was supported interchangeably by two ERS guideline methodologists, who consulted the panel throughout the entire process.

Formulation of questions and selection of outcomes

This document was developed according to the ERS methodology for clinical practice guidelines [15]. Two types of questions were addressed. Questions in the PICO format were answered using systematic searches, risk of bias assessment and certainty of evidence assessment. Narrative questions, which were meant to complement the PICO questions and were not comparative, were answered using systematic searches and narrative synthesis of evidence [15, 16]. GRADE (Grading of Recommendations Assessment, Development and Evaluation) Evidence to Decision (EtD) frameworks were used for discussion of both question types. Research questions were initially proposed by the chairs and were unanimously approved by the panel.

The panel selected the patient relevant outcomes which were agreed by the patient representatives. They rated their importance for clinical decision-making, using three levels of importance: 1) critical, 2) important but not critical, and 3) of limited importance for clinical decision-making [17]. Outcomes rated as critical and important were analysed and reported in this document.

Literature searches and evidence synthesis

A librarian from Université Libre de Bruxelles (Brussels, Belgium) designed the search strategies in collaboration with the methodology working group (T. Berghmans, T.G. Blum, A. Brunelli, G. Hardavella and R.M. Huber). The literature searches were conducted in the first quarter of 2021 using Ovid Medline for all questions, and additionally SciVerse Scopus database for PICO questions and APA PsycInfo through the Ebsco interface for narrative question 2a. As this follows the previous guideline [1], studies published since 2009 were searched. Relevant studies published before 2009 and utilised in the previous guidelines were also used to form the evidence base of this project and considered in the EtD frameworks. No language filters were used. Searches were updated in October 2022 and June 2024. Search strategies are shown in supplement A.

Screening for relevant studies was performed by two reviewers independently against predefined inclusion/exclusion criteria, in two phases (title/abstract and full text screening), using Covidence (www.covidence.org). Differences between reviewers were resolved by discussion or by a third reviewer. Systematic reviews, randomised controlled trials and observational studies (with more than 40 participants) were considered for inclusion. The screening results are presented using the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram (supplement A) [18]. Data extractions were done by at least two task force members per PICO or narrative question. The evidence synthesis incorporated all relevant study characteristics and results. As meta-analyses were not possible, due to large clinical and statistical differences between studies, a narrative evidence synthesis approach was used instead.

Assessment of quality of evidence and strength of the recommendations

For all PICO questions, risk of bias in observational studies was assessed using the QUIPS (Quality in Prognosis Studies) tool [19] (of note: no randomised controlled trials were detected for any of the four PICO questions). The certainty of evidence was assessed with GRADE, taking into consideration risk of bias, inconsistency, indirectness, imprecision and publication bias of included evidence [20]. GRADE has four levels of certainty of evidence (very low, low, moderate and high), representing the degree of confidence we have in effect estimates to support a recommendation [20]. As the guideline dealt with prognostic questions, we followed GRADE guidance and assigned high certainty of evidence as the starting point even for non-randomised studies [21].

For deciding on direction and strength of recommendations, EtD frameworks were used [22, 23], taking into account the balance between benefits and harms, certainty of the evidence, patient values and preferences, health equity, costs, feasibility and acceptability. Strong recommendations are presented as "we recommend". Conditional recommendations are presented as "we suggest". The panel decided on the recommendations with voting. Recommendations were agreed only when a consensus of >90% was achieved. Disagreements were resolved by discussion.

Conflict of interest management

All task force members signed a confidentiality agreement and declared potential conflicts of interest following ERS rules.

Results

This section provides all recommendations as well as an executive summary for the four PICO and seven narrative questions of this clinical practice guideline. Supplement B lists the underlying GRADE evidence profiles and EtD frameworks.

PICO Question 1: Should D_{LCO} testing be used in lung cancer patients undergoing radical treatment (surgery and/or immunochemoradiotherapy) for risk stratification of mortality, length of stay, morbidity and quality of life following treatment (compared to not using it)?

Recommendations

1) The panel recommends performing pre-operative measurement of carbon monoxide lung diffusion capacity (D_{LCO}) to define the pre-operative risk of post-operative mortality and complications, as well as a baseline test for follow-up in lung cancer patients who are evaluated for lung cancer surgery (Strong recommendation for the intervention, low certainty of evidence).

Remark: The panel suggests the D_{LCO} categories ⩾80%, 60–79%, 40–59% and <40% to stratify the pre-operative mortality and morbidity risks as normal, mild, moderate and high, respectively.

2) The panel suggests performing pre-operative measurement of D_{LCO} *after completion of induction therapy to re-define* the pre-operative risk of post-operative mortality and complications in lung cancer patients who are *re-evaluated* for lung cancer surgery (Conditional recommendation for the intervention, very low certainty of evidence).

Remark: Although evidence on the clinical relevance of certain D_{LCO} thresholds/categories is limited, D_{LCO} <80% suggests a higher risk for post-operative mortality/morbidity.

3) The panel suggests performing pre-operative measurement of D_{LCO} to define the pre-treatment risk of respiratory impairment and to serve as a baseline test for follow-up in lung cancer patients being considered for concurrent chemoradiotherapy and radiotherapy ± chemotherapy (Conditional recommendation for the intervention, very low certainty of evidence).

Remark: Evidence supporting the clinical relevance of specific D_{LCO} thresholds or categories in this setting is limited.

Summary of evidence and overall certainty of evidence

We selected 75 observational studies out of the 1730 initially identified abstracts [4, 24–97]. Due to substantial heterogeneity of the body of evidence relating to treatment modalities, we formed four subgroups (1: surgical resection irrespective of neoadjuvant or adjuvant therapy; 2: neoadjuvant therapy followed by surgical resection; 3: concurrent chemoradiotherapy; 4: radiotherapy ± chemotherapy) which allowed clinically rational pooling of data. Varying D_{LCO} thresholds precluded meaningful meta-analyses. Thus, for each reported D_{LCO} threshold, their related effects per outcome were narratively assessed then an overall effect was estimated for each of the outcomes. The overall certainty of evidence was rated as very low for subgroups 1, 2 and 4, and low for subgroup 3.

Desirable effects

In the surgical subgroup (53 studies) [4, 24–75], despite the narrative assessment of included studies per outcome and the variation of applied D_{LCO} thresholds, D_{LCO} values below a certain threshold indicated poorer mortality and morbidity rates, poorer overall survival, reduced quality of life and increased length of stay, yet with varying effect strengths (supplement B, table 1).

In the subgroup of patients with neoadjuvant therapy followed by surgical resection (five studies) [76–80], lower D_{LCO} values were associated with poorer 30-, 90-day and overall mortality, as well as respiratory morbidity (supplement B, table 2).

In the two remaining subgroups based on concurrent chemoradiotherapies (eight studies) [81–88] and radiotherapy ± chemotherapy (nine studies) [89–97] lower D_{LCO} values were associated with a small–moderate reduction of overall survival as well as a moderate increase of the risk of radiation pneumonitis (supplement B, tables 3 and 4).

Undesirable effects

No harms for measurement were identified in the 75 studies included [4, 24–97].

Justification of recommendations

1) The recommendation for D_{LCO} testing as part of evaluation for lung cancer surgery is based on 53 observational studies of varying sizes (65–13 376 patients) [4, 24–97]. Few studies applied multivariate analyses taking into account confounding factors (predictive or prognostic variables). The recommendation is strong despite the very low certainty of evidence as all studies show an association between low values of D_{LCO} and post-operative adverse events. Yet no substantial harms became evident or are foreseen by us related to performance of D_{LCO} measurements. One large multicentre study (13 376 patients) demonstrated significantly increasing absolute 30-day mortality and cardiopulmonary morbidity rates in the suggested D_{LCO} categories ⩾80%, 60–79%, 40–59% and <40%, allowing us to stratify for both pre-operative risks accordingly [26].

2) The recommendation for D_{LCO} testing as part of re-evaluation for lung cancer surgery after completion of induction therapy is based on five observational studies of small to medium size (21–1001 patients) [76–80]. Not all studies applied multivariate analyses taking into account confounding factors (predictive or prognostic variables). The recommendation is conditional due to the very low certainty of evidence. Yet no substantial harms became evident or are foreseen by us related to performance of D_{LCO} measurements. The largest study (1001) patients indicated significantly increased 30-day mortality and overall/respiratory morbidity for post-induction D_{LCO} <80%, prompting us to suggest the threshold of D_{LCO} <80% accordingly [76].

3) The recommendation for D_{LCO} testing as part of pre-therapeutic evaluation before initiation of radiotherapy in lung cancer therapy is based on eight and nine small to medium-sized observational studies in lung cancer patients with concurrent chemoradiotherapy (112–557 patients) [81–88] and radiotherapy ± chemotherapy (31–483 patients) [89–97], respectively. Few studies applied multivariate analyses accounting for confounding factors (predictive or prognostic variables). The recommendation is conditional due to the very low certainty of evidence. Yet no substantial harms became evident or are foreseen by us related to performance of D_{LCO} measurements. There are insufficient data to define a D_{LCO} threshold below which radiotherapy would be contraindicated.

Additional remarks and practical considerations

D_{LCO} measurement is a well-established pulmonary function test aiming to describe gas exchange at rest. While D_{LCO} has been recommended as an essential first step beside forced expiratory volume in 1 s (FEV_1) in the risk stratification algorithm of the 2009 ERS/ESTS guidelines [1], D_{LCO} is still not regularly assessed in the routine pre-operative setting in many places.

The panel considers D_{LCO} measurements to be an essential part of pre-operative and pre-radiation risk stratification strategies. D_{LCO} measurements are commonly available in respiratory medicine services and lung cancer services; they represent rapid and safe tests at reasonable costs. Qualified technicians are required to ensure satisfactory performance of D_{LCO} testing.

Recommendations for future research

Despite limited certainty and varying strengths of evidence relating to our predefined outcomes, we are confident to suggest the integration of D_{LCO} measurements into pre-radiotherapy risk evaluation algorithms. The role of D_{LCO} measurement should be further investigated in the various radiotherapy settings and the context of multimodality treatment including chemotherapy and immunotherapy, and it should be considered in a wider clinical context.

Future research needs to support the current thresholds with better data deriving from both population-based clinical cancer registries as well as specialised respiratory medicine and lung cancer services.

PICO Question 2a: Should predicted post-operative FEV_1 be measured in lung cancer patients, candidates for radical treatment (surgery and/or immunochemoradiotherapy), for risk stratification of mortality, length of stay, morbidity and quality of life following treatment (compared to not using it)?

Recommendations

1) The panel suggests assessing predicted post-operative FEV_1 ($ppoFEV_1$) to define the pre-operative risk of post-operative mortality and complications in lung cancer patients who are evaluated for lung cancer surgery (Conditional recommendation for the intervention, very low certainty of evidence).

Remark: The panel suggests the $ppoFEV_1$ categories ⩾60%, 40–59% and <40% to stratify the pre-operative mortality and morbidity risks as normal, moderate and high, respectively.

2) The panel suggests assessing $ppoFEV_1$ *after completion of induction therapy to re-define* the pre-operative risk of post-operative mortality and complications in lung cancer patients who are *re-evaluated* for lung cancer surgery (Conditional recommendation for the intervention, very low certainty of evidence).

Remark: Although evidence on the clinical relevance of certain $ppoFEV_1$ thresholds/categories is limited, $ppoFEV_1$ <60% suggests a higher risk for post-operative mortality/morbidity.

Summary of evidence and overall quality of evidence

We selected 26 observational studies out of the 1730 initially identified abstracts [24, 26, 27, 29, 30, 37, 41, 44, 46, 49, 54, 56–58, 71, 72, 74, 77, 98–105]. Due to substantial heterogeneity of the body of evidence relating to treatment modalities, we formed two subgroups (1: surgical resection irrespective of neoadjuvant or adjuvant therapy; and 2: neoadjuvant therapy followed by surgical resection) which allowed clinically rational pooling of data. Varying $ppoFEV_1$ thresholds precluded meaningful meta-analyses. Thus, for each reported $ppoFEV_1$ threshold, their related effects per outcome were narratively assessed and then an overall effect estimated for each of the outcomes. The overall certainty of evidence was rated as very low and low for subgroups 1 and 2, respectively.

Desirable effects

In the surgical subgroup (25 studies), despite the narrative assessment of included studies per outcome and the variation of applied $ppoFEV_1$ thresholds, $ppoFEV_1$ values below a certain threshold indicated higher mortality and morbidity rates as well as poorer overall survival and reduced quality of life, yet with varying effect strengths (supplement A, table 5) [24, 26, 27, 29, 30, 37, 41, 44, 46, 49, 54, 56–58, 71, 72, 74, 98–105].

In the subgroup of patients with neoadjuvant therapy followed by surgical resection (one study), similar benefits of $ppoFEV_1$ were only reported and seen for overall and respiratory morbidity (supplement B, table 6) [77].

Undesirable effects

No harms in $ppoFEV_1$ measurement were identified in any of the 26 studies included [24, 26, 27, 29, 30, 37, 41, 44, 46, 49, 54, 56–58, 71, 72, 74, 77, 98–105].

Justification of recommendations

1) The recommendation for $ppoFEV_1$ assessment as part of evaluation for lung cancer surgery is based on 25 observational studies of varying sizes (50–13 376 patients) [24, 26, 27, 29, 30, 37, 41, 44, 46, 49, 54, 56–58, 71, 72, 74, 98–105]. Few studies applied multivariate analyses integrating confounding factors (predictive or prognostic variables). The recommendation is conditional due to the very low certainty of evidence. Yet no substantial harms became evident or are foreseen by us related to $ppoFEV_1$ assessments. One large multicentre study (13 376 patients) demonstrated significantly increasing absolute 30-day mortality and cardiopulmonary morbidity rates in the suggested $ppoFEV_1$ categories ⩾80%, 60–79%, 40–59% and <40%, allowing us to stratify for both pre-operative risks accordingly [26].

2) The recommendation for $ppoFEV_1$ assessment in re-evaluation for lung cancer surgery after completion of induction therapy is based on one small-sized observational study (66 patients) [77]. No multivariate analyses were performed. The recommendation is conditional due to the very low certainty of evidence. Yet no substantial harms became evident or are foreseen by us related to performance of $ppoFEV_1$

assessment. Due to limited data in this small study, the suggested threshold ppoFEV$_1$<80% to indicate a higher risk for post-operative mortality/morbidity is based on a conservative estimate by us.

Additional remarks and practical considerations

The calculation of ppoFEV$_1$ is a well-established spirometry-based parameter to estimate post-operative forced expiratory pulmonary function at rest. While ppoFEV$_1$ has been recommended as an essential second step (if FEV$_1$ and/or D_{LCO} are impaired) in the risk stratification algorithm of the 2009 ERS/ESTS guideline [1], ppoFEV$_1$ is not regularly assessed in the routine pre-operative setting. The panel considers the calculation of ppoFEV$_1$ to be an essential part in pre-operative risk stratification strategies and it should be included in the standard of care in respiratory medicine and lung cancer services, as it represents a rapid and safe measurement.

Recommendations for future research

Despite limited certainty and varying effect strengths of evidence relating to our predefined outcomes, we suggest the integration of ppoFEV$_1$ measurements into pre-therapeutic surgical risk evaluation.

Future research needs to shed light on the implementation of split function in radiotherapy settings. Further research is required into consolidating the current thresholds with better data deriving from both population-based clinical cancer registries, as well as specialised respiratory medicine and lung cancer services.

PICO 2b: Should predicted post-operative D_{LCO} be measured in lung cancer patients, candidates for radical treatment (surgery and/or immunochemoradiotherapy), for risk stratification of mortality, length of stay, morbidity and quality of life following treatment (compared to not using it)?

Recommendation

1) The panel suggests assessing predicted post-operative D_{LCO} (ppoD_{LCO}) to define the pre-operative risk of post-operative mortality and complications in lung cancer patients who are evaluated for lung cancer surgery (Conditional recommendation for the intervention, very low certainty of evidence).

Remark: The panel suggests the ppoD_{LCO} categories ⩾60%, 40–59% and <40% to stratify the pre-operative mortality and morbidity risks as normal, moderate and high, respectively.

2) The panel suggests assessing ppoD_{LCO} *after completion of induction therapy to re-define* the pre-operative risk of post-operative mortality and complications in lung cancer patients who are *re-evaluated* for lung cancer surgery (Conditional recommendation for the intervention, very low certainty of evidence).

Remark: Although evidence on the clinical relevance of certain ppoD_{LCO} thresholds/categories is limited, ppoD_{LCO} <60% suggests a higher risk for post-operative mortality/morbidity.

Summary of evidence and overall quality of evidence

We selected 24 observational studies out of the 1730 initially identified abstracts [24, 26, 29, 37, 41, 44–46, 49, 54, 56–58, 71, 72, 74, 77, 98, 100, 102, 103, 105–107]. Due to substantial heterogeneity of the body of evidence relating to treatment modalities, we formed two subgroups (1: surgical resection irrespective of neoadjuvant or adjuvant therapy; and 2: neoadjuvant therapy followed by surgical resection) which allowed clinically rational pooling of data. Varying ppoD_{LCO} thresholds precluded meaningful meta-analyses. Thus, for each reported ppoD_{LCO} threshold, their related effects per outcome were narratively assessed and then an overall effect estimated for each of the outcomes. From our predefined critical or important outcomes of interest, the following were addressed in the included studies: 30-day, 90-day and 1-year mortality, overall survival, overall morbidity, respiratory morbidity and various other types of morbidity, as well as periprocedural quality of life. The overall certainty of evidence was rated as very low and low for subgroups 1 and 2, respectively.

Desirable effects

In the surgical subgroup (23 studies), despite the narrative assessment of included studies per outcome and the variation of applied ppoD_{LCO} thresholds, ppoD_{LCO} values below a certain threshold almost always indicated poorer mortality and morbidity rates, as well as poorer overall survival and reduced quality of life, yet with varying effect strengths (supplement B, table 8) [24, 26, 29, 37, 41, 44–46, 49, 54, 56–58, 71, 72, 74, 98, 100, 102, 103, 105–107].

In the subgroup of patients with neoadjuvant therapy followed by surgical resection (one study), similar benefits of ppoD_{LCO} were only reported and seen for overall and respiratory morbidity [77].

Undesirable effects

No harms were identified for any of both subgroups with a total of 24 studies included [24, 26, 29, 37, 41, 44–46, 49, 54, 56–58, 71, 72, 74, 77, 98, 100, 102, 103, 105–107].

Justification of recommendations

1) The recommendation for ppoD_{LCO} assessment as part of evaluation for lung cancer surgery is based on 23 observational studies of varying sizes (50–13 376 patients) [24, 26, 29, 37, 41, 44–46, 49, 54, 56–58, 71, 72, 74, 98, 100, 102, 103, 105–107]. Few studies applied multivariate analyses exploring confounding factors (predictive or prognostic variables). The recommendation is conditional due to the very low certainty of evidence. Yet no substantial harms became evident or are foreseen by us related to ppoD_{LCO} assessments. One large multicentre study (13 376 patients) demonstrated significantly increasing absolute 30-day mortality and cardiopulmonary morbidity rates in the suggested ppoD_{LCO} categories ⩾80%, 60–79%, 40–59% and <40%, allowing us to stratify for both pre-operative risks accordingly [26].

2) The recommendation for ppoD_{LCO} assessment in re-evaluation for lung cancer surgery after completion of induction therapy is based on one small-sized observational study (66 patients) [77]. No multivariate analyses were performed taking into account confounding factors (predictive or prognostic variables). The recommendation is conditional due to the very low certainty of evidence. Yet no substantial harms became evident or are foreseen by us related to performance of ppoD_{LCO} assessment. Due to limited data in this small study, the suggested threshold ppoD_{LCO} <80% to indicate a higher risk for post-operative mortality/morbidity is based on a conservative estimate by us.

From a clinical perspective, we are confident in both recommendations.

Additional remarks and practical considerations

The calculation of ppoD_{LCO} is an established lung function-based parameter. Although ppoD_{LCO} has been recommended as an essential second step (if FEV_1 and/or D_{LCO} are impaired) in the risk stratification algorithm of the 2009 ERS/ESTS guideline [1], ppoD_{LCO} is not regularly assessed in the routine pre-operative setting. The panel considers ppoD_{LCO} assessment to be an essential part of the pre-operative risk stratification.

Recommendations for future research

Despite limited certainty and varying effect of strengths of evidence relating to our predefined outcomes, we suggest the integration of ppoD_{LCO} measurements into pre-therapeutic surgical risk evaluation; however, prospective registries are advised.

Future research needs to shed light on the implementation of split function in radiotherapy/chemoradiotherapy and neoadjuvant settings with the view to consolidate and validate specific cut-offs relating to increased overall and lung cancer-specific mortality. Further research is required into consolidating the current thresholds with better data deriving from population-based clinical cancer registries, as well as specialised respiratory medicine and lung cancer services.

PICO Question 3: Should field exercise tests (6-min walk test/shuttle walk test, stair climbing test, BODE score) be used in lung cancer patients, candidates for radical treatment (surgery and/or immunochemoradiotherapy) for risk stratification of mortality, length of stay and quality of life following treatment (compared to not using them)?

Recommendation

1) The panel suggests using one low technology test (6-min walk test/shuttle walk test, stair climbing test, BODE score) to define the risk of early mortality and complications in lung cancer patients who will undergo surgery (Conditional recommendation for the intervention, very low quality of evidence). The panel cannot suggest any specific cut-off to define patients at very high or very low mortality/morbidity risk.

Remarks: Although no specific thresholds can be recommended due to lack of evidence, 6-min walk test or shuttle walk test distance above 400 m and a stair climb height of more than 10 m suggest a lower surgical risk.

There is no available data for stratifying lung cancer patients before radical radiotherapy or multimodality treatment options.

The panel suggests that patients with poor performance in a low technology test should be referred to a formal cardiopulmonary exercise test (CPET) to better define their surgical risk and possibly improve their fitness for radical treatment.

No recommendation can be made about the predictive role of low technology tests in patients who will undergo radiotherapy, due to lack of data.

The BODE score is a multidimensional scoring system in COPD patients based on body mass index, airflow obstruction (FEV_1), dyspnoea, and exercise (6-min walk test) [108]. Due to inclusions of the other non-field exercise test (FET) parameters, we appraised it separately.

Summary of evidence and overall quality of evidence

30 studies (21 prospective, nine retrospective studies) were selected out of the 2071 initially identified abstracts [67, 71, 109–136], which were appraised separately relating to 6-minute walk test/shuttle walk test, stair climbing test and BODE score. In all studies, FETs were performed before radical surgery and none before radiotherapy. No subgroups were defined. The following outcomes were addressed by the selected studies: early mortality (30- or 90-day, in-hospital, 1-year mortality/survival), post-operative complications (pulmonary, cardiac, cardiopulmonary, any toxic events and some specific complications such as atrial fibrillation or prolonged air leak), hospital and intensive care unit (ICU) stay duration. All outcomes were considered critical. The overall certainty of evidence was rated as low.

Undesirable effects

No harms were identified for any of both subgroups in the 30 studies included [67, 71, 109–136].

Justification of recommendation

Although the evidence consists of small-sized studies with few multivariate analyses and valid concerns about bias, inconsistency and imprecision risks, and heterogeneity and the low quality of the studies not allowing for defining a specific cut-off, 14 studies found a statistically significant inverse relationship between mortality and acceptable FET results. The odds ratio of mortality ranged between 1.23 and 6.27, showing a lower risk of early mortality (30-day, 90-day, in-hospital, or 1-year) in patients with good results compared to those with poor test results. 24 studies [71, 109, 110, 114–126, 128, 129, 132, 135, 137–140] suggest that patients with good results have a lower risk of post-operative complications (OR 1.1–84.9). However, there is heterogeneity in the results due to differences in testing methods, threshold values and subgrouping analysis across the studies. No test helps predicting a specific complication (supplement B, tables 10–12), hence justifying referral of poor performers at FET to a more formal CPET to better define their fitness.

Additional remarks or practical considerations

FETs are simple, low-cost technology tests that can be easily performed in any clinical setting during a consultation. Trained personnel are required to conduct 6-min walk test and shuttle walk tests, as well as standardisation, *e.g.* stair height, for the stair climbing test.

Recommendations for future research

Comparative trials are necessary to confirm the validity of FETs and determine the best cut-off values associated with increased risk of post-operative mortality, morbidity and quality of life in radically treated lung cancer patients. Furthermore, FETs should be compared with more complex tests, such as CPET, to determine their relative effectiveness. Additionally, comparative data before radical (chemo-)radiotherapy and combined treatment modalities are needed.

PICO Question 4: Should laboratory exercise tests ($\dot{V}_{O_2 max}$ or $\dot{V}_E/\dot{V}_{CO_2}$ measured at CPET) be used in lung cancer patients, candidates for radical treatment (surgery and/or immunochemoradiotherapy) for risk stratification of morbidity, mortality or impaired quality of life following treatment (compared to not using them)?

Recommendation

1) The panel suggests using CPET in lung cancer patients with altered pulmonary function and suboptimal results from low-technology tests performed before surgery to predict the risk of early post-operative mortality and complications (Conditional recommendation for the intervention, very low certainty of evidence).

Remarks: In many studies, $\dot{V}_{O_2 max}$ and $\dot{V}_{O_2 peak}$ are used interchangeably. $\dot{V}_{O_2 max}$ is considered an index of cardiovascular fitness and is measured in millilitres per minute per kilogram of body weight ($mL \cdot min^{-1} \cdot kg^{-1}$). It refers to the maximum amount of oxygen consumed during maximal exercise. $\dot{V}_{O_2 peak}$

is also measured in millilitres per minute per kilogram of body weight ($mL \cdot min^{-1} \cdot kg^{-1}$). It is considered a performance index and refers to the highest oxygen consumption achieved during a specific exercise test. When analysed separately, both measures can provide different insight into patient fitness. In pre-operative testing $\dot{V}_{O_2peak}$ is measured.

Due to the limited number and quality of studies, the panel cannot recommend any specific parameter (such as $\dot{V}_{O_2max}$, $\dot{V}_{O_2peak}$, $\dot{V}_{O_2}$ as % of predicted values, $\dot{V}_E/\dot{V}_{CO_2}$ slope) or specific cut-offs for defining patients at very high or low risk of mortality/morbidity.

$\dot{V}_{O_2peak}$ below 12 $mL \cdot min^{-1} \cdot kg^{-1}$ or $\dot{V}_E/\dot{V}_{CO_2}$ slope at an anaerobic threshold greater than 40 can suggest a high surgical risk.

There is lack of data for risk stratification prior to radical radiotherapy or multimodality treatment options.

Summary of evidence and overall quality of evidence

44 studies (29 prospective, 15 retrospectives) and four systematic reviews/meta-analyses were selected out of the 2071 initially identified abstracts [46, 69, 74, 75, 109, 130, 141–178].

In all studies, all CPET exercise tests were performed before radical surgery and none before radiotherapy. Due to substantial heterogeneity of the body of evidence relating to treatment modalities, we formed two subgroups (1: surgical resection irrespective of neoadjuvant or adjuvant therapy; and 2: concurrent chemoradiotherapy) which allowed clinically rational pooling of data. The selected studies addressed the following outcomes: early mortality (30- or 90-day, in-hospital, 1-year mortality/survival), post-operative complications (pulmonary, cardiac, cardiopulmonary, any toxic events and some specific complications such as atrial fibrillation or prolonged air leak), hospital and ICU stay duration. All outcomes were considered critical. The overall quality of evidence was rated as low.

Undesirable effects

No harms were identified for any subgroups in the 44 studies included.

Justification of recommendation

Although the evidence consists of multiple heterogenous small-sized studies with few multivariate analyses and concerns about bias, inconsistency and imprecision risks, most of the studies found a lower risk of early mortality (30-day, 90-day, in-hospital and 1-year) [59, 60, 65, 67, 70, 73, 79, 80, 82–83, 85, 87, 91, 94, 98] and complications [25, 59–66, 68–71, 73, 74, 77–85, 87, 89–92, 94, 96–98, 100] in patients with higher values of performance at CPET. The highest level of evidence for the relationship between CPET and mortality is observed with $\dot{V}_E/\dot{V}_{CO_2}$ slope confirmed in two multivariable analyses suggesting that a lower $\dot{V}_E/\dot{V}_{CO_2}$ slope is associated with a lower mortality risk as an indicator of better aerobic capacity and ventilator efficiency.

Additional remarks or practical considerations

Patients with potential cardiovascular risk factors (such as a history of cardiovascular disease or abnormal ECG results) should be assessed before CPET. Combining pulmonary and cardiovascular testing for some high-risk patients can benefit a more comprehensive evaluation; however, it is essential to standardise the testing process to ensure that the results can be accurately compared and interpreted.

CPET requires specific devices and trained staff to perform the test and interpret the results. CPET access may be difficult in low income countries, especially in rural and remote areas.

Recommendations for future research

Randomised studies and high-quality prospective registries are needed to define the optimal parameters and thresholds for CPET and compare it to low technology testing methods, such as the 6-min walk test and stair climbing. This information would determine the most reliable and cost-effective method for assessing patients' exercise capacity. More data is required to determine the utility of CPET in the context of radical (chemo-)radiotherapy and other combined treatment modalities.

Narrative questions

All narrative questions are presented as executive summaries. Detailed results for each of the underlying narrative reviews are reported in the corresponding GRADE EtDs in supplement B.

Narrative question 1: Which measures should be used to minimise the cardiovascular risk in NSCLC patients, candidates for radical treatment (surgery and/or immunochemoradiotherapy)?

Recommendation

1) The panel suggests that patients with NSCLC who are potential candidates for curative intent treatment and present a history or have some evidence of suspect cardiovascular diseases (general heart disease, atrial fibrillation, coronary artery disease, left ventricular heart failure, right ventricular dysfunction, valvular heart disease, patent foramen ovale and pulmonary hypertension), should undergo a cardiology evaluation. Depending on the outcome, further diagnostic tests should be completed where appropriate (Conditional recommendation, very low certainty of evidence, stemming from narrative review).

Remarks: 1) The cardiology evaluation should be performed according to cardiology guidelines applicable to the respective institution.

2) The cardiology evaluation should be performed during the standard work-up process, aiming to minimise any delay of treatment initiation

3) The cardiology evaluation should be performed considering patient needs and preferences.

Brief summary of the narrative review

We selected 29 studies [179–207] out of the 178 initially identified abstracts consisting of 16 prospective, five prospective diagnostic/observational studies, six reviews and two guidelines. Our narrative review assessed: 1) general heart disease [179–182], 2) cardiovascular risk scores, risk factors and biomarkers [183–194], 3) atrial fibrillation [195], 4) coronary artery disease [196], 5) heart failure [197–199], 6) right ventricular dysfunction [200–202], 7) valvular heart disease/patent foramen ovale [203], and 8) pulmonary hypertension [204–207]. None of the studies justified specific conclusions regarding specific considerations going beyond our general suggestion to perform a cardiology evaluation in patients with a suspicion or history of cardiovascular diseases relating to any of these eight subtopics.

The systematic use of pre-operative risk scores as well as the cardiology evaluation may help to reduce morbidity and mortality following surgery and radiotherapy with curative intent. Patients at high risk and with evidence of cardiovascular diseases should undergo more extensive pre-operative evaluation and closer post-operative monitoring.

Additional invasive investigations should only be considered in patients with positive non-invasive screening tests appraising also potential adverse events.

Narrative question 2

Narrative question 2 was divided into subsections a–g, to assess the overall narrative question: which other factors should be taken into consideration for selection of NSCLC patients, candidates for radical treatment (surgery and/or immunochemoradiotherapy)?

Narrative question 2a: What is the predictive impact of subjective factors (clinician gestalt/eyeballing and patient-reported outcomes) for selection of NSCLC patients, candidates for radical treatment (surgery and/or immunochemoradiotherapy)?

Recommendations

1) The panel suggests being more rigorous about collecting health-related quality of life (HRQoL) data before and after curative treatments (surgery or SBRT). The appropriate questionnaires must be chosen to measure patient-reported outcomes (PROs). Particularly, the preferred patient-reported outcome measure (PROM) tools must be applicable at baseline and at follow-up visits. Follow-up visits should extend up to 12 months post-surgery and up to 2 years post-SBRT at regular intervals for accurate longitudinal PRO assessment (Conditional recommendation, low certainty of evidence, stemming from narrative review).

2) The panel suggests using cancer-specific internationally validated tools such as EORTC QLQ-C30, EORTC QLQ-LC29 and the National Institutes of Health-sponsored Patient Reported Outcome Measurement Information System (PROMIS) to assess quality of life after curative treatment (Conditional recommendation, low certainty of evidence, stemming from narrative review).

3) The panel suggests to assess the effect of acute side-effects on HRQoL within 3 months of treatment and severe symptoms (symptoms that are grade 3 and above according to Common Terminology Criteria for Adverse Events) with appropriate questionnaires as patient-reported symptoms should be managed

properly to hasten recovery time after definitive treatment (Conditional recommendation, low certainty of evidence, stemming from narrative review).

Remarks: 1) The assessment of PROs before radical treatment for lung cancer has the potential to identify predictors of outcomes which are not captured by traditional objective parameters traditionally used to assess fitness.

2) Tailored PRO tools, timing of assessment and strategies to increase the completion rate should be considered according to the population of interest.

3) By integrating PRO assessment into clinical practice, physicians can better identify patients at high risk of decline in HRQoL domains, such as emotional and physical functioning. This can enable the implementation of targeted psychological and physical support programmes tailored to benefit these patients.

Brief summary of narrative review

Eight out of 29 studies assessed the predictive impact of pre-treatment HRQoL on short-term outcomes [68, 72, 73, 208–212].

Studies were heterogeneous regarding applied tools (EORTC QLQ-C30, EORTC QLQ-LC13, SF-36, PROMIS), assessment time-points and outcomes. Pre-operative HRQoL functions measured by PROs may identify surgical patients at risk for longer post-operative length of stay and increased complications [73, 208, 209]. Interestingly, pre-operative HRQoL scores in early-stage COPD patients were not significantly associated with post-operative complications after lung cancer surgery in the included study [68].

Studies utilising different tools indicated that regular post-interventional evaluations of physiological, psychological and social impairments bear the potential to improve HRQoL in the further course of lung cancer patients after thoracic surgery or SBRT.

Narrative question 2b: What is the predictive impact of risk scores and nomograms, nutritional status and frailty for selection of NSCLC patients, candidates for radical treatment (surgery and/or immunochemoradiotherapy)?

Recommendations

Risk scores and nomograms

1) The panel suggests that none of the current risk scores or risk nomograms on an individual basis has a role for patient selection for radical treatment (radiotherapy and/or surgery) (Conditional recommendation against, low certainty of evidence, stemming from narrative review).

2) The panel suggests EuroLung 2 risk score as a good tool to be used for comparison in surgical trials or benchmarking assessment. (Conditional recommendation, low certainty of evidence, stemming from narrative review).

Remarks: Risk modelling for post-operative morbidity and 30-day mortality has only moderate predictive value. Final decisions on surgical treatment should not be made based on these models alone. Other variables should also be considered.

Nutritional status

3) The panel suggests to evaluate the nutritional status of lung cancer patients before any type of treatment (Conditional recommendation, low certainty of evidence, stemming from narrative review).

Remarks: For nutritional status evaluation, using either the Nutritional Risk Index or Nutritional Risk Score can be considered targeting patients who are underweight (body mass index <18.5 $kg \cdot m^{-2}$), who have suffered unintentional loss of 10% or more of their body weight, or who are >70 years of age.

Frailty

4) The panel suggests that frailty should be evaluated and taken into consideration when selecting lung cancer patients for any type of treatment (Conditional recommendation, low certainty of evidence, stemming from narrative review).

Remarks: Regarding frailty, the use of the frailty phenotype assessment (Fried's Frailty Phenotype) can be considered for patients >60 years of age.

Brief summary of narrative review

Risk scores and nomograms

We included two systematic reviews [213, 214] and six observational studies [183, 215–219] in our narrative review. 22 risk models assessed the post-operative mortality risk incorporating different parameters in lung cancer patients [213]. Validations and external evaluations were performed in series of patients operated before 2016 and beyond when minimally invasive surgery was not routinely applied.

In the context of radiotherapy, limited but detailed evidence elaborated a small number of variables predicting the development of radiation pneumonitis (prevalence of 15–40% of patients receiving concurrent chemoradiation) which include dose–volume parameters (especially V20), lower lobe tumour location, and treatment with carboplatin/paclitaxel [214]. Nevertheless, given the limitations, none of the risk scores seems currently applicable in routine lung cancer surgery and radiotherapy. Yet EuroLung 2 showed a good adjustment to observed 30 days mortality, justifying its usage in clinical trials.

Nutritional status

Eight studies [220–227] and one systematic review [228] were selected out of the systematic literature search. Malnutrition influences outcomes after chemotherapy treatments [220]. A pilot study using three different immunonutritional supplements for 7 to 14 days prior to surgery showed improvement in immunonutritional parameters [226]. A reduction greater than 22% of the baseline prognostic nutritional index predicted poorer overall survival in one study [227], while another study highlighted fewer post-operative complications in patients receiving nutritional supplements [225].

Frailty

We included two systematic reviews [14, 229] and three observational studies [230–232]. In a recently published meta-analysis, frailty is strongly associated with adverse health outcomes in elective cancer surgery [229]. A recent consensus paper from the American Association for Thoracic Surgery identified the most important factors considered determining high risk in lung cancer resections, in which frailty ranked second in relative importance [14]. Frailty can be assessed using Fried's frailty criteria [230]. The use of other metrics for frailty assessment (Modified Frailty Index, Risk Analysis Index) is more useful at a population level than at an individual patient level [231, 232].

Narrative question 2c: What is the predictive impact of planned extent of surgical resection (e.g. sublobar parenchymal sparing resections, lobectomy) for selection of NSCLC patients, candidates for radical treatment (surgery and/or immunochemoradiotherapy)?

Recommendation

1) The panel suggests that in high-risk patients, the overall feasibility of a sublobar resection may influence the selection of patients for surgery (Conditional recommendation, low certainty of evidence, stemming from narrative review).

Remarks: 1) There is insufficient data available on the immediate post-operative lung function loss between lobectomy and the various sublobar resection types.

2) Current studies represent patients of mixed fitness levels, but with largely non-compromised physiology and lung function. There is insufficient data available on the role of segmentectomy in patients with compromised cardiorespiratory reserve.

3) Subjective measures of changes in dyspnoea scales or functional status at these early to mid-term time periods (PROMs) may represent a more important outcome. There is insufficient literature available reporting on these outcomes.

4) There is likely to be a difference in the degree of lung function preserved by each anatomical segmentectomy. Further heterogeneity results when considering bi- and multi-segmental resections in various conformations. There is insufficient data available on this topic.

Brief summary of narrative review

We selected two randomised controlled trials [2, 8] and two observational studies for this narrative review [233, 234]. The implementation of lung cancer screening programmes across Europe will cause an increase in the detection of small or minimally invasive lesions, also in compromised patients. More patients will present with multiple lung nodules. Lung sparing procedures have the appeal of allowing for subsequent curative treatments by preserving lung parenchyma and, potentially, lung function. Findings from two large randomised controlled trials performed in fit patients have shown that sublobar resections are at least similar to lobectomies in terms of overall survival [2, 8].

A small reduction in perioperative morbidity and mortality appears to be associated with sublobar resections in the high-risk group of patients [233]. The evidence is inconsistent across study designs. However, current studies represent patients of mixed fitness levels, but with largely non-compromised physiology and lung function.

Sublobar resections seemed to offer a variable degree of functional preservation, as measured by spirometry at 6 to 12 months post-operatively compared to baseline. In addition, a recent trial revealed that patients undergoing sublobar resection have an increased ability to tolerate subsequent treatment procedures, ultimately leading to improved survival [8]. Recent evidence suggests that segmentectomy is associated with reduced risk of patient-reported post-operative dyspnoea deterioration in long term survivors after minimally invasive curative lung resection, pointing to a better HRQoL [234].

Narrative question 2d: What is the predictive impact of pulmonary rehabilitation for selection of NSCLC patients, candidates for radical treatment (surgery and/or immunochemoradiotherapy)?

Recommendations

1) The panel suggests that prehabilitation has a role in preparing patients for tumour-specific treatments of lung cancer, as it can decrease the incidence of post-operative pulmonary complications in high-risk patients, and therefore might increase the number of patients eligible to undergo surgery (Conditional recommendation, moderate certainty of evidence, stemming from narrative review).

2) The panel suggests that post-operative rehabilitation has a role in the after care of patients who underwent tumour-specific treatments of lung cancers, as it can improve functional recovery in selected patients with persisting functional limitations, including those who followed prehabilitation (Conditional recommendation, moderate certainty of evidence, based on narrative review).

Brief summary of narrative review

The presented evidence on the effects of pre- and post-operative rehabilitation interventions is based on five recent systematic reviews of randomised controlled trials [235–239] and one randomised controlled trial [240]. There is consistent evidence that patients who are at high risk of developing post-operative complications and taught pre-operatively by a physiotherapist on how to perform breathing exercises after surgery or who strengthen their respiratory muscles before surgery with a loaded resistive breathing device can halve their risk of developing complications after major surgery. Additionally, post-operative length of hospital stay may be reduced [235, 237]. Combined respiratory muscle and exercise training can also improve (functional) exercise capacity with largest improvements in those presenting with lowest exercise capacity [235, 237]. Exercise training increases exercise capacity and quadriceps muscle force following lung resection for NSCLC [236]. Post-operative exercise training can significantly improve the quality of life of patients undergoing lung surgery [236, 238]. Only one adverse event (hip fracture) was reported in the intervention group of one randomised controlled trial evaluating post-operative interventions [236]. Patients valued respiratory prehabilitation including breathing exercises [240]. The optimal FITT-PV parameters (frequency, intensity, type, timing, progression and volume) for different patient profiles remain uncertain both for pre- and post-rehabilitation interventions due to insufficient evidence and large heterogeneity between studies.

Narrative question 2e: What is the predictive impact of age for selection of NSCLC patients, candidates for radical treatment (surgery and/or immunochemoradiotherapy)?

Recommendation

1) The panel suggests that patient age alone should not be used as an independent predictive factor to affect the decision process for treatment modalities in radical lung cancer treatment settings (Conditional recommendation against, low certainty of evidence, stemming from narrative review).

Remarks: The evaluation of age in combination with current performance status prior to radical treatment, comorbidities and TNM should be considered as a whole to recommend for or against radical treatment approaches in elderly patients ensuring efficacy and safety.

Brief summary of narrative review

45 out of 369 publications were selected for the narrative review [70, 172, 241–283]. Definitions of age cut-offs in the elderly varied across the selected studies, which used cut-offs at 65 years [247], 70 years [70, 241, 242, 244, 246, 248, 250, 252–254, 260, 264, 267, 269, 273, 276–283], 75 years [243, 249, 255,

258, 259, 262, 263, 265, 270, 271, 275] and 80 years [245, 272, 274]. Regarding radical treatment modalities, most studies address surgical resection [70, 241, 243–247, 257, 259, 260, 263–268, 273, 278, 279, 282], few radiotherapy [242, 249, 252, 254, 255, 261] and fewer chemotherapy [249, 253] in the elderly.

Surgery

Older age does not seem to independently impact on surgical outcomes (morbidity, mortality, survival) when patients are properly selected [245, 248, 250, 275, 279, 280] and minimally invasive approaches are used [247, 260] while poorer D_{LCO} [70] and pre-operative American Society of Anesthesiologists Physical Status [283], greater extent of resections and in particular right-sided pneumonectomy [47, 247, 273, 281], the TNM staging [283], and comorbidity [251, 256, 260] negatively affect outcomes. Only one study found that age was a predictor of death within the early post-operative period [269].

The elderly tend to have longer recovery periods than younger patients. While one study showed a similar length of hospital stay in elderly compared to younger patients [251], a large proportion of them (up to 24%) are transferred to specialised care facilities after operation [260] as they fail to make a complete recovery and show a decreased tendency to achieve the pre-operative level of quality of life compared to younger patients [277].

Chemotherapy

Induction chemotherapy followed by major lung resection can be performed with acceptable short-and long-term results in appropriately selected elderly patients with toxicities and mortality rates that are comparable to those of younger patients [253, 261, 282]. Chemotherapy relapse patterns seem to be similar between younger and older patients [261]. Only one study reported more grade 4 toxicities in the elderly [276].

Radiotherapy

Age does not seem to be an independent predictive factor for radiotherapy-related toxicities [252] and overall survival [255] while these outcomes correlated with comorbidities [252] and performance status [261]. Elderly patients undergoing SBRT for early-stage NSCLC appear to have similar risk of toxicity and rate of efficacy as in younger patients. These findings support the use of SBRT in appropriately selected elderly patients [262].

Chemoradiotherapy

The elderly experienced more toxicities as well as worse mortality and overall survival when receiving concurrent chemoradiotherapy in trials [278] and routine care [249] in comparison to younger patients.

Narrative question 2f: What is the predictive impact of performance status and sarcopenia for selection of NSCLC patients, candidates for radical treatment (surgery and/or immunochemoradiotherapy)?

Recommendations

Performance status

1) The panel suggests that assessment of performance status and its documentation can have an important role in the selection of patients being considered for radical treatment of lung cancer (Conditional recommendation, low certainty of evidence, stemming from narrative review).

Remarks: The panel cannot provide a performance status threshold for an absolute contraindication to radical treatment, but healthcare providers should recognise the increased risk of perioperative mortality and morbidity associated with any Eastern Cooperative Oncology Group (ECOG) performance status >0, and in particular with ECOG performance status ⩾2.

Sarcopenia

2) The panel suggests that the assessment of sarcopenia by computed tomography (CT) scan can have a promising role as a semi-quantitative tool to directly assess muscle mass, which could be complementary to the overall frailty phenotype (Conditional recommendation, low certainty of evidence, stemming from narrative review).

Remarks: There is considerable variation regarding the assessment tools for sarcopenia and reference race- and gender-adjusted cut-off values, the patient population studied and the relevant surgical procedures and outcomes, such as prognosis and post-operative complications, in the published reports. Thus, further validation, methodological refinement and larger studies are required to guide clinical practice.

Brief summary of narrative review

Performance status

The ECOG [284] and the Karnofsky scale [285] are widely implemented performance status tools in oncology to both predict prognosis and determine patient fitness to undergo anti-cancer therapies, primarily for systemic therapies. Our systematic literature search detected 11 eligible studies [269, 286–295]. Study cohorts receiving radical therapies were mainly composed of patients with performance status 0/1. Only a small number of studies enrolled small numbers of participants with performance status 2/3 [286, 288, 294]. The impact of performance status on outcomes was ambiguous. While larger datasets indicate increased perioperative morbidity and mortality in performance status ⩾1 [269, 286, 291, 292, 295] or in performance status ⩾2 in another study [293], data from single or multicentre retrospective cohorts showed differing trends.

Sarcopenia

Sarcopenia is common in NSCLC patients and is considered an independent risk factor for post-operative complications and poor prognosis after lung resection [296]. 17 publications reporting on the impact of sarcopenia on short-term post-operative outcomes in lung cancer were included [296–312], of which 16 were retrospective studies [297–312] and one was a systematic review with meta-analysis [296]. Studies used different sarcopenia diagnostic tools, software and cut-off values. Most of the studies use abdominal CT scan at the level of the third lumbar vertebra (L3), by taking either the psoas muscle mass index (cross-sectional area of the psoas muscle/height; $cm^2 \cdot m^{-2}$) [297–300, 308, 309, 312] or skeletal muscle index (cross-sectional area of skeletal muscle/height; $cm^2 \cdot m^{-2}$) [297–300, 308, 309, 312].

10 studies found poorer post-operative outcomes associated with sarcopenia, namely higher post-operative complication [297–299, 301–303, 307–309], increased 30-day mortality [303, 304], longer hospital [298, 302, 304, 308] and ICU stay [302], as well as shorter 1-year overall and disease-free survival [311].

Narrative question 2g: What is the predictive impact of different comorbidities (other than cardiovascular diseases) for selection of NSCLC patients, candidates for radical treatment (surgery and/or immunochemoradiotherapy)?

Recommendations

1) The panel suggests that the risk of surgery or radiotherapy is increased in patients with comorbidities and physicians need to be cautious if Charlson Comorbidity Index is increasing when providing surgery or radiotherapy with curative intent (Conditional recommendation, low certainty of evidence, stemming from narrative review).

2) The panel suggests that patients with non-dialysed chronic kidney disease seem not at an increased risk of surgery in early-stage NSCLC. Nevertheless, an additional risk is observed in those patients >75 years old (Conditional recommendation, low certainty of evidence, stemming from narrative review).

3) The panel suggests that patients with lung cancer and cirrhosis have an increased risk of complications and liver decompensation after surgery (Conditional recommendation, low certainty of evidence, stemming from narrative review).

4) The panel suggests that based on the available literature, no recommendation can be proposed for curative intent treatment in patients with autoimmune diseases and early lung cancer (Conditional recommendation, very low certainty of evidence, stemming from narrative review).

5) The panel suggests that the risk of post-surgical complications in HIV patients with early-stage NSCLC is dependent on CD4 count, the HIV viral load and the optimal antiviral therapy (highly active antiretroviral therapy). The decision must take into account on the potential detrimental long-term prognosis related to HIV status (Conditional recommendation, very low certainty of evidence, stemming from narrative review).

6) Based on the available literature, no recommendation can be made for or against chemoradiotherapy or definitive radiotherapy in HIV patients (Conditional recommendation, very low certainty of evidence, stemming from narrative review).

7) The panel suggests adapting HIV therapy while planning chemotherapy to avoid detrimental interactions (Conditional recommendation, low certainty of evidence, stemming from narrative review).

8) The panel suggests that stroke or cerebrovascular disease are not associated with a detrimental impact on mortality, while more post-surgical complications are observed (Conditional recommendation, low certainty of evidence, stemming from narrative review).

9) The panel suggests performing a pre-operative work-up to assess the risk of a cerebrovascular incident during surgical procedure (Conditional recommendation, low certainty of evidence, stemming from narrative review).

10) The panel suggests that diabetes is associated with an increased risk for post-surgical complications. Adequate diabetes control and vascular assessment are recommended before surgery to reduce post-operative complications (Conditional recommendation, low certainty of evidence, stemming from narrative review).

11) The panel suggests recommending definitive radiation to unresectable or inoperable NSCLC patients with diabetes despite an increase in radiation pneumonitis (Conditional recommendation, low certainty of evidence, stemming from narrative review).

12) The panel suggests that thoracic surgery in solid organ transplant recipients is associated with potential increase in early mortality and risk of respiratory failure but with adequate long-term survival (Conditional recommendation, low certainty of evidence, stemming from narrative review).

13) The panel suggests that patients with interstitial lung disease (ILD) are at increasing risk of complications after thoracic surgery and/or radiotherapy (Conditional recommendation, low certainty of evidence, stemming from narrative review).

14) The panel suggests considering SBRT as the treatment of choice, with RFA reserved for cases where SBRT is unavailable, contraindicated, or as a salvage treatment following SBRT. Final decisions should take into account the benefit/risk ratio for each option (Conditional recommendation, low certainty of evidence, stemming from narrative review).

Brief summary of narrative review

Comorbidities are frequent [313] and may occur concomitantly in a substantial number of lung cancer patients [314]. Our systematic literature search retrieved 133 publications [43, 47, 98, 183–185, 205, 274, 291, 303, 306, 315–436]. We assessed the predictive impact of comorbidities globally in the Charlson Comorbidity Index (28 studies) [98, 205, 303, 306, 315–338] as well as specifically in kidney (eight studies) [47, 183, 339–344], liver (six studies) [291, 345–349], autoimmune (three studies) [350–352], viral (nine studies, all on HIV) [353–361], and neurological diseases (five studies) [184, 341, 362–364], diabetes (18 studies) [185, 274, 343, 365–379], and diseases going along with immunosuppression (two studies) [380, 381] as well as ILD with radiotherapy (13 studies; two systematic reviews) [382–396] and surgery (36 studies; nine systematic reviews) [43, 326, 352, 386, 396–436]. The main characteristics and results of the retrieved series are reported in supplement B (tables 25–33). The evidence focuses mostly on surgery, while studies on radiotherapy, considering conventional or hypofractionated schedules, are scarce apart from in ILD. Overall, patients with comorbidities have an increased risk of early complications (in the year after surgery and/or radiotherapy), even though the impact of comorbidities is inconsistent across various series, probably due to the low number of patients, selection biases and variable definitions of specific comorbidities. Particularly, ILD patients are at increased risk of exacerbations with relevant mortality subsequent to surgery or radiotherapy (regardless if SBRT or conventionally fractionated radiation). However, this should not preclude considerations for locally ablative therapies in these patients.

The data suggest that comorbidities should be critically reviewed, weighing benefits and harms when considering curative surgery or radiotherapy in lung cancer patients. Lung cancer patients with specific conditions such as dialysis, post-transplantation, HIV or ILD should be treated in lung cancer services with the possibility of direct collaboration with these comorbidity-specific disciplines (table 1).

Good practice statement about smoking cessation

The panel suggests that actively smoking patients who are considered for radical lung cancer treatment should either receive a brief smoking cessation intervention or be given access to a structured smoking cessation programme pre-therapeutically (Good practice statement).

Brief summary of underlying evidence

Smoking can cause, among others, lung cancer and COPD. Quitting smoking at or around diagnosis improves overall survival of lung cancer patients [437]. Patients who quit smoking approximately 4 weeks

TABLE 1 Definition of high-risk patients for surgery

Risk factors	Stratification
ppoD_{LCO} <40%	Relative
CPET: $\dot{V}_{O_2peak}$ <12 mL·kg^{-1}·min^{-1}	Relative
CPET: $\dot{V}_E/\dot{V}_{CO_2}$ slope >40	Absolute
High cardiovascular risk	Absolute
Pulmonary hypertension	Absolute
Impaired performance status (ECOG ⩾2)	Absolute
Interstitial lung disease	Relative, if stable; almost absolute, if progressive
Dialysis, hepatic failure	Relative
Severe immunosuppression	Relative
Severe autoimmune disease	Relative
Organ transplant	Relative
HIV	Relative

The presence of at least one absolute risk factor or a minimum of two relative risk factors defines a high-risk patient for surgery. For high-risk patients, consider alternative non-surgical curative treatments and management in highly specialised centres with experience in multidisciplinary support. The definitions and thresholds of the different risk factors were derived from our narrative literature search and review. ppoD_{LCO}: predicted post-operative diffusing capacity of the lung for carbon monoxide; CPET: cardiopulmonary exercise test; $\dot{V}_{O_2peak}$: peak oxygen uptake; $\dot{V}_E$: minute ventilation; $\dot{V}_{CO_2}$: carbon dioxide production; ECOG: Eastern Cooperative Oncology Group.

before any surgery have a reduced risk of post-surgical complications [438]. Thoracic surgery is prone to post-operative pulmonary complications, which can also be reduced by quitting smoking [439]. Smoking cessation seems to be of benefit even with shorter intervals to surgery [66, 440]. The risk reduction from smoking cessation seems also to be relevant with contemporary surgical and perioperative approaches [441].

We suggest including smoking cessation as a risk-modifying procedure in perioperative management.

Discussion

The previous ERS/ESTS guidelines evaluating fitness for radical treatment of lung cancer were published in 2009. From that publication, the management of NSCLC has rapidly evolved with the improvement of perioperative care and the introduction of novel surgical and non-surgical strategies (including radiotherapy and systemic anti-cancer treatment). In this context, ERS and ESTS agreed to update the previous guidelines with the latest evidence. Compared to the previous guidelines, a more robust methodology was applied, the scope of the guidelines was expanded to also include non-surgical treatments, and newly published evidence has been included. The relevance of a multidisciplinary approach and including comorbidities in the evaluation for the most suitable treatment is emphasised.

Based on the latest literature search, the current guidelines confirmed that pulmonary function tests, and in particular FEV_1 and D_{LCO}, should be measured in all surgical candidates. Split lung function should be calculated for both FEV_1 and D_{LCO} based on the number of functioning segments to be resected.

A novel recommendation compared to the previous guidelines is to repeat the pulmonary function tests (FEV_1 and D_{LCO}) after completion of a neoadjuvant systemic treatment.

Similar to the 2009 guidelines and the ACCP guidelines, we recommend the utilisation of a low technology test prior to lung resection and the referral to a formal CPET in case of poor performance during the low technology tests (*i.e.* shuttle walk test or stair climbing test). Due to the heterogeneity of the publications, it was difficult to define a clear-cut high-risk threshold. In any case, we suggest that a shuttle walking distance or 6 min walking distance shorter than 400 m and a $\dot{V}_{O_2peak}$ lower than 12 mL·min^{-1}·kg^{-1} measured at CPET should be regarded as associated with increased risk of post-operative adverse events.

Recent literature has shown the relevance of the inefficiency slope ($\dot{V}_E/\dot{V}_{CO_2}$ slope) measured during CPET as a parameter associated with post-operative risk of mortality and respiratory complications, especially when greater than 40.

We confirm the importance of a cardiologic evaluation before surgery and, in case of cardiologic risk factors, specialist input should be requested to determine the need for further tests.

TABLE 2 Definition of high-risk patients for radiotherapy

Risk factors	Stratification	Notes
D_{LCO} <40%	Relative	Conditional to size of the radiation field and exposure and the presence of other risk factors; increased risk for impaired respiratory function in combination with immunotherapy
High cardiovascular risk	Relative	Risk varies according to size of the radiation field, dose and anatomical location; increased risk for radiation pneumonitis in combination with immunotherapy
Impaired performance status (ECOG ⩾2)	Relative	Risk varies depending on the presence of other risk factors
Interstitial lung disease	Relative, if stable; absolute, if progressive	Increased risk of radiation pneumonitis

The definitions and thresholds of the different risk factors were derived from our narrative literature search and review. D_{LCO}: diffusing capacity of the lung for carbon monoxide; ECOG: Eastern Cooperative Oncology Group.

One important new aspect of this task force is the relevance given to PROs. The panel is suggesting being more rigorous in collecting PROMs before and after treatment.

Another new recommendation compared to existing guidelines is the evaluation of the nutritional status and frailty of lung cancer patients before any type of treatment.

In recent years the role of sublobar resections has been popularised and this task force believes that in high-risk patients their overall feasibility may influence the selection of patients for surgery.

Among the novel aspects of the current project is the analysis of the impact of prehabilitation in the selection of patients for curative treatment. Since this intervention has a role in improving physical function and decreasing the incidence of post-operative pulmonary complications, it might increase the number of patients who are eligible to undergo surgery.

Based on a narrative review of the systematically collected evidence we propose definitions of high-risk patients for surgery, radiotherapy and systemic anti-cancer treatment (tables 1, 2 and 3) and a patient centred work-up algorithm (figures 1, 2 and 3). We hope these elements will represent useful guidance for

TABLE 3 Definition of high-risk patients for systemic anti-cancer treatment

Risk factors	Stratification	Notes
D_{LCO} <40%	Relative	Deterioration of respiratory function with some chemotherapeutic substances and with immune pneumonitis
High cardiovascular risk	Relative	Higher risk with the occurrence of immune-related carditis; other chemotherapeutic agents can induce cardiac toxicity, *i.e.* adriamycin (heart failure, rarely arrhythmia), high dose cyclophosphamide (heart failure), taxanes (arrhythmia)
Impaired performance status (ECOG ⩾2)	Relative	Depending on the type of drug and regimen
Interstitial lung disease	Relative, if stable; almost absolute, if progressive	Risk of immune-related pneumonitis with immune therapy and acceleration of interstitial lung disease; other chemotherapeutic agents can also induce pneumonitis
Dialysis, hepatic failure	Relative	Pharmacodynamics altered, depending on the drug and regimen
Hepatic failure	Relative	Depending on the level of hepatic failure: Child–Pugg A, probably minor; Child–Pugg B, at risk and must be discussed with the hepatologist; Child–Pugg C, avoid any systemic treatment
Severe immunosuppression	Relative	Increased risk of infections; conditional to the presence of other risk factors
HIV	Relative	Immunotherapy can safely be given in patients with controlled disease and correct CD4 count; the infectious risk is increased with chemotherapy as well as drug interactions between HIV therapy and some chemotherapeutic agents

For systemic treatment we intend only a treatment for local/locoregional non-small cell lung cancer/small cell lung cancer with intended curative treatment, as we did not look at stage IV or palliative therapies. The definitions and thresholds of the different risk factors were derived from our narrative literature search and review. D_{LCO}: diffusing capacity of the lung for carbon monoxide; ECOG: Eastern Cooperative Oncology Group.

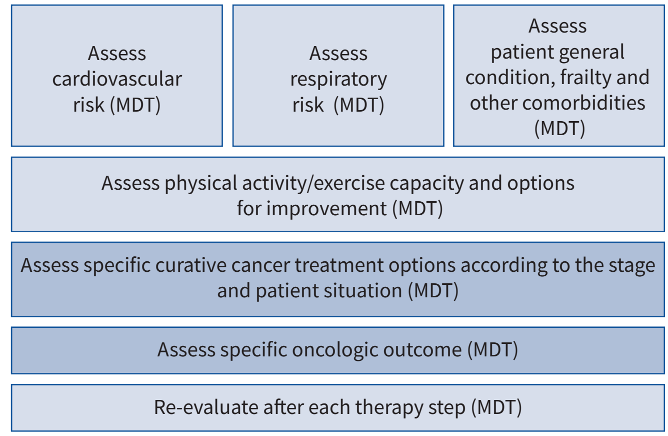

FIGURE 1 General fitness evaluation flow-chart for curative treatment of non-small cell lung cancer. The patient's values and preferences should always be taken into account in the shared decision-making process. MDT: multidisciplinary team.

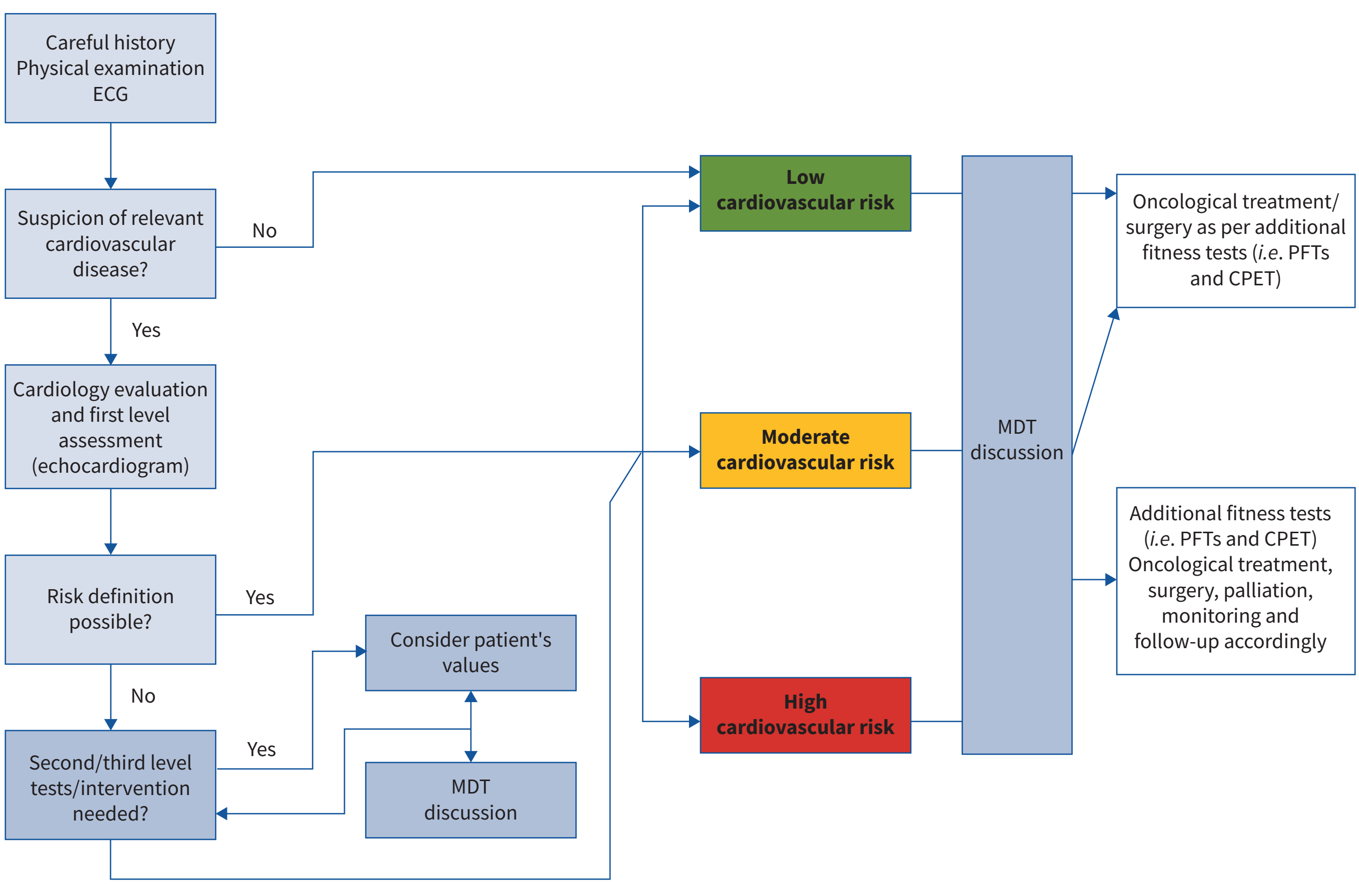

FIGURE 2 Algorithm for evaluating cardiovascular risk for curative treatment of non-small cell lung cancer. Algorithm was developed considering the recommendations and remarks arising from the evidence review performed for the narrative question, along with an educated judgement derived from clinical practice. MDT: multidisciplinary team; PFT: pulmonary function test; CPET: cardiopulmonary exercise test.

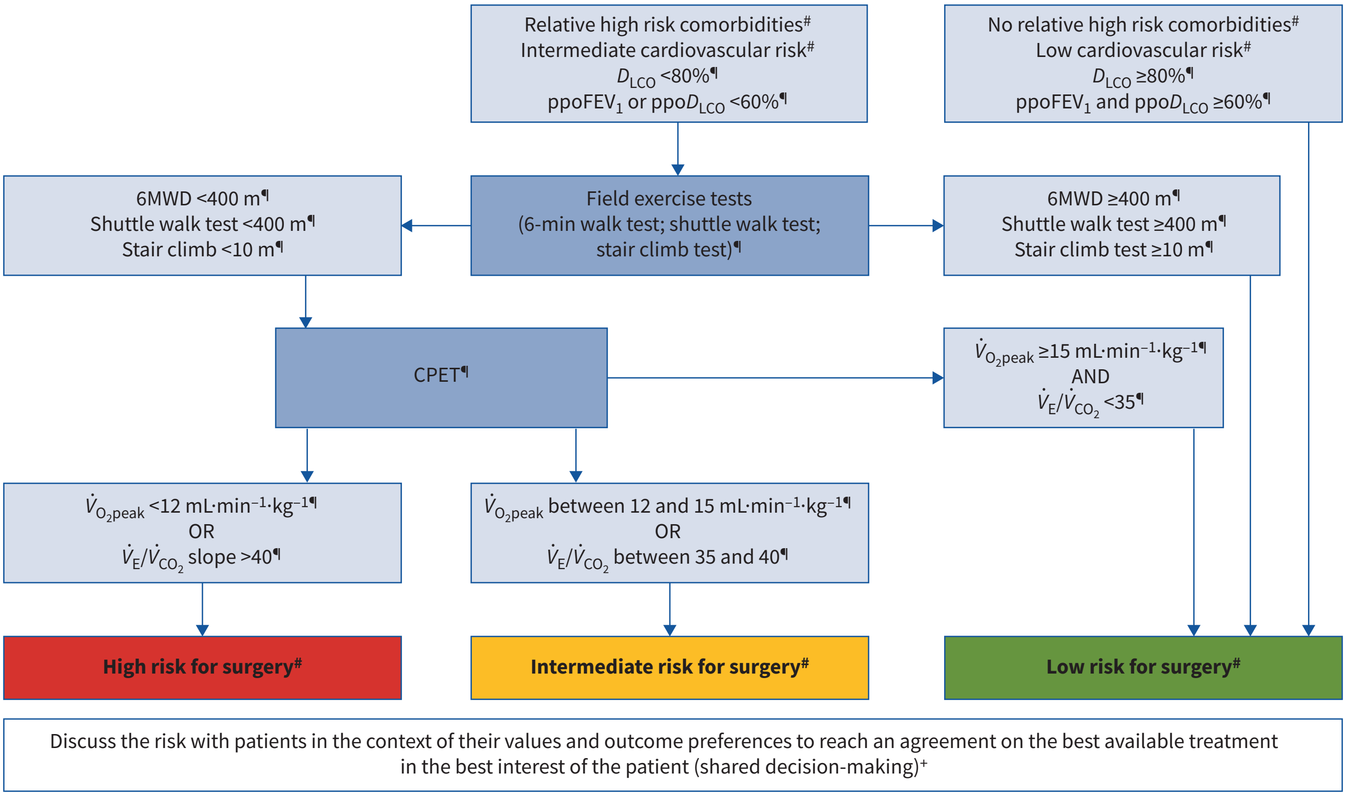

FIGURE 3 Algorithm for evaluating cardiorespiratory fitness for surgical treatment of non-small cell lung cancer. Algorithm was developed considering the recommendations and remarks arising from the evidence review performed for the PICO (¶) and narrative questions (+), along with an educated judgement derived from clinical practice (#). D_{LCO}: diffusing capacity of the lung for carbon monoxide; ppoD_{LCO}: predicted post-operative D_{LCO}; ppoFEV$_1$: predicted post-operative forced expiratory volume in 1 s; 6MWD: 6-min walk distance; CPET: cardiopulmonary exercise test; $\dot{V}_{O_2peak}$: peak oxygen uptake; $\dot{V}_E$: minute ventilation; $\dot{V}_{CO_2}$: carbon dioxide production.

practising clinicians involved in the management of patients with NSCLC. The algorithms should be used as a general guide only and patients must be evaluated and risk-assessed on an individual basis.

Conclusions

In conclusion, we think the current guidelines represent an up-to-date evidence-based guidance for practising clinicians involved in the curative treatment of NSCLC. It expands the previous guidelines published more than 15 years ago by way of a more holistic and patient-centric approach.

This document was endorsed by the ERS Executive Committee on 19 August 2025, the European Society of Thoracic Surgeons on 13 August 2025, the International Association for the Study of Lung Cancer on 19 August 2025, the European Society for Radiotherapy and Oncology on 29 September 2025, and the European Society of Anaesthesiology and Intensive Care on 30 September 2025.

The guidelines published by the European Respiratory Society (ERS) incorporate data obtained from a comprehensive and systematic literature review of the most recent studies available at the time. Health professionals are encouraged to take the guidelines into account in their clinical practice. However, the recommendations issued by this guideline may not be appropriate for use in all situations. It is the individual responsibility of health professionals to consult other sources of relevant information, to make appropriate and accurate decisions in consideration of each patient's health condition and in consultation with that patient and the patient's caregiver where appropriate and/or necessary, and to verify rules and regulations applicable to drugs and devices at the time of prescription.

A lay summary of this document is available at https://europeanlung.org/en/information-hub/guidelines/the-benefits-and-risks-of-lung-cancer-treatments/

Conflict of interest: A. Brunelli reports consultancy fees from AstraZeneca, BMS, Ethicon, MSD, Medtronic and Roche, payment or honoraria for lectures, presentations, manuscript writing or educational events from AstraZeneca, BMS, Ethicon, MSD, Medtronic and Roche, and a leadership role with the European Society of Thoracic Surgeons. R.M. Huber reports participation on a data safety monitoring board or advisory board with Janssen Germany, Merck Germany, Boehringer Ingelheim, Sanofi Germany, Novocure and AstraZeneca, and leadership roles with IASLC and Ludwig-Maximilians-Universität (LMU) ethics committee. T. Berghmans reports consultancy fees from Inhatarget, payment or honoraria for lectures, presentations, manuscript writing or educational events from Bayer, Janssen, Merck, BMS, Daiichi-Sankyo and Roche, support for attending meetings from Takeda and Johnson & Johnson, participation on a data safety monitoring board or advisory board with Bayer, Janssen, Merck, BMS, Daiichi-Sankyo and Roche, and leadership roles with ELCWP (President) and EORTC Lung Cancer Group (Treasurer). A. Frille reports grants from the MetaRot programme supported by the Federal Ministry of Education and Research (BMBF), Germany, Mitteldeutsche Gesellschaft für Pneumologie (MDGP) e.V., Medical Faculty, University of Leipzig and Novartis Foundation, and support for attending meetings from the European Respiratory Society (ERS). M. Rodriguez reports consultancy fees from AstraZeneca and Johnson & Johnson, payment or honoraria for lectures, presentations, manuscript writing or educational events from AstraZeneca, Johnson & Johnson and Intuitive/Abex, support for attending meetings from Intuitive/Abex and Medtronic, and stock (or stock options) with Intuitive and Medtronic. L. Depypere reports consultancy fees from Medtronic and Ethicon, and support for attending meetings from BD. T. Batchelor reports consultancy fees from AstraZeneca and BMS, and payment or honoraria for lectures, presentations, manuscript writing or educational events from Intuitive, Johnson & Johnson and Medtronic. D. De Ruysscher reports grants from AstraZeneca, BMS, Beigene, Philips and Olink, and participation on data safety monitoring or advisory boards with AstraZeneca, BMS, Beigene, Philips, Olink and Eli-Lilly. C. Faivre-Finn reports grants from AstraZeneca, Merck and Elekta, consultancy fees from AstraZeneca, payment or honoraria for lectures, presentations, manuscript writing or educational events from Guy's and St Thomas NHS Hospital, and support for attending meetings from AstraZeneca, Elekta and Merck. B. Nagavci acted as ERS methodologist (2020–2022). N. Novoa reports grants from University of Toronto (lung transplant project) and payment or honoraria for lectures, presentations, manuscript writing or educational events from Medela, Medtronic, AstraZeneca and Johnson & Johnson. C. Pompili reports consultancy fees from Roche, payment or honoraria for lectures, presentations, manuscript writing or educational events from AstraZeneca, BMS and Johnson & Johnson, and support for attending meetings from AstraZeneca and Medela. J. Rawlinson reports support for attending meetings from British Thoracic Oncology Group, EORTC MCCR workshop (with AACR/ESMO), UKIO, Queen Mary University London, UK LC clinical expert group and ERS/ELF, expenses or honoraria related to patient representative work from Nottingham University Hospital/Optellum study, UCL lung cancer PPI group, University of Birmingham ICRB and Oxford cancer PPI group, and is a member of the SOLACE science and ethics board and evaluation group. T. Tonia acts as ERS Methodologist. W.H. van Geffen reports a leadership role with NVALT (Dutch Society of Respiratory Physicians) and is local PI for trials run by his department funded by Roche, Novocure and MSD. E.J. Caruana reports payment or honoraria for lectures, presentations, manuscript writing or educational events from AstraZeneca, AtriCure and MSD. U. Mansmann reports grants from European Community and BMBF, German Government. V. Fallet reports consultancy fees from Pfizer, MSD, BMS, AstraZeneca, Takeda, Janssen, Regeneron, Sanofi and Amgen, payment or honoraria for lectures, presentations, manuscript writing or educational events from Pfizer, MSD, BMS and AstraZeneca, and support for attending meetings from Pfizer, AstraZeneca, IsisMedical, Janssen and Takeda. The remaining authors have no potential conflicts of interest to disclose.

Support statement: This work was supported by the European Respiratory Society (TF-2020-07) and the European Society of Thoracic Surgeons. Funding information for this article has been deposited with the Open Funder Registry.

References

1 Brunelli A, Charloux A, Bolliger CT, *et al.* ERS/ESTS clinical guidelines on fitness for radical therapy in lung cancer patients (surgery and chemo-radiotherapy). *Eur Respir J* 2009; 34: 17–41.
2 Altorki N, Wang X, Kozono D, *et al.* Lobar or sublobar resection for peripheral stage IA non-small-cell lung cancer. *N Engl J Med* 2023; 388: 489–498.
3 Batchelor TJP, Rasburn NJ, Abdelnour-Berchtold E, *et al.* Guidelines for enhanced recovery after lung surgery: recommendations of the Enhanced Recovery After Surgery (ERAS®) Society and the European Society of Thoracic Surgeons (ESTS). *Eur J Cardiothorac Surg* 2019; 55: 91–115.
4 Ceppa DP, Kosinski AS, Berry MF, *et al.* Thoracoscopic lobectomy has increasing benefit in patients with poor pulmonary function: a Society of Thoracic Surgeons Database analysis. *Ann Surg* 2012; 256: 487–493.
5 Falcoz PE, Puyraveau M, Thomas PA, *et al.* Video-assisted thoracoscopic surgery *versus* open lobectomy for primary non-small-cell lung cancer: a propensity-matched analysis of outcome from the European Society of Thoracic Surgeon database. *Eur J Cardiothorac Surg* 2016; 49: 602–609.

6 Lim E, Batchelor TJP, Dunning J, *et al.* Video-assisted thoracoscopic or open lobectomy in early-stage lung cancer. *NEJM Evid* 2022; 1: EVIDoa2100016.
7 Paul S, Altorki NK, Sheng S, *et al.* Thoracoscopic lobectomy is associated with lower morbidity than open lobectomy: a propensity-matched analysis from the STS database. *J Thorac Cardiovasc Surg* 2010; 139: 366–378.
8 Saji H, Okada M, Tsuboi M, *et al.* Segmentectomy *versus* lobectomy in small-sized peripheral non-small-cell lung cancer (JCOG0802/WJOG4607L): a multicentre, open-label, phase 3, randomised, controlled, non-inferiority trial. *Lancet* 2022; 399: 1607–1617.
9 Ball D, Mai GT, Vinod S, *et al.* Stereotactic ablative radiotherapy *versus* standard radiotherapy in stage 1 non-small-cell lung cancer (TROG 09.02 CHISEL): a phase 3, open-label, randomised controlled trial. *Lancet Oncol* 2019; 20: 494–503.
10 Postmus PE, Kerr KM, Oudkerk M, *et al.* Early and locally advanced non-small-cell lung cancer (NSCLC): ESMO Clinical Practice Guidelines for diagnosis, treatment and follow-up. *Ann Oncol* 2017; 28: Suppl. 4, iv1–iv21.
11 Sorin M, Prosty C, Ghaleb L, *et al.* Neoadjuvant chemoimmunotherapy for NSCLC: a systematic review and meta-analysis. *JAMA Oncol* 2024; 10: 621–633.
12 Daly ME, Singh N, Ismaila N, *et al.* Management of stage III non-small-cell lung cancer: ASCO guideline. *J Clin Oncol* 2022; 40: 1356–1384.
13 Brunelli A, Kim AW, Berger KI, *et al.* Physiologic evaluation of the patient with lung cancer being considered for resectional surgery: diagnosis and management of lung cancer, 3rd ed: American College of Chest Physicians evidence-based clinical practice guidelines. *Chest* 2013; 143: Suppl. 5, e166S–e190S.
14 Pennathur A, Brunelli A, Criner GJ, *et al.* Definition and assessment of high risk in patients considered for lobectomy for stage I non-small cell lung cancer: the American Association for Thoracic Surgery expert panel consensus document. *J Thorac Cardiovasc Surg* 2021; 162: 1605–1618.
15 Nagavci B, Tonia T, Roche N, *et al.* European Respiratory Society clinical practice guidelines: methodological guidance. *ERJ Open Res* 2022; 8: 00655-2021.
16 Miravitlles M, Tonia T, Rigau D, *et al.* New era for European Respiratory Society clinical practice guidelines: joining efficiency and high methodological standards. *Eur Respir J* 2018; 51: 1800221.
17 Guyatt GH, Oxman AD, Kunz R, *et al.* GRADE guidelines: 2. Framing the question and deciding on important outcomes. *J Clin Epidemiol* 2011; 64: 395–400.
18 Moher D, Liberati A, Tetzlaff J, *et al.* Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS Med* 2009; 6: e1000097.
19 Hayden JA, van der Windt DA, Cartwright JL, *et al.* Assessing bias in studies of prognostic factors. *Ann Intern Med* 2013; 158: 280–286.
20 Schünemann H, Brożek J, Guyatt G, *et al.*, eds. GRADE Handbook for Grading Quality of Evidence and Strength of Recommendations. Updated October 2013. The GRADE Working Group, 2013.
21 Iorio A, Spencer FA, Falavigna M, *et al.* Use of GRADE for assessment of evidence about prognosis: rating confidence in estimates of event rates in broad categories of patients. *BMJ* 2015; 350: h870.
22 Alonso-Coello P, Oxman AD, Moberg J, *et al.* GRADE Evidence to Decision (EtD) frameworks: a systematic and transparent approach to making well informed healthcare choices. 2: Clinical practice guidelines. *BMJ* 2016; 353: i2089.
23 Alonso-Coello P, Schunemann HJ, Moberg J, *et al.* GRADE Evidence to Decision (EtD) frameworks: a systematic and transparent approach to making well informed healthcare choices. 1: Introduction. *BMJ* 2016; 353: i2016.
24 Barnett SA, Rusch VW, Zheng J, *et al.* Contemporary results of surgical resection of non-small cell lung cancer after induction therapy: a review of 549 consecutive cases. *J Thorac Oncol* 2011; 6: 1530–1536.
25 Bongiolatti S, Gonfiotti A, Vokrri E, *et al.* Thoracoscopic lobectomy for non-small-cell lung cancer in patients with impaired pulmonary function: analysis from a national database. *Interact Cardiovasc Thorac Surg* 2020; 30: 803–811.
26 Burt BM, Kosinski AS, Shrager JB, *et al.* Thoracoscopic lobectomy is associated with acceptable morbidity and mortality in patients with predicted postoperative forced expiratory volume in 1 second or diffusing capacity for carbon monoxide less than 40% of normal. *J Thorac Cardiovasc Surg* 2014; 148: 19–28.
27 Cerfolio RJ, Bryant AS, Jones VL, *et al.* Pulmonary resection after concurrent chemotherapy and high dose (60Gy) radiation for non-small cell lung cancer is safe and may provide increased survival. *Eur J Cardiothorac Surg* 2009; 35: 718–723.
28 Estors-Guerrero M, Lafuente-Sanchis A, Quero-Valenzuela F, *et al.* Risk factors for the development of complications after surgical treatment for bronchopulmonary carcinoma. *Cir Esp (Engl Ed)* 2020; 98: 226–234.
29 Fujiu K, Kanno R, Suzuki H, *et al.* Preoperative pulmonary function as a predictor of respiratory complications and mortality in patients undergoing lung cancer resection. *Fukushima J Med Sci* 2003; 49: 117–127.

30 Kim JB, Lee SW, Park SI, *et al.* Risk factor analysis for postoperative acute respiratory distress syndrome and early mortality after pneumonectomy: the predictive value of preoperative lung perfusion distribution. *J Thorac Cardiovasc Surg* 2010; 140: 26–31.

31 Solli P, Leo F, Veronesi G, *et al.* Impact of limited pulmonary function on the management of resectable lung cancer. *Lung Cancer* 2003; 41: 71–79.

32 Voltolini L, Rapicetta C, Ligabue T, *et al.* Short- and long-term results of lung resection for cancer in octogenarians. *Asian Cardiovasc Thorac Ann* 2009; 17: 147–152.

33 Wang JS. Relationship of carbon monoxide pulmonary diffusing capacity to postoperative cardiopulmonary complications in patients undergoing pneumonectomy. *Kaohsiung J Med Sci* 2003; 19: 437–446.

34 Brunelli A, Dinesh P, Woodcock-Shaw J, *et al.* Ninety-day mortality after video-assisted thoracoscopic lobectomy: incidence and risk factors. *Ann Thorac Surg* 2017; 104: 1020–1026.

35 Almquist D, Khanal N, Smith L, *et al.* Preoperative pulmonary function tests (PFTs) and outcomes from resected early stage non-small cell lung cancer (NSCLC). *Anticancer Res* 2018; 38: 2903–2907.

36 Brunelli A, Salati M, Refai M, *et al.* Development of a patient-centered aggregate score to predict survival after lung resection for non-small cell lung cancer. *J Thorac Cardiovasc Surg* 2013; 146: 385–390.e2.

37 Ferguson MK, Watson S, Johnson E, *et al.* Predicted postoperative lung function is associated with all-cause long-term mortality after major lung resection for cancer. *Eur J Cardiothorac Surg* 2014; 45: 660–664.

38 Galata C, Messerschmidt A, Kostic M, *et al.* Prognostic factors for long-term survival following complete resection by lobectomy in stage I non-small cell lung cancer. *Thorac Cancer* 2022; 13: 2861–2866.

39 Towe CW, Thibault DP, Worrell SG, *et al.* Factors associated with successful postoperative day one discharge after anatomic lung resection. *Ann Thorac Surg* 2021; 112: 221–227.

40 Berry MF, Villamizar-Ortiz NR, Tong BC, *et al.* Pulmonary function tests do not predict pulmonary complications after thoracoscopic lobectomy. *Ann Thorac Surg* 2010; 89: 1044–1051.

41 Cerfolio RJ, Allen MS, Trastek VF, *et al.* Lung resection in patients with compromised pulmonary function. *Ann Thorac Surg* 1996; 62: 348–351.

42 Fernando HC, Landreneau RJ, Mandrekar SJ, *et al.* Thirty- and ninety-day outcomes after sublobar resection with and without brachytherapy for non-small cell lung cancer: results from a multicenter phase III study. *J Thorac Cardiovasc Surg* 2011; 142: 1143–1151.

43 Ohsawa M, Tsutani Y, Fujiwara M, *et al.* Predicting severe postoperative complication in patients with lung cancer and interstitial pneumonia. *Ann Thorac Surg* 2020; 109: 1054–1060.

44 Pieretti P, Alifano M, Roche N, *et al.* Predictors of an appropriate admission to an ICU after a major pulmonary resection. *Respiration* 2006; 73: 157–165.

45 Powell ES, Pearce AC, Cook D, *et al.* UK pneumonectomy outcome study (UKPOS): a prospective observational study of pneumonectomy outcome. *J Cardiothorac Surg* 2009; 4: 41.

46 Rodrigues F, Grafino M, Faria I, *et al.* Surgical risk evaluation of lung cancer in COPD patients – a cohort observational study. *Rev Port Pneumol (2006)* 2016; 22: 266–272.

47 Takamochi K, Oh S, Matsuoka J, *et al.* Risk factors for morbidity after pulmonary resection for lung cancer in younger and elderly patients. *Interact Cardiovasc Thorac Surg* 2011; 12: 739–743.

48 Taylor LJ, Julliard WA, Maloney JD. Predictive value of pulmonary function measures for short-term outcomes following lung resection: analysis of a single high-volume institution. *J Thorac Dis* 2018; 10: 1072–1076.

49 Win T, Jackson A, Sharples L, *et al.* Relationship between pulmonary function and lung cancer surgical outcome. *Eur Respir J* 2005; 25: 594–599.

50 Yano T, Yokoyama H, Fukuyama Y, *et al.* The current status of postoperative complications and risk factors after a pulmonary resection for primary lung cancer. A multivariate analysis. *Eur J Cardiothorac Surg* 1997; 11: 445–449.

51 Karush JM, Alex G, Geissen N, *et al.* Predicting non-home discharge after lung surgery: analysis of the General Thoracic Surgery Database. *Ann Thorac Surg* 2023; 115: 687–692.

52 Kong S, Shin S, Jeon YJ, *et al.* Factors associated with failure of cardiopulmonary function recovery after lung cancer surgery. *Respirology* 2023; 28: 1060–1068.

53 Lee JY, Jin SM, Lee CH, *et al.* Risk factors of postoperative pneumonia after lung cancer surgery. *J Korean Med Sci* 2011; 26: 979–984.

54 Amar D, Munoz D, Shi W, *et al.* A clinical prediction rule for pulmonary complications after thoracic surgery for primary lung cancer. *Anesth Analg* 2010; 110: 1343–1348.

55 Benattia A, Debeaumont D, Guyader V, *et al.* Physiologic assessment before video thoracoscopic resection for lung cancer in patients with abnormal pulmonary function. *J Thorac Dis* 2016; 8: 1170–1178.

56 Cao C, Louie BE, Melfi F, *et al.* Impact of pulmonary function on pulmonary complications after robotic-assisted thoracoscopic lobectomy. *Eur J Cardiothorac Surg* 2020; 57: 338–342.

57 Diaz-Ravetllat V, Ferrer M, Gimferrer-Garolera JM, *et al.* Risk factors of postoperative nosocomial pneumonia after resection of bronchogenic carcinoma. *Respir Med* 2012; 106: 1463–1471.

58 Mao X, Zhang W, Ni YQ, *et al.* A prediction model for postoperative pulmonary complication in pulmonary function-impaired patients following lung resection. *J Multidiscip Healthc* 2021; 14: 3187–3194.

59 Yao L, Luo J, Liu L, *et al.* Risk factors for postoperative pneumonia and prognosis in lung cancer patients after surgery: a retrospective study. *Medicine (Baltimore)* 2021; 100: e25295.
60 Zhao D, Ma A, Li S, *et al.* Development and validation of a nomogram for predicting pulmonary complications after video-assisted thoracoscopic surgery in elderly patients with lung cancer. *Front Oncol* 2023; 13: 1265204.
61 Zhou J, Wu D, Zheng Q, *et al.* A clinical prediction model for postoperative pneumonia after lung cancer surgery. *J Surg Res* 2023; 284: 62–69.
62 Linhardt FC, Santer P, Xu X, *et al.* Reintubation after lung cancer resection: development and external validation of a predictive score. *Ann Thorac Surg* 2024; 117: 173–180.
63 Brunelli A, Socci L, Refai M, *et al.* Quality of life before and after major lung resection for lung cancer: a prospective follow-up analysis. *Ann Thorac Surg* 2007; 84: 410–416.
64 Handy JR Jr., Asaph JW, Skokan L, *et al.* What happens to patients undergoing lung cancer surgery? Outcomes and quality of life before and after surgery. *Chest* 2002; 122: 21–30.
65 Khullar OV, Wei JW, Wagh K, *et al.* Preoperative lung function is associated with patient-reported outcomes after lung cancer surgery. *Ann Thorac Surg* 2021; 112: 415–422.
66 Fukui M, Suzuki K, Matsunaga T, *et al.* Importance of smoking cessation on surgical outcome in primary lung cancer. *Ann Thorac Surg* 2019; 107: 1005–1009.
67 He Z, Li H, Cao B, *et al.* Predictive value of skeletal muscle function test combined with climbing test for postoperative cardiopulmonary complications in patients with COPD and concurrent lung cancer. *Int J Chron Obstruct Pulmon Dis* 2023; 18: 2699–2706.
68 Kim ES, Kim YT, Kang CH, *et al.* Prevalence of and risk factors for postoperative pulmonary complications after lung cancer surgery in patients with early-stage COPD. *Int J Chron Obstruct Pulmon Dis* 2016; 11: 1317–1326.
69 Kristenson K, Hedman K. Percent predicted peak oxygen uptake is superior to weight-indexed peak oxygen uptake in risk stratification before lung cancer lobectomy. *J Thorac Cardiovasc Surg* 2024; 168: 1375–1384.e4.
70 Park B, Lee G, Kim HK, *et al.* A retrospective comparative analysis of elderly and younger patients undergoing pulmonary resection for stage I non-small cell lung cancer. *World J Surg Oncol* 2016; 14: 13.
71 Pierce RJ, Copland JM, Sharpe K, *et al.* Preoperative risk evaluation for lung cancer resection: predicted postoperative product as a predictor of surgical mortality. *Am J Respir Crit Care Med* 1994; 150: 947–955.
72 Pompili C, Brunelli A, Xiume F, *et al.* Predictors of postoperative decline in quality of life after major lung resections. *Eur J Cardiothorac Surg* 2011; 39: 732–737.
73 Pompili C, McLennan Battleday F, Chia WL, *et al.* Poor preoperative quality of life predicts prolonged hospital stay after VATS lobectomy for lung cancer. *Eur J Cardiothorac Surg* 2021; 59: 116–121.
74 Ribas J, Diaz O, Barbera JA, *et al.* Invasive exercise testing in the evaluation of patients at high-risk for lung resection. *Eur Respir J* 1998; 12: 1429–1435.
75 Rushwan A, Stefanou D, Tariq J, *et al.* Increased minute ventilation-to-carbon dioxide slope during cardiopulmonary exercise test is associated with poor postoperative outcome following lung cancer resection. *Eur J Cardiothorac Surg* 2024; 65: ezad337.
76 Connolly JG, Fiasconaro M, Tan KS, *et al.* Postinduction therapy pulmonary function retesting is necessary before surgical resection for non-small cell lung cancer. *J Thorac Cardiovasc Surg* 2022; 164: 389–397.
77 Takeda S, Funakoshi Y, Kadota Y, *et al.* Fall in diffusing capacity associated with induction therapy for lung cancer: a predictor of postoperative complication? *Ann Thorac Surg* 2006; 82: 232–236.
78 Shin S, Choi YS, Jung JJ, *et al.* Impact of diffusing lung capacity before and after neoadjuvant concurrent chemoradiation on postoperative pulmonary complications among patients with stage IIIA/N2 non-small-cell lung cancer. *Respir Res* 2020; 21: 13.
79 Kim HE, Yu WS, Lee CY, *et al.* Risk factors for pulmonary complications after neoadjuvant chemoradiotherapy followed by surgery for non-small cell lung cancer. *Thorac Cancer* 2022; 13: 361–368.
80 Etienne H, Fournel L, Mordant P, *et al.* Anatomic lung resection after immune checkpoint inhibitors for initially unresectable advanced-staged non-small cell lung cancer: a retrospective cohort analysis. *J Thorac Dis* 2023; 15: 270–280.
81 Videtic GM, Stitt LW, Ash RB, *et al.* Impaired diffusion capacity predicts for decreased treatment tolerance and survival in limited stage small cell lung cancer patients treated with concurrent chemoradiation. *Lung Cancer* 2004; 43: 159–166.
82 Lee TH, Kang BH, Kim HJ, *et al.* Predictors of post-chemoradiotherapy pulmonary complication in locally advanced non-small cell lung cancer. *Cancer Res Treat* 2023; 55: 865–874.
83 Preti BTB, Sanatani MS, Breadner D, *et al.* Real-world analysis of durvalumab after chemoradiation in stage III non-small-cell lung cancer. *Curr Oncol* 2023; 30: 7713–7721.
84 Torre-Bouscoulet L, Munoz-Montano WR, Martinez-Briseno D, *et al.* Abnormal pulmonary function tests predict the development of radiation-induced pneumonitis in advanced non-small cell lung Cancer. *Respir Res* 2018; 19: 72.

85 Wang J, Cao J, Yuan S, *et al.* Poor baseline pulmonary function may not increase the risk of radiation-induced lung toxicity. *Int J Radiat Oncol Biol Phys* 2013; 85: 798–804.

86 Zhou Y, Yan T, Zhou X, *et al.* Acute severe radiation pneumonitis among non-small cell lung cancer (NSCLC) patients with moderate pulmonary dysfunction receiving definitive concurrent chemoradiotherapy: impact of pre-treatment pulmonary function parameters. *Strahlenther Onkol* 2020; 196: 505–514.

87 Stana M, Grambozov B, Karner J, *et al.* Chemo-radio-immunotherapy for NSCLC III: ESR/ATS thresholds for DL_{CO} correlate with radiation dosimetry and pneumonitis rate. *Cancers (Basel)* 2023; 15: 1966.

88 Voorn MJJ, Aerts LPA, Bootsma GP, *et al.* Associations of pretreatment physical status parameters with tolerance of concurrent chemoradiation and survival in patients with non-small cell lung cancer. *Lung* 2021; 199: 223–234.

89 Lee NS, Shafiq J, Field M, *et al.* Predicting 2-year survival in stage I–III non-small cell lung cancer: the development and validation of a scoring system from an Australian cohort. *Radiat Oncol* 2022; 17: 74.

90 Jang JY, Kim SS, Song SY, *et al.* Clinical outcome of stereotactic body radiotherapy in patients with early-stage lung cancer with ground-glass opacity predominant lesions: a single institution experience. *Cancer Res Treat* 2023; 55: 1181–1189.

91 Dupic G, Biau J, Molnar I, *et al.* Significant correlation between overall survival and mean lung dose in lung stereotactic body radiation therapy (SBRT). *Front Oncol* 2020; 10: 1577.

92 Guckenberger M, Kestin LL, Hope AJ, *et al.* Is there a lower limit of pretreatment pulmonary function for safe and effective stereotactic body radiotherapy for early-stage non-small cell lung cancer? *J Thorac Oncol* 2012; 7: 542–551.

93 Lopez Guerra JL, Gomez D, Zhuang Y, *et al.* Change in diffusing capacity after radiation as an objective measure for grading radiation pneumonitis in patients treated for non-small-cell lung cancer. *Int J Radiat Oncol Biol Phys* 2012; 83: 1573–1579.

94 Miller KL, Kocak Z, Kahn D, *et al.* Preliminary report of the 6-minute walk test as a predictor of radiation-induced pulmonary toxicity. *Int J Radiat Oncol Biol Phys* 2005; 62: 1009–1013.

95 Pagel J, Mohorn M, Kloetzer KH, *et al.* Inhalative versus systemische Pneumonitisprophylaxe bei Thoraxbestrahlungen [The inhalation *versus* systemic prevention of pneumonitis during thoracic irradiation]. *Strahlenther Onkol* 1998; 174: 25–29.

96 Badola A, Gupta M, Bansal S, *et al.* The predictive role of baseline pulmonary function test in lung carcinoma patients for radiation-induced lung toxicity treated with conformal radiation therapy. *Indian J Cancer* 2024; 61: 75–80.

97 Stanic S, Paulus R, Timmerman RD, *et al.* No clinically significant changes in pulmonary function following stereotactic body radiation therapy for early-stage peripheral non-small cell lung cancer: an analysis of RTOG 0236. *Int J Radiat Oncol Biol Phys* 2014; 88: 1092–1099.

98 Eguchi T, Bains S, Lee MC, *et al.* Impact of increasing age on cause-specific mortality and morbidity in patients with stage I non-small-cell lung cancer: a competing risks analysis. *J Clin Oncol* 2017; 35: 281–290.

99 Ozeki N, Kadomatsu Y, Mizuno Y, *et al.* Risk assessment for loss-of-exercise capacity after lung cancer surgery: current advances in surgery and systemic treatment. *World J Surg* 2022; 46: 933–941.

100 Ozeki N, Kawaguchi K, Okasaka T, *et al.* Marginal pulmonary function is associated with poor short- and long-term outcomes in lung cancer surgery. *Nagoya J Med Sci* 2017; 79: 37–42.

101 Brunelli A, Al Refai M, Monteverde M, *et al.* Predictors of early morbidity after major lung resection in patients with and without airflow limitation. *Ann Thorac Surg* 2002; 74: 999–1003.

102 Vanstraelen S, Tan KS, Dycoco J, *et al.* A new functional threshold for minimally invasive lobectomy. *Ann Surg* 2024; 280: 1029–1037.

103 Alam N, Park BJ, Wilton A, *et al.* Incidence and risk factors for lung injury after lung cancer resection. *Ann Thorac Surg* 2007; 84: 1085–1091.

104 Haraguchi S, Koizumi K, Hatori N, *et al.* Prediction of the postoperative pulmonary function and complication rate in elderly patients. *Surg Today* 2001; 31: 860–865.

105 Santini M, Fiorello A, Vicidomini G, *et al.* Role of diffusing capacity in predicting complications after lung resection for cancer. *Thorac Cardiovasc Surg* 2007; 55: 391–394.

106 Aguinagalde B, Insausti A, Lopez I, *et al.* VATS lobectomy morbidity and mortality is lower in patients with the same ppoDLCO: analysis of the database of the Spanish Video-Assisted Thoracic Surgery Group. *Arch Bronconeumol (Engl Ed)* 2021; 57: 750–756.

107 Shen Q, Lai Y, Li X, *et al.* The role of an array of routine clinical variables to the occurrence and severity of postoperative pneumonia in non-small cell lung cancer patients. *Int Surg* 2018; 102: 396–403.

108 Celli BR, Cote CG, Marin JM, *et al.* The body-mass index, airflow obstruction, dyspnea, and exercise capacity index in chronic obstructive pulmonary disease. *N Engl J Med* 2004; 350: 1005–1012.

109 Ellenberger C, Garofano N, Reynaud T, *et al.* Patient and procedural features predicting early and mid-term outcome after radical surgery for non-small cell lung cancer. *J Thorac Dis* 2018; 10: 6020–6029.

110 Ersöz H, Özalevli S, Karakılıç A, *et al.* Role of body mass index, airflow obstruction, dyspnea level, exercise capacity index and maximal oxygen uptake on predicting the postoperative complications of lung resections

for patients with lung cancer and chronic obstructive pulmonary disease. *Turkish J Thoracic Cardiovasc Surg* 2016; 24: 297–304.

111 Holden DA, Rice TW, Stelmach K, *et al.* Exercise testing, 6-min walk, and stair climb in the evaluation of patients at high risk for pulmonary resection. *Chest* 1992; 102: 1774–1779.

112 Ueda T, Takamochi K, Fukui M, *et al.* Significance of preoperative exercise oxygen desaturation in lung cancer with interstitial lung disease. *Eur J Cardiothorac Surg* 2024; 65: ezae142.

113 Erdogan Y, Gunay E, Ergun P, *et al.* Can exercise capacity assessed by the shuttle walk test predict the development of post-operative complications in patients with lung cancer? *Tuberk Toraks* 2013; 61: 28–32.

114 Brunelli A, Refai M, Xiume F, *et al.* Oxygen desaturation during maximal stair-climbing test and postoperative complications after major lung resections. *Eur J Cardiothorac Surg* 2008; 33: 77–82.

115 Brunelli A, Sabbatini A, Xiume F, *et al.* Inability to perform maximal stair climbing test before lung resection: a propensity score analysis on early outcome. *Eur J Cardiothorac Surg* 2005; 27: 367–372.

116 Irie M, Nakanishi R, Yasuda M, *et al.* Risk factors for short-term outcomes after thoracoscopic lobectomy for lung cancer. *Eur Respir J* 2016; 48: 495–503.

117 Lee H, Kim HK, Kang D, *et al.* Prognostic value of 6-min walk test to predict postoperative cardiopulmonary complications in patients with non-small cell lung cancer. *Chest* 2020; 157: 1665–1673.

118 Marjanski T, Badocha M, Wnuk D, *et al.* Result of the 6-min walk test is an independent prognostic factor of surgically treated non-small-cell lung cancer. *Interact Cardiovasc Thorac Surg* 2019; 28: 368–374.

119 Marjanski T, Wnuk D, Bosakowski D, *et al.* Patients who do not reach a distance of 500 m during the 6-min walk test have an increased risk of postoperative complications and prolonged hospital stay after lobectomy. *Eur J Cardiothorac Surg* 2015; 47: e213–e219.

120 Ninan M, Sommers KE, Landreneau RJ, *et al.* Standardized exercise oximetry predicts postpneumonectomy outcome. *Ann Thorac Surg* 1997; 64: 328–332.

121 Ha D, Choi H, Zell K, *et al.* Association of impaired heart rate recovery with cardiopulmonary complications after lung cancer resection surgery. *J Thorac Cardiovasc Surg* 2015; 149: 1168–1173.

122 Nakagawa T, Tomioka Y, Toyazaki T, *et al.* Association between values of preoperative 6-min walk test and surgical outcomes in lung cancer patients with decreased predicted postoperative pulmonary function. *Gen Thorac Cardiovasc Surg* 2018; 66: 220–224.

123 Nakamura T, Sawabata N, Susaki Y, *et al.* Desaturation during the stair-climbing test for patients who will undergo pulmonary resection: an indicator of postoperative complications. *Gen Thorac Cardiovasc Surg* 2020; 68: 49–56.

124 Brunelli A, Al Refai M, Monteverde M, *et al.* Stair climbing test predicts cardiopulmonary complications after lung resection. *Chest* 2002; 121: 1106–1110.

125 Brunelli A, Refai M, Xiume F, *et al.* Performance at symptom-limited stair-climbing test is associated with increased cardiopulmonary complications, mortality, and costs after major lung resection. *Ann Thorac Surg* 2008; 86: 240–247.

126 Dong J, Mao Y, Li J, *et al.* Stair-climbing test predicts postoperative cardiopulmonary complications and hospital stay in patients with non-small cell lung cancer. *Med Sci Monit* 2017; 23: 1436–1441.

127 Hamada K, Irie M, Fujino Y, *et al.* Prognostic value of preoperative exercise capacity in patients undergoing thoracoscopic lobectomy for non-small cell lung cancer. *Lung Cancer* 2019; 128: 47–52.

128 Hattori K, Matsuda T, Takagi Y, *et al.* Preoperative six-minute walk distance is associated with pneumonia after lung resection. *Interact Cardiovasc Thorac Surg* 2018; 26: 277–283.

129 Wesolowski S, Orlowski TM, Kram M. The 6-min walk test in the functional evaluation of patients with lung cancer qualified for lobectomy. *Interact Cardiovasc Thorac Surg* 2020; 30: 559–564.

130 Win T, Jackson A, Groves AM, *et al.* Comparison of shuttle walk with measured peak oxygen consumption in patients with operable lung cancer. *Thorax* 2006; 61: 57–60.

131 Win T, Jackson A, Groves AM, *et al.* Relationship of shuttle walk test and lung cancer surgical outcome. *Eur J Cardiothorac Surg* 2004; 26: 1216–1219.

132 Brunelli A, Monteverde M, Al Refai M, *et al.* Stair climbing test as a predictor of cardiopulmonary complications after pulmonary lobectomy in the elderly. *Ann Thorac Surg* 2004; 77: 266–270.

133 Brunelli A, Monteverde M, Salati M, *et al.* Stair-climbing test to evaluate maximum aerobic capacity early after lung resection. *Ann Thorac Surg* 2001; 72: 1705–1710.

134 Brunelli A, Pompili C, Berardi R, *et al.* Performance at preoperative stair-climbing test is associated with prognosis after pulmonary resection in stage I non-small cell lung cancer. *Ann Thorac Surg* 2012; 93: 1796–1800.

135 Toker A, Ziyade S, Bayrak Y, *et al.* Prediction of cardiopulmonary morbidity after resection for lung cancer: stair climbing test complications after lung cancer surgery. *Thorac Cardiovasc Surg* 2007; 55: 253–256.

136 Win T, Sharples L, Groves AM, *et al.* Predicting survival in potentially curable lung cancer patients. *Lung* 2008; 186: 97–102.

137 Marjanski T, Wnuk D, Dziedzic R, *et al.* Physiological biomarkers assessed by low-tech exercise tests predict complications and overall survival in patients undergoing pneumonectomy due to lung cancer. *Cancers (Basel)* 2021; 13: 735.

138 Xiao F, Shao W, Zhang J, *et al.* The predictive value of stair climbing test on postoperative complications in lung cancer patients with limited pulmonary function. *Ann Thorac Cardiovasc Surg* 2022; 28: 381–388.

139 Boujibar F, Gillibert A, Gravier FE, *et al.* Performance at stair-climbing test is associated with postoperative complications after lung resection: a systematic review and meta-analysis. *Thorax* 2020; 75: 791–797.

140 Helminen O, Valo J, Andersen H, *et al.* Association of performance in a stair-climbing test with complications and survival after lung cancer resection in the video-assisted thoracoscopic surgery era: population-based outcomes. *ERJ Open Res* 2021; 7: 00110-2021.

141 Begum SS, Papagiannopoulos K, Falcoz PE, *et al.* Outcome after video-assisted thoracoscopic surgery and open pulmonary lobectomy in patients with low VO_2 max: a case-matched analysis from the ESTS database. *Eur J Cardiothorac Surg* 2016; 49: 1054–1058.

142 Brat K, Tothova Z, Merta Z, *et al.* Resting end-tidal carbon dioxide predicts respiratory complications in patients undergoing thoracic surgical procedures. *Ann Thorac Surg* 2016; 102: 1725–1730.

143 Chouinard G, Roy P, Blais MC, *et al.* Exercise testing and postoperative complications after minimally invasive lung resection: a cohort study. *Front Physiol* 2022; 13: 951460.

144 Dun Y, Wu S, Cui N, *et al.* Prognostic role of minute ventilation/carbon dioxide production slope for perioperative morbidity and long-term survival in resectable patients with nonsmall-cell lung cancer: a prospective study using propensity score overlap weighting. *Int J Surg* 2023; 109: 2650–2659.

145 Kristenson K, Hylander J, Boros M, *et al.* VE/VCO_2 slope threshold optimization for preoperative evaluation in lung cancer surgery: identifying true high- and low-risk groups. *J Thorac Dis* 2024; 16: 123–132.

146 Bechard D, Wetstein L. Assessment of exercise oxygen consumption as preoperative criterion for lung resection. *Ann Thorac Surg* 1987; 44: 344–349.

147 Jones LW, Watson D, Herndon JE 2nd, *et al.* Peak oxygen consumption and long-term all-cause mortality in nonsmall cell lung cancer. *Cancer* 2010; 116: 4825–4832.

148 Kasikcioglu E, Toker A, Tanju S, *et al.* Oxygen uptake kinetics during cardiopulmonary exercise testing and postoperative complications in patients with lung cancer. *Lung Cancer* 2009; 66: 85–88.

149 Matsuoka H, Nishio W, Sakamoto T, *et al.* Prediction of morbidity after lung resection with risk factors using treadmill exercise test. *Eur J Cardiothorac Surg* 2004; 26: 480–482.

150 Mazur A, Brat K, Homolka P, *et al.* Ventilatory efficiency is superior to peak oxygen uptake for prediction of lung resection cardiovascular complications. *PLoS ONE* 2022; 17: e0272984.

151 Bobbio A, Chetta A, Internullo E, *et al.* Exercise capacity assessment in patients undergoing lung resection. *Eur J Cardiothorac Surg* 2009; 35: 419–422.

152 Nakagawa K, Nakahara K, Miyoshi S, *et al.* Oxygen transport during incremental exercise load as a predictor of operative risk in lung cancer patients. *Chest* 1992; 101: 1369–1375.

153 Puente-Maestu L, Villar F, Gonzalez-Casurran G, *et al.* Early and long-term validation of an algorithm assessing fitness for surgery in patients with postoperative FEV_1 and diffusing capacity of the lung for carbon monoxide <40%. *Chest* 2011; 139: 1430–1438.

154 Win T, Jackson A, Sharples L, *et al.* Cardiopulmonary exercise tests and lung cancer surgical outcome. *Chest* 2005; 127: 1159–1165.

155 Wyser C, Stulz P, Soler M, *et al.* Prospective evaluation of an algorithm for the functional assessment of lung resection candidates. *Am J Respir Crit Care Med* 1999; 159: 1450–1456.

156 Brunelli A, Belardinelli R, Refai M, *et al.* Peak oxygen consumption during cardiopulmonary exercise test improves risk stratification in candidates to major lung resection. *Chest* 2009; 135: 1260–1267.

157 Brutsche MH, Spiliopoulos A, Bolliger CT, *et al.* Exercise capacity and extent of resection as predictors of surgical risk in lung cancer. *Eur Respir J* 2000; 15: 828–832.

158 Epstein SK, Faling LJ, Daly BD, *et al.* Predicting complications after pulmonary resection. Preoperative exercise testing *vs* a multifactorial cardiopulmonary risk index. *Chest* 1993; 104: 694–700.

159 Fang Y, Ma G, Lou N, *et al.* Preoperative maximal oxygen uptake and exercise-induced changes in pulse oximetry predict early postoperative respiratory complications in lung cancer patients. *Scand J Surg* 2014; 103: 201–208.

160 Loewen GM, Watson D, Kohman L, *et al.* Preoperative exercise VO_2 measurement for lung resection candidates: results of Cancer and Leukemia Group B Protocol 9238. *J Thorac Oncol* 2007; 2: 619–625.

161 Mao YS, He J, Yan SP, *et al.* Cardiopulmonary exercise testing in the evaluation of high risk patients with lung cancer. *Chin Med J (Engl)* 2010; 123: 3089–3094.

162 Beccaria M, Corsico A, Fulgoni P, *et al.* Lung cancer resection: the prediction of postsurgical outcomes should include long-term functional results. *Chest* 2001; 120: 37–42.

163 Bolliger CT, Jordan P, Soler M, *et al.* Exercise capacity as a predictor of postoperative complications in lung resection candidates. *Am J Respir Crit Care Med* 1995; 151: 1472–1480.

164 Richter Larsen K, Svendsen UG, Milman N, *et al.* Exercise testing in the preoperative evaluation of patients with bronchogenic carcinoma. *Eur Respir J* 1997; 10: 1559–1565.

165 Miyazaki T, Callister MEJ, Franks K, *et al.* Minute ventilation-to-carbon dioxide slope is associated with postoperative survival after anatomical lung resection. *Lung Cancer* 2018; 125: 218–222.

166 Shafiek H, Valera JL, Togores B, *et al.* Risk of postoperative complications in chronic obstructive lung diseases patients considered fit for lung cancer surgery: beyond oxygen consumption. *Eur J Cardiothorac Surg* 2016; 50: 772–779.

167 Villani F, Busia A. Preoperative evaluation of patients submitted to pneumonectomy for lung carcinoma: role of exercise testing. *Tumori* 2004; 90: 405–409.

168 Dales RE, Dionne G, Leech JA, *et al.* Preoperative prediction of pulmonary complications following thoracic surgery. *Chest* 1993; 104: 155–159.

169 Licker M, Schnyder JM, Frey JG, *et al.* Impact of aerobic exercise capacity and procedure-related factors in lung cancer surgery. *Eur Respir J* 2011; 37: 1189–1198.

170 Pate P, Tenholder MF, Griffin JP, *et al.* Preoperative assessment of the high-risk patient for lung resection. *Ann Thorac Surg* 1996; 61: 1494–1500.

171 Stanzani F, Paisani Dde M, Oliveira A, *et al.* Morbidity, mortality, and categorization of the risk of perioperative complications in lung cancer patients. *J Bras Pneumol* 2014; 40: 21–29.

172 Torchio R, Guglielmo M, Giardino R, *et al.* Exercise ventilatory inefficiency and mortality in patients with chronic obstructive pulmonary disease undergoing surgery for non-small-cell lung cancer. *Eur J Cardiothorac Surg* 2010; 38: 14–19.

173 Walsh GL, Morice RC, Putnam JB Jr, *et al.* Resection of lung cancer is justified in high-risk patients selected by exercise oxygen consumption. *Ann Thorac Surg* 1994; 58: 704–710.

174 Wang JS, Abboud RT, Evans KG, *et al.* Role of CO diffusing capacity during exercise in the preoperative evaluation for lung resection. *Am J Respir Crit Care Med* 2000; 162: 1435–1444.

175 Nagamatsu Y, Shima I, Hayashi A, *et al.* Preoperative spirometry *versus* expired gas analysis during exercise testing as predictors of cardiopulmonary complications after lung resection. *Surg Today* 2004; 34: 107–110.

176 Perentes J, Bopp S, Krueger T, *et al.* Impact of lung function changes after induction radiochemotherapy on resected T4 non-small cell lung cancer outcome. *Ann Thorac Surg* 2012; 94: 1815–1822.

177 Rocco G, Gatani T, Di Maio M, *et al.* The impact of decreasing cutoff values for maximal oxygen consumption (VO_2max) in the decision-making process for candidates to lung cancer surgery. *J Thorac Dis* 2013; 5: 12–18.

178 Villani F, De Maria P, Busia A. Exercise testing as a predictor of surgical risk after pneumonectomy for bronchogenic carcinoma. *Respir Med* 2003; 97: 1296–1298.

179 Jean RA, Chiu AS, Hoag JR, *et al.* Identifying drivers of multiple readmissions after pulmonary lobectomy. *Ann Thorac Surg* 2019; 107: 947–953.

180 Totzeck M, Aide N, Bauersachs J, *et al.* Nuclear medicine in the assessment and prevention of cancer therapy-related cardiotoxicity: prospects and proposal of use by the European Association of Nuclear Medicine (EANM). *Eur J Nucl Med Mol Imaging* 2023; 50: 792–812.

181 Walls GM, O'Connor J, Harbinson M, *et al.* Association between statin therapy dose intensity and radiation cardiotoxicity in non-small cell lung cancer: results from the NI-HEART study. *Radiother Oncol* 2023; 186: 109762.

182 Yegya-Raman N, Berlin E, Feigenberg SJ, *et al.* Cardiovascular toxicity and risk mitigation with lung cancer treatment. *Curr Oncol Rep* 2023; 25: 433–444.

183 Brunelli A, Salati M, Rocco G, *et al.* European risk models for morbidity (EuroLung1) and mortality (EuroLung2) to predict outcome following anatomic lung resections: an analysis from the European Society of Thoracic Surgeons database. *Eur J Cardiothorac Surg* 2017; 51: 490–497.

184 Kawaguchi Y, Hanaoka J, Ohshio Y, *et al.* A risk score to predict postoperative complications after lobectomy in elderly lung cancer patients. *Gen Thorac Cardiovasc Surg* 2018; 66: 537–542.

185 Puri V, Crabtree TD, Bell JM, *et al.* National cooperative group trials of "high-risk" patients with lung cancer: are they truly "high-risk"? *Ann Thorac Surg* 2014; 97: 1678–1683.

186 Brunelli A, Cassivi SD, Fibla J, *et al.* External validation of the recalibrated thoracic revised cardiac risk index for predicting the risk of major cardiac complications after lung resection. *Ann Thorac Surg* 2011; 92: 445–448.

187 Brunelli A, Ferguson MK, Salati M, *et al.* Thoracic revised cardiac risk index is associated with prognosis after resection for stage I lung cancer. *Ann Thorac Surg* 2015; 100: 195–200.

188 Brunelli A, Varela G, Salati M, *et al.* Recalibration of the revised cardiac risk index in lung resection candidates. *Ann Thorac Surg* 2010; 90: 199–203.

189 Ferguson MK, Saha-Chaudhuri P, Mitchell JD, *et al.* Prediction of major cardiovascular events after lung resection using a modified scoring system. *Ann Thorac Surg* 2014; 97: 1135–1140.

190 Hino H, Karasaki T, Yoshida Y, *et al.* Competing risk analysis in lung cancer patients over 80 years old undergoing surgery. *World J Surg* 2019; 43: 1857–1866.

191 Lee CT, Strauss DM, Stone LE, *et al.* Preoperative CHA2DS2-VASc score predicts postoperative atrial fibrillation after lobectomy. *Thorac Cardiovasc Surg* 2019; 67: 125–130.

192 Nojiri T, Inoue M, Shintani Y, *et al.* B-type natriuretic peptide-guided risk assessment for postoperative complications in lung cancer surgery. *World J Surg* 2015; 39: 1092–1098.

193 Thomas DC, Blasberg JD, Arnold BN, *et al.* Validating the thoracic revised cardiac risk index following lung resection. *Ann Thorac Surg* 2017; 104: 389–394.

194 Nwaejike N, Elbur E, Malagon I, *et al.* Is there a role for the high-risk multidisciplinary team meeting in thoracic surgery? *Interact Cardiovasc Thorac Surg* 2016; 22: 397–400.

195 Onaitis M, D'Amico T, Zhao Y, *et al.* Risk factors for atrial fibrillation after lung cancer surgery: analysis of the Society of Thoracic Surgeons general thoracic surgery database. *Ann Thorac Surg* 2010; 90: 368–374.

196 Stolz AJ, Harustiak T, Simonek J, *et al.* Pneumonectomy for non-small cell lung cancer: predictors of early mortality and morbidity. *Acta Chir Belg* 2014; 114: 25–30.

197 Lamperti M, Romero CS, Guarracino F, *et al.* Preoperative assessment of adults undergoing elective noncardiac surgery: updated guidelines from the European Society of Anaesthesiology and Intensive Care. *Eur J Anaesthesiol* 2025; 42: 1–35.

198 Li M, Huang H. Anesthetic management of patients with dilated cardiomyopathy undergoing noncardiac surgery. *Medicina (Kaunas)* 2023; 59: 1567.

199 Thompson A, Fleischmann KE, Smilowitz NR, *et al.* 2024 AHA/ACC/ACS/ASNC/HRS/SCA/SCCT/SCMR/SVM guideline for perioperative cardiovascular management for noncardiac surgery: a report of the American College of Cardiology/American Heart Association joint committee on clinical practice guidelines. *Circulation* 2024; 150: e351–e442.

200 Chen L, Huang J, Wu W, *et al.* The impact of right ventricular function on prognosis in patients with stage III non-small cell lung cancer after concurrent chemoradiotherapy. *Int J Cardiovasc Imaging* 2019; 35: 1009–1017.

201 Glass A, McCall P, Arthur A, *et al.* Pulmonary artery wave reflection and right ventricular function after lung resection. *Br J Anaesth* 2023; 130: e128–e136.

202 Tadic M, Kersten J, Buckert D, *et al.* Right ventricle and radiotherapy: more questions than answers. *Diagnostics (Basel)* 2023; 13: 164.

203 Cagini L, Cardaioli G, Andolfi M, *et al.* Interatrial shunting through an asymptomatic patent foramen ovale in thoracic surgery. *Ann Thorac Surg* 2019; 107: 1040–1045.

204 Asakura K, Mitsuboshi S, Tsuji M, *et al.* Pulmonary arterial enlargement predicts cardiopulmonary complications after pulmonary resection for lung cancer: a retrospective cohort study. *J Cardiothorac Surg* 2015; 10: 113.

205 Daffrè E, Prieto M, Huang H, *et al.* Normalized pulmonary artery diameter predicts occurrence of postpneumonectomy respiratory failure, ARDS, and mortality. *Cancers (Basel)* 2020; 12: 1515.

206 Dauriat G, LePavec J, Pradere P, *et al.* Our current understanding of and approach to the management of lung cancer with pulmonary hypertension. *Expert Rev Respir Med* 2021; 15: 373–384.

207 Gürdoğan M, Demir M, Yalta K, *et al.* Cancer therapy-related pulmonary hypertension: a review of mechanisms and implications for clinical practice. *Anatol J Cardiol* 2023; 27: 299–307.

208 Valsangkar N, Wei JW, Binongo JN, *et al.* Association between patient physical function and length of stay after thoracoscopic lung cancer surgery. *Semin Thorac Cardiovasc Surg* 2021; 33: 559–566.

209 Pompili C, Velikova G, White J, *et al.* Poor preoperative patient-reported quality of life is associated with complications following pulmonary lobectomy for lung cancer. *Eur J Cardiothorac Surg* 2017; 51: 526–531.

210 Leo F, Scanagatta P, Vannucci F, *et al.* Impaired quality of life after pneumonectomy: who is at risk? *J Thorac Cardiovasc Surg* 2010; 139: 49–52.

211 Nestle U, Adebahr S, Kaier K, *et al.* Quality of life after pulmonary stereotactic fractionated radiotherapy (SBRT): results of the phase II STRIPE trial. *Radiother Oncol* 2020; 148: 82–88.

212 Adebahr S, Hechtner M, Schrader N, *et al.* Early impact of pulmonary fractionated stereotactic body radiotherapy on quality of life: benefit for patients with low initial scores (STRIPE trial). *J Thorac Oncol* 2019; 14: 408–419.

213 Taylor M, Hashmi SF, Martin GP, *et al.* A systematic review of risk prediction models for perioperative mortality after thoracic surgery. *Interact Cardiovasc Thorac Surg* 2021; 32: 333–342.

214 Palma DA, Senan S, Tsujino K, *et al.* Predicting radiation pneumonitis after chemoradiation therapy for lung cancer: an international individual patient data meta-analysis. *Int J Radiat Oncol Biol Phys* 2013; 85: 444–450.

215 Brunelli A, Cicconi S, Decaluwe H, *et al.* Parsimonious Eurolung risk models to predict cardiopulmonary morbidity and mortality following anatomic lung resections: an updated analysis from the European Society of Thoracic Surgeons database. *Eur J Cardiothorac Surg* 2020; 57: 455–461.

216 Gomez de Antonio D, Crowley Carrasco S, Romero Roman A, *et al.* External validation of the European Society of Thoracic Surgeons morbidity and mortality risk models. *Eur J Cardiothorac Surg* 2022; 62: ezac170.

217 Nagoya A, Kanzaki R, Kanou T, *et al.* Validation of Eurolung risk models in a Japanese population: a retrospective single-centre analysis of 612 cases. *Interact Cardiovasc Thorac Surg* 2019; 29: 722–728.

218 Ponholzer F, Chorazy K, Ng C, *et al.* External validation of risk prediction scores in patients undergoing anatomic video-assisted thoracoscopic resection. *Surg Endosc* 2023; 37: 2789–2799.

219 Yun JK, Jeong JH, Lee GD, *et al.* Predicting postoperative complications and long-term survival after lung cancer surgery using Eurolung risk score. *J Korean Med Sci* 2022; 37: e36.

220 Burtin C, Bezuidenhout J, Sanders KJC, *et al.* Handgrip weakness, low fat-free mass, and overall survival in non-small cell lung cancer treated with curative-intent radiotherapy. *J Cachexia Sarcopenia Muscle* 2020; 11: 424–431.

221 Defraene G, Dankers F, Price G, *et al.* Multifactorial risk factors for mortality after chemotherapy and radiotherapy for non-small cell lung cancer. *Radiother Oncol* 2020; 152: 117–125.

222 Dehing-Oberije C, De Ruysscher D, van der Weide H, *et al.* Tumor volume combined with number of positive lymph node stations is a more important prognostic factor than TNM stage for survival of non-small-cell lung cancer patients treated with (chemo)radiotherapy. *Int J Radiat Oncol Biol Phys* 2008; 70: 1039–1044.

223 Jochems A, Deist TM, El Naqa I, *et al.* Developing and validating a survival prediction model for NSCLC patients through distributed learning across 3 countries. *Int J Radiat Oncol Biol Phys* 2017; 99: 344–352.

224 Speirs CK, DeWees TA, Rehman S, *et al.* Heart dose is an independent dosimetric predictor of overall survival in locally advanced non-small cell lung cancer. *J Thorac Oncol* 2017; 12: 293–301.

225 Kaya SO, Akcam TI, Ceylan KC, *et al.* Is preoperative protein-rich nutrition effective on postoperative outcome in non-small cell lung cancer surgery? A prospective randomized study. *J Cardiothorac Surg* 2016; 11: 14.

226 Shoji F, Kozuma Y, Toyokawa G, *et al.* Impact of preoperative immunonutritional support in patients undergoing elective thoracic surgery. *JMA J* 2021; 4: 387–396.

227 Kaymak ZA, Ozkan EE. The prognostic value of decrease in prognostic nutritional index in stage III non-small cell lung cancer patients during curative thoracic radiotherapy. *Indian J Cancer* 2023; 60: 18–23.

228 Caccialanza R, Cotogni P, Cereda E, *et al.* Nutritional support in cancer patients: update of the Italian Intersociety Working Group practical recommendations. *J Cancer* 2022; 13: 2705–2716.

229 Shaw JF, Budiansky D, Sharif F, *et al.* The association of frailty with outcomes after cancer surgery: a systematic review and metaanalysis. *Ann Surg Oncol* 2022; 29: 4690–4704.

230 Beckert AK, Huisingh-Scheetz M, Thompson K, *et al.* Screening for frailty in thoracic surgical patients. *Ann Thorac Surg* 2017; 103: 956–961.

231 Lee ACH, Lee SM, Ferguson MK. Frailty is associated with adverse postoperative outcomes after lung cancer resection. *JTO Clin Res Rep* 2022; 3: 100414.

232 Wan MA, Clark JM, Nuno M, *et al.* Can the risk analysis index for frailty predict morbidity and mortality in patients undergoing high-risk surgery? *Ann Surg* 2022; 276: e721–e727.

233 Brunelli A, Decaluwe H, Gossot D, *et al.* Perioperative outcomes of segmentectomies *versus* lobectomies in high-risk patients: an ESTS database analysis. *Eur J Cardiothorac Surg* 2021; 59: 389–394.

234 Brunelli A, Tariq J, Mittal A, *et al.* Self-reported dyspnoea and shortness of breathing deterioration in long-term survivors after segmentectomy or lobectomy for early-stage lung cancer. *Eur J Cardiothorac Surg* 2024; 65: ezae200.

235 Assouline B, Cools E, Schorer R, *et al.* Preoperative exercise training to prevent postoperative pulmonary complications in adults undergoing major surgery. A systematic review and meta-analysis with trial sequential analysis. *Ann Am Thorac Soc* 2021; 18: 678–688.

236 Cavalheri V, Burtin C, Formico VR, *et al.* Exercise training undertaken by people within 12 months of lung resection for non-small cell lung cancer. *Cochrane Database Syst Rev* 2019; 6: CD009955.

237 Granger C, Cavalheri V. Preoperative exercise training for people with non-small cell lung cancer. *Cochrane Database Syst Rev* 2022; 9: CD012020.

238 Wang L, Yu M, Ma Y, *et al.* Effect of pulmonary rehabilitation on postoperative clinical status in patients with lung cancer and chronic obstructive pulmonary disease: a systematic review and meta-analysis. *Evid Based Complement Alternat Med* 2022; 2022: 4133237.

239 Boden I, Denehy L. Respiratory prehabilitation for the prevention of postoperative pulmonary complications after major surgery. *Curr Anesthesiol Rep* 2021; 12: 44–58.

240 Boden I, Skinner EH, Browning L, *et al.* Preoperative physiotherapy for the prevention of respiratory complications after upper abdominal surgery: pragmatic, double blinded, multicentre randomised controlled trial. *BMJ* 2018; 360: j5916.

241 Annessi V, Paci M, Ricchetti T, *et al.* Is age over 70 years a risk factor for pneumonectomy? *Asian Cardiovasc Thorac Ann* 2009; 17: 272–277.

242 Aridgides PD, Janik A, Bogart JA, *et al.* Radiotherapy for stage III non-small-cell lung carcinoma in the elderly (age ⩾70 years). *Clin Lung Cancer* 2013; 14: 674–679.

243 Beshay M, Dorn P, Ris HB, *et al.* Influence of comorbidity on outcome after pulmonary resection in the elderly. *Asian Cardiovasc Thorac Ann* 2007; 15: 297–302.

244 Bolton WD, Rice DC, Correa AM, *et al.* Influence of age on choice of therapy and surgical outcomes in patients with nonsmall cell lung cancer. *Am Surg* 2009; 75: 598–603.

245 Bongiolatti S, Gonfiotti A, Borgianni S, *et al.* Post-operative outcomes and quality of life assessment after thoracoscopic lobectomy for non-small-cell lung cancer in octogenarians: analysis from a national database. *Surg Oncol* 2021; 37: 101530.

246 Bongiolatti S, Mazzoni F, Gonfiotti A, *et al.* Short and mid-term outcomes of multimodal treatment for locally-advanced non-small cell lung cancer in elderly patients. *Gen Thorac Cardiovasc Surg* 2020; 68: 1290–1297.

247 De Leon LE, Rochefort MM, Bravo-Iniguez CE, *et al.* Opportunities for quality improvement in the morbidity pattern of older adults undergoing pulmonary lobectomy for cancer. *J Geriatr Oncol* 2021; 12: 416–421.

248 de Perrot M, Licker M, Reymond MA, *et al.* Influence of age on operative mortality and long-term survival after lung resection for bronchogenic carcinoma. *Eur Respir J* 1999; 14: 419–422.

249 Driessen EJM, Schulkes KJG, Dingemans AC, *et al.* Patterns of treatment and survival among older patients with stage III non-small cell lung cancer. *Lung Cancer* 2018; 116: 55–61.

250 Fan J, Wang XJ, Jiang GN, *et al.* Survival and outcomes of surgical treatment of the elderly NSCLC in China: a retrospective matched cohort study. *Eur J Surg Oncol* 2007; 33: 639–643.

251 Finlayson E, Fan Z, Birkmeyer JD. Outcomes in octogenarians undergoing high-risk cancer operation: a national study. *J Am Coll Surg* 2007; 205: 729–734.

252 Firat S, Byhardt RW, Gore E. The effects of comorbidity and age on RTOG study enrollment in stage III non-small cell lung cancer patients who are eligible for RTOG studies. *Int J Radiat Oncol Biol Phys* 2010; 78: 1394–1399.

253 Fruh M, Rolland E, Pignon JP, *et al.* Pooled analysis of the effect of age on adjuvant cisplatin-based chemotherapy for completely resected non-small-cell lung cancer. *J Clin Oncol* 2008; 26: 3573–3581.

254 Giuliani M, Hope A, Guckenberger M, *et al.* Stereotactic body radiation therapy in octo- and nonagenarians for the treatment of early-stage lung cancer. *Int J Radiat Oncol Biol Phys* 2017; 98: 893–899.

255 Hayakawa K, Mitsuhashi N, Katano S, *et al.* High-dose radiation therapy for elderly patients with inoperable or unresectable non-small cell lung cancer. *Lung Cancer* 2001; 32: 81–88.

256 Husain ZA, Kim AW, Yu JB, *et al.* Defining the high-risk population for mortality after resection of early stage NSCLC. *Clin Lung Cancer* 2015; 16: e183–e187.

257 Joo JH, Song SY, Kim SS, *et al.* Definitive radiotherapy alone over 60 Gy for patients unfit for combined treatment to stage II–III non-small cell lung cancer: retrospective analysis. *Radiat Oncol* 2015; 10: 250.

258 Kass KS, Velez-Cubian FO, Zhang WW, *et al.* Effect of advanced age on peri-operative outcomes after robotic-assisted pulmonary lobectomy: retrospective analysis of 287 consecutive cases. *J Geriatr Oncol* 2017; 8: 102–107.

259 Liu HC, Huang WC, Wu CL, *et al.* Surgery for elderly lung cancer. *Ann Thorac Cardiovasc Surg* 2013; 19: 416–422.

260 Lou X, Sanders A, Wagh K, *et al.* Safety and feasibility of thoracoscopic lung resection for non-small-cell lung cancer in octogenarians. *Innovations (Phila)* 2021; 16: 68–74.

261 Ludbrook JJ, Truong PT, MacNeil MV, *et al.* Do age and comorbidity impact treatment allocation and outcomes in limited stage small-cell lung cancer? A community-based population analysis. *Int J Radiat Oncol Biol Phys* 2003; 55: 1321–1330.

262 Mancini BR, Park HS, Harder EM, *et al.* Elderly patients undergoing SBRT for inoperable early-stage NSCLC achieve similar outcomes to younger patients. *Lung Cancer* 2016; 97: 22–27.

263 Mery CM, Pappas AN, Bueno R, *et al.* Similar long-term survival of elderly patients with non-small cell lung cancer treated with lobectomy or wedge resection within the surveillance, epidemiology, and end results database. *Chest* 2005; 128: 237–245.

264 Moller A, Sartipy U. Changes in quality of life after lung surgery in old and young patients: are they similar? *World J Surg* 2010; 34: 684–691.

265 Ogawa F, Wang G, Matsui Y, *et al.* Risk factors for postoperative complications in the elderly with lung cancer. *Asian Cardiovasc Thorac Ann* 2013; 21: 313–318.

266 Okami J, Ito Y, Higashiyama M, *et al.* Sublobar resection provides an equivalent survival after lobectomy in elderly patients with early lung cancer. *Ann Thorac Surg* 2010; 90: 1651–1656.

267 Owonikoko TK, Ragin CC, Belani CP, *et al.* Lung cancer in elderly patients: an analysis of the surveillance, epidemiology, and end results database. *J Clin Oncol* 2007; 25: 5570–5577.

268 Pepe C, Hasan B, Winton TL, *et al.* Adjuvant vinorelbine and cisplatin in elderly patients: National Cancer Institute of Canada and Intergroup Study JBR.10. *J Clin Oncol* 2007; 25: 1553–1561.

269 Powell HA, Tata LJ, Baldwin DR, *et al.* Early mortality after surgical resection for lung cancer: an analysis of the English National Lung cancer audit. *Thorax* 2013; 68: 826–834.

270 Qiang G, Liang C, Guo Y, *et al.* Video-assisted thoracoscopic lobectomy for elderly nonsmall cell lung cancer: short-term and long-term outcomes. *J Cancer Res Ther* 2015; 11: 793–797.

271 Rivera C, Jougon J, Dahan M, *et al.* Are postoperative consequences of neoadjuvant chemotherapy for non-small cell lung cancer more severe in elderly patients? *Lung Cancer* 2012; 76: 216–221.

272 Rodriguez M, Gomez Hernandez MT, Novoa NM, *et al.* Morbidity and mortality in octogenarians with lung cancer undergoing pneumonectomy. *Arch Bronconeumol* 2015; 51: 219–222.

273 Roxburgh JC, Thompson J, Goldstraw P. Hospital mortality and long-term survival after pulmonary resection in the elderly. *Ann Thorac Surg* 1991; 51: 800–803.

274 Saha SP, Bender M, Ferraris VA, *et al.* Surgical treatment of lung cancer in octogenarians. *South Med J* 2013; 106: 356–361.

275 Sawada S, Komori E, Nogami N, *et al.* Advanced age is not correlated with either short-term or long-term postoperative results in lung cancer patients in good clinical condition. *Chest* 2005; 128: 1557–1563.

276 Schild SE, Stella PJ, Geyer SM, *et al.* The outcome of combined-modality therapy for stage III non-small-cell lung cancer in the elderly. *J Clin Oncol* 2003; 21: 3201–3206.

277 Schulte T, Schniewind B, Walter J, *et al.* Age-related impairment of quality of life after lung resection for non-small cell lung cancer. *Lung Cancer* 2010; 68: 115–120.

278 Stinchcombe TE, Zhang Y, Vokes EE, *et al.* Pooled analysis of individual patient data on concurrent chemoradiotherapy for stage III non-small-cell lung cancer in elderly patients compared with younger patients who participated in US National Cancer Institute Cooperative Group Studies. *J Clin Oncol* 2017; 35: 2885–2892.

279 Suemitsu R, Takeo S, Hamatake M, *et al.* The perioperative complications for elderly patients with lung cancer associated with a pulmonary resection under general anesthesia. *J Thorac Oncol* 2009; 4: 193–197.

280 Tantraworasin A, Siwachat S, Tanatip N, *et al.* Outcomes of pulmonary resection in non-small cell lung cancer patients older than 70 years old. *Asian J Surg* 2020; 43: 154–165.

281 van Meerbeeck JP, Damhuis RA, Vos de Wael ML. High postoperative risk after pneumonectomy in elderly patients with right-sided lung cancer. *Eur Respir J* 2002; 19: 141–145.

282 Yang CJ, Mayne NR, Wang H, *et al.* Outcomes of major lung resection after induction therapy for non-small cell lung cancer in elderly patients. *Ann Thorac Surg* 2016; 102: 962–970.

283 Zhang L. Short- and long-term outcomes in elderly patients with locally advanced non-small-cell lung cancer treated using video-assisted thoracic surgery lobectomy. *Ther Clin Risk Manag* 2018; 14: 2213–2220.

284 Oken MM, Creech RH, Tormey DC, *et al.* Toxicity and response criteria of the Eastern Cooperative Oncology Group. *Am J Clin Oncol* 1982; 5: 649–655.

285 Karnofsky D, Burchenal J. Evaluation of chemotherapeutic agents: the clinical evaluation of chemotherapeutic agents in cancer. *In:* MacLeod CM, ed. Evaluation of Chemotherapeutic Agents. New York, Columbia University Press, 1949; pp. 191–205.

286 Bernard A, Rivera C, Pages PB, *et al.* Risk model of in-hospital mortality after pulmonary resection for cancer: a national database of the French Society of Thoracic and Cardiovascular Surgery (Epithor). *J Thorac Cardiovasc Surg* 2011; 141: 449–458.

287 Bowden JCS, Williams LJ, Simms A, *et al.* Prediction of 90 day and overall survival after chemoradiotherapy for lung cancer: role of performance status and body composition. *Clin Oncol (R Coll Radiol)* 2017; 29: 576–584.

288 Cao C, Louie BE, Melfi F, *et al.* Outcomes of major complications after robotic anatomic pulmonary resection. *J Thorac Cardiovasc Surg* 2020; 159: 681–686.

289 Crabtree T, Puri V, Timmerman R, *et al.* Treatment of stage I lung cancer in high-risk and inoperable patients: comparison of prospective clinical trials using stereotactic body radiotherapy (RTOG 0236), sublobar resection (ACOSOG Z4032), and radiofrequency ablation (ACOSOG Z4033). *J Thorac Cardiovasc Surg* 2013; 145: 692–699.

290 Detillon D, Veen EJ. Postoperative outcome after pulmonary surgery for non-small cell lung cancer in elderly patients. *Ann Thorac Surg* 2018; 105: 287–293.

291 Endo S, Ikeda N, Kondo T, *et al.* Model of lung cancer surgery risk derived from a Japanese nationwide web-based database of 78 594 patients during 2014–2015. *Eur J Cardiothorac Surg* 2017; 52: 1182–1189.

292 Khakwani A, Harden S, Beckett P, *et al.* Post-treatment survival difference between lobectomy and stereotactic ablative radiotherapy in stage I non-small cell lung cancer in England. *Thorax* 2020; 75: 237–243.

293 Kozower BD, Sheng S, O'Brien SM, *et al.* STS database risk models: predictors of mortality and major morbidity for lung cancer resection. *Ann Thorac Surg* 2010; 90: 875–881.

294 Lewis JA, Petty WJ, Tooze JA, *et al.* Low-dose CT lung cancer screening practices and attitudes among primary care providers at an Academic Medical Center. *Cancer Epidemiol Biomarkers Prev* 2015; 24: 664–670.

295 Luchtenborg M, Jakobsen E, Krasnik M, *et al.* The effect of comorbidity on stage-specific survival in resected non-small cell lung cancer patients. *Eur J Cancer* 2012; 48: 3386–3395.

296 Kawaguchi Y, Hanaoka J, Ohshio Y, *et al.* Does sarcopenia affect postoperative short- and long-term outcomes in patients with lung cancer? A systematic review and meta-analysis. *J Thorac Dis* 2021; 13: 1358–1369.

297 Chang BS, Peng TC, Lue KH, *et al.* Comprehensive assessment of the clinical risk factors of postoperative adverse events and survival in patients with non-small-cell lung cancer. *In Vivo* 2023; 37: 1358–1364.

298 Hasenauer A, Forster C, Hungerbuhler J, *et al.* CT-derived sarcopenia and outcomes after thoracoscopic pulmonary resection for non-small cell lung cancer. *Cancers (Basel)* 2023; 15: 790.

299 Kawaguchi Y, Hanaoka J, Ohshio Y, *et al.* Sarcopenia predicts poor postoperative outcome in elderly patients with lung cancer. *Gen Thorac Cardiovasc Surg* 2019; 67: 949–954.

300 Kim EY, Lee HY, Kim KW, *et al.* Preoperative computed tomography-determined sarcopenia and postoperative outcome after surgery for non-small cell lung cancer. *Scand J Surg* 2018; 107: 244–251.

301 Lee J, Moon SW, Choi JS, *et al.* Impact of sarcopenia on early postoperative complications in early-stage non-small-cell lung cancer. *Korean J Thorac Cardiovasc Surg* 2020; 53: 93–103.

302 Madariaga MLL, Troschel FM, Best TD, *et al.* Low thoracic skeletal muscle area predicts morbidity after pneumonectomy for lung cancer. *Ann Thorac Surg* 2020; 109: 907–913.

303 Martini K, Chassagnon G, Fournel L, *et al.* Sarcopenia as independent risk factor of postpneumonectomy respiratory failure, ARDS and mortality. *Lung Cancer* 2020; 149: 130–136.

304 Miller JA, Harris K, Roche C, *et al.* Sarcopenia is a predictor of outcomes after lobectomy. *J Thorac Dis* 2018; 10: 432–440.

305 Miura A, Yamamoto H, Sato H, *et al.* The prognostic impact of sarcopenia on elderly patients undergoing pulmonary resection for non-small cell lung cancer. *Surg Today* 2021; 51: 1203–1211.

306 Nakada T, Noda Y, Kato D, *et al.* Risk factors and cancer recurrence associated with postoperative complications after thoracoscopic lobectomy for clinical stage I non-small cell lung cancer. *Thorac Cancer* 2019; 10: 1945–1952.

307 Nakamura R, Inage Y, Tobita R, *et al.* Sarcopenia in resected NSCLC: effect on postoperative outcomes. *J Thorac Oncol* 2018; 13: 895–903.

308 Ponholzer F, Groemer G, Ng C, *et al.* Sarcopenia and mediastinal adipose tissue as a prognostic marker for short- and long-term outcomes after primary surgical treatment for lung cancer. *Cancers (Basel)* 2023; 15: 5666.

309 Sato S, Sato M, Shinohara H. Significance of preoperative evaluation of skeletal muscle index and immune-nutritional status for patients with early-stage non-small cell lung cancer. *Gen Thorac Cardiovasc Surg* 2023; 71: 354–362.

310 Shinohara S, Otsuki R, Kobayashi K, *et al.* Impact of sarcopenia on surgical outcomes in non-small cell lung cancer. *Ann Surg Oncol* 2020; 27: 2427–2435.

311 Takamori S, Toyokawa G, Okamoto T, *et al.* Clinical impact and risk factors for skeletal muscle loss after complete resection of early non-small cell lung cancer. *Ann Surg Oncol* 2018; 25: 1229–1236.

312 Tsukioka T, Nishiyama N, Izumi N, *et al.* Sarcopenia is a novel poor prognostic factor in male patients with pathological stage I non-small cell lung cancer. *Jpn J Clin Oncol* 2017; 47: 363–368.

313 Carter BD, Abnet CC, Feskanich D, *et al.* Smoking and mortality – beyond established causes. *N Engl J Med* 2015; 372: 631–640.

314 Dy SM, Sharkey P, Herbert R, *et al.* Comorbid illnesses and health care utilization among Medicare beneficiaries with lung cancer. *Crit Rev Oncol Hematol* 2006; 59: 218–225.

315 Baker S, Sharma A, Peric R, *et al.* Prediction of early mortality following stereotactic body radiotherapy for peripheral early-stage lung cancer. *Acta Oncol* 2019; 58: 237–242.

316 Dogru MV, Sezen CB, Aker C, *et al.* Evaluation of factors affecting morbidity and mortality in pneumonectomy patients. *Acta Chir Belg* 2021; 121: 301–307.

317 Green A, Hauge J, Iachina M, *et al.* The mortality after surgery in primary lung cancer: results from the Danish Lung Cancer Registry. *Eur J Cardiothorac Surg* 2016; 49: 589–594.

318 Kim DY, Song C, Kim SH, *et al.* Chemoradiotherapy *versus* radiotherapy alone following induction chemotherapy for elderly patients with stage III lung cancer. *Radiat Oncol J* 2019; 37: 176–184.

319 Klement RJ, Belderbos J, Grills I, *et al.* Prediction of early death in patients with early-stage NSCLC – can we select patients without a potential benefit of SBRT as a curative treatment approach? *J Thorac Oncol* 2016; 11: 1132–1139.

320 Otake S, Ohtsuka T, Asakura K, *et al.* Impact of comorbidity index on morbidity and survival in non-small cell lung cancer. *Asian Cardiovasc Thorac Ann* 2016; 24: 30–33.

321 Pagès PB, Cottenet J, Mariet AS, *et al.* In-hospital mortality following lung cancer resection: nationwide administrative database. *Eur Respir J* 2016; 47: 1809–1817.

322 Quero-Valenzuela F, Piedra-Fernández I, Hernández-Escobar F, *et al.* Half the deaths after surgery for lung cancer occur after discharge. *Surg Oncol* 2018; 27: 630–634.

323 Sánchez PG, Vendrame GS, Madke GR, *et al.* Lobectomy for treating bronchial carcinoma: analysis of comorbidities and their impact on postoperative morbidity and mortality. *J Bras Pneumol* 2006; 32: 495–504.

324 Sato S, Nakamura M, Shimizu Y, *et al.* Impact of postoperative complications on outcomes of second surgery for second primary lung cancer. *Surg Today* 2020; 50: 1452–1460.

325 Zhang R, Kyriss T, Dippon J, *et al.* Impact of comorbidity burden on morbidity following thoracoscopic lobectomy: a propensity-matched analysis. *J Thorac Dis* 2018; 10: 1806–1814.

326 Huang C, Sun YG, Ma C, *et al.* Surgical outcomes and perioperative risk factors of patients with interstitial lung disease after pulmonary resection. *J Cardiothorac Surg* 2024; 19: 72.

327 Baker R, Han G, Sarangkasiri S, *et al.* Clinical and dosimetric predictors of radiation pneumonitis in a large series of patients treated with stereotactic body radiation therapy to the lung. *Int J Radiat Oncol Biol Phys* 2013; 85: 190–195.

328 Birim O, Zuydendorp HM, Maat AP, *et al.* Lung resection for non-small-cell lung cancer in patients older than 70: mortality, morbidity, and late survival compared with the general population. *Ann Thorac Surg* 2003; 76: 1796–1801.

329 Birim O, Kappetein AP, Goorden T, *et al.* Proper treatment selection may improve survival in patients with clinical early-stage nonsmall cell lung cancer. *Ann Thorac Surg* 2005; 80: 1021–1026.

330 Borreman P, De Leyn P, Decaluwé H, *et al.* Morbidity and mortality after induction chemotherapy followed by surgery in IIIa-N2 non small cell lung cancer. *Acta Chir Belg* 2009; 109: 333–339.

331 Dreyer J, Bremer M, Henkenberens C. Comorbidity indexing for prediction of the clinical outcome after stereotactic body radiation therapy in non-small cell lung cancer. *Radiat Oncol* 2018; 13: 213.

332 Endoh H, Yamamoto R, Satoh Y, *et al.* Risk analysis of pulmonary resection for elderly patients with lung cancer. *Surg Today* 2013; 43: 514–520.

333 Halvorsen TO, Sundstrøm S, Fløtten Ø, *et al.* Comorbidity and outcomes of concurrent chemo- and radiotherapy in limited disease small cell lung cancer. *Acta Oncol* 2016; 55: 1349–1354.

334 Hino H, Karasaki T, Yoshida Y, *et al.* Risk factors for postoperative complications and long-term survival in lung cancer patients older than 80 years. *Eur J Cardiothorac Surg* 2018; 53: 980–986.

335 Infante MV, Benato C, Silva R, *et al.* What counts more: the patient, the surgical technique, or the hospital? A multivariable analysis of factors affecting perioperative complications of pulmonary lobectomy by video-assisted thoracoscopic surgery from a large nationwide registry. *Eur J Cardiothorac Surg* 2019; 56: 1097–1103.

336 Pei G, Zhou S, Han Y, *et al.* Risk factors for postoperative complications after lung resection for non-small cell lung cancer in elderly patients at a single institution in China. *J Thorac Dis* 2014; 6: 1230–1238.

337 Uyterlinde W, Belderbos J, Baas C, *et al.* Prediction of acute toxicity grade ⩾3 in patients with locally advanced non-small-cell lung cancer receiving intensity modulated radiotherapy and concurrent low-dose cisplatin. *Clin Lung Cancer* 2013; 14: 541–548.

338 Oh TK, Song IA, Hwang I, *et al.* Risks and outcome of fatal respiratory events after lung cancer surgery: cohort study in South Korea. *J Thorac Dis* 2023; 15: 1036–1045.

339 Dell'Amore A, Monteverde M, Martucci N, *et al.* Early and long-term results of pulmonary resection for non-small-cell lung cancer in patients over 75 years of age: a multi-institutional study. *Interact Cardiovasc Thorac Surg* 2013; 16: 250–256.

340 Dell'Amore A, Monteverde M, Martucci N, *et al.* Lobar and sub-lobar lung resection in octogenarians with early stage non-small cell lung cancer: factors affecting surgical outcomes and long-term results. *Gen Thorac Cardiovasc Surg* 2015; 63: 222–230.

341 Dominguez-Ventura A, Allen MS, Cassivi SD, *et al.* Lung cancer in octogenarians: factors affecting morbidity and mortality after pulmonary resection. *Ann Thorac Surg* 2006; 82: 1175–1179.

342 Dominguez-Ventura A, Cassivi SD, Allen MS, *et al.* Lung cancer in octogenarians: factors affecting long-term survival following resection. *Eur J Cardiothorac Surg* 2007; 32: 370–374.

343 Wright CD, Gaissert HA, Grab JD, *et al.* Predictors of prolonged length of stay after lobectomy for lung cancer: a Society of Thoracic Surgeons General Thoracic Surgery Database risk-adjustment model. *Ann Thorac Surg* 2008; 85: 1857–1865.

344 Yamamoto Y, Kanzaki R, Kanou T, *et al.* Long-term outcomes of pulmonary resection for lung cancer patients with chronic kidney disease. *World J Surg* 2019; 43: 3249–3258.

345 Iwasaki A, Shirakusa T, Okabayashi K, *et al.* Lung cancer surgery in patients with liver cirrhosis. *Ann Thorac Surg* 2006; 82: 1027–1032.

346 Iwata T, Inoue K, Nishiyama N, *et al.* Factors predicting early postoperative liver cirrhosis-related complications after lung cancer surgery in patients with liver cirrhosis. *Interact Cardiovasc Thorac Surg* 2007; 6: 720–730.

347 Iwata T, Nishiyama N, Nagano K, *et al.* Pulmonary resection for non-small cell lung cancer in patients with hepatocellular carcinoma. *World J Surg* 2008; 32: 2204–2212.

348 Rivera C, Chevalier B, Fabre E, *et al.* Chirurgie du cancer du poumon chez le cirrhotique [Lung cancer surgery and cirrhosis]. *Rev Pneumol Clin* 2015; 71: 12–19.

349 Iwata T, Inoue K, Nishiyama N, *et al.* Long-term outcome of surgical treatment for non-small cell lung cancer with comorbid liver cirrhosis. *Ann Thorac Surg* 2007; 84: 1810–1817.

350 Nakajima J, Takamoto S, Murakawa T, *et al.* Is interstitial pneumonia in patients with collagen diseases a contraindication to lung cancer surgery? *Surg Today* 2007; 37: 14–18.

351 Diao K, Chen YH, Catalano PJ, *et al.* Radiation toxicity in patients with collagen vascular disease and intrathoracic malignancy treated with modern radiation techniques. *Radiother Oncol* 2017; 125: 301–309.

352 Maeda H, Kanzaki M, Sakamoto K, *et al.* Effect of collagen vascular disease-associated interstitial lung disease on the outcomes of lung cancer surgery. *Surg Today* 2017; 47: 1072–1079.

353 Asakawa A, Horio H, Yamamichi T, *et al.* Clinical features of HIV-infected patients with non-small-cell lung cancer after lung resection. *Gen Thorac Cardiovasc Surg* 2020; 68: 38–42.

354 Hooker CM, Meguid RA, Hulbert A, *et al.* Human immunodeficiency virus infection as a prognostic factor in surgical patients with non-small cell lung cancer. *Ann Thorac Surg* 2012; 93: 405–412.
355 Chi A, Adams BE, Sesti J, *et al.* Outcomes following major oncologic operations for non-AIDS-defining cancers in the HIV population: a matched comparison to the general population. *World J Surg* 2019; 43: 3019–3026.
356 Chapman CH, Shen J, Filion EJ, *et al.* Marked tumor response and fatal hemoptysis during radiation for lung cancer in a human immunodeficiency virus-positive patient taking nelfinavir. *J Thorac Oncol* 2009; 4: 1587–1589.
357 Okuma Y, Yanagisawa N, Hosomi Y, *et al.* Concomitant chemoradiotherapy and antiretroviral therapy for HIV-infected patients with locoregionally advanced non-small cell lung cancer: benefit and tolerability of treatment in 2 cases. *Onkologie* 2013; 36: 586–590.
358 Massera F, Rocco G, Rossi G, *et al.* Pulmonary resection for lung cancer in HIV-positive patients with low (<200 lymphocytes/mm^3) CD4$^+$ count. *Lung Cancer* 2000; 29: 147–149.
359 Thurer RJ, Jacobs JP, Holland FW 2nd, *et al.* Surgical treatment of lung cancer in patients with human immunodeficiency virus. *Ann Thorac Surg* 1995; 60: 599–602.
360 Spano JP, Massiani MA, Bentata M, *et al.* Lung cancer in patients with HIV infection and review of the literature. *Med Oncol* 2004; 21: 109–115.
361 Brandão M, Durieux V, Auprih M, *et al.* Systemic treatment and radiotherapy for patients with non-small cell lung cancer (NSCLC) and HIV infection – a systematic review. *Lung Cancer* 2023; 178: 75–86.
362 Billmeier SE, Ayanian JZ, Zaslavsky AM, *et al.* Predictors and outcomes of limited resection for early-stage non-small cell lung cancer. *J Natl Cancer Inst* 2011; 103: 1621–1629.
363 Wang Z, Zhang J, Cheng Z, *et al.* Factors affecting major morbidity after video-assisted thoracic surgery for lung cancer. *J Surg Res* 2014; 192: 628–634.
364 Ali K, Sakowitz S, Chervu NL, *et al.* Association of dementia with clinical and financial outcomes following lobectomy for lung cancer. *JTCVS Open* 2023; 16: 965–975.
365 Kalman NS, Hugo GD, Mahon RN, *et al.* Diabetes mellitus and radiation induced lung injury after thoracic stereotactic body radiotherapy. *Radiother Oncol* 2018; 129: 270–276.
366 Ergen SA, Dincbas FO, Yücel B, *et al.* Risk factors of radiation pneumonitis in patients with NSCLC treated with concomitant chemoradiotherapy – Are we underestimating diabetes? – Turkish Oncology Group (TOG)/ Lung Cancer Study Group. *Clin Respir J* 2020; 14: 871–879.
367 Kong M, Lim YJ, Kim Y, *et al.* Diabetes mellitus is a predictive factor for radiation pneumonitis after thoracic radiotherapy in patients with lung cancer. *Cancer Manag Res* 2019; 11: 7103–7110.
368 Hattori A, Takamochi K, Kitamura Y, *et al.* Risk factor analysis of cerebral infarction and clinicopathological characteristics of left upper pulmonary vein stump thrombus after lobectomy. *Gen Thorac Cardiovasc Surg* 2019; 67: 247–253.
369 Hu XF, Duan L, Jiang GN, *et al.* A clinical risk model for the evaluation of bronchopleural fistula in non-small cell lung cancer after pneumonectomy. *Ann Thorac Surg* 2013; 96: 419–424.
370 Hung SK, Lee MS, Chiou WY, *et al.* High incidence of ischemic stroke occurrence in irradiated lung cancer patients: a population-based surgical cohort study. *PLoS ONE* 2014; 9: e94377.
371 Ishibashi H, Wakejima R, Asakawa A, *et al.* Postoperative atrial fibrillation in lung cancer lobectomy – analysis of risk factors and prognosis. *World J Surg* 2020; 44: 3952–3959.
372 Komatsu T, Chen-Yoshikawa TF, Ikeda M, *et al.* Impact of diabetes mellitus on postoperative outcomes in individuals with non-small-cell lung cancer: a retrospective cohort study. *PLoS ONE* 2020; 15: e0241930.
373 Mansour Z, Kochetkova EA, Santelmo N, *et al.* Risk factors for early mortality and morbidity after pneumonectomy: a reappraisal. *Ann Thorac Surg* 2009; 88: 1737–1743.
374 Motoishi M, Sawai S, Hori T, *et al.* The preoperative HbA1c level is an independent prognostic factor for the postoperative survival after resection of non-small cell lung cancer in elderly patients. *Surg Today* 2018; 48: 517–524.
375 Romano PS, Mark DH. Patient and hospital characteristics related to in-hospital mortality after lung cancer resection. *Chest* 1992; 101: 1332–1337.
376 Varela G, Jiménez MF, Novoa N. Aplicabilidad de un modelo predictivo de muerte por resección de cáncer de pulmón a la toma de decisiones individualizadas [A model to predict death after lung cancer resection: applicability to individual cases]. *Arch Bronconeumol* 2003; 39: 249–252.
377 Washington I, Chino JP, Marks LB, *et al.* Diabetes mellitus: a significant co-morbidity in the setting of lung cancer? *Thorac Cancer* 2013; 4: 123–130.
378 Hong SW, Lee SA, Kim SH. Prediction of postoperative pulmonary complications in older patients undergoing lobectomy for lung cancer based on skeletal muscle mass. *J Thorac Dis* 2023; 15: 1063–1074.
379 Zhang L, Guan L, Tang X, *et al.* Effect of type 2 diabetes on the development of acute respiratory distress syndrome (ARDS) in patients with lung cancer after surgery and its prognosis. *Int J Gen Med* 2023; 16: 4573–4584.

380 Arame A, Rivera C, Borik W, *et al.* Chirurgie du cancer du poumon chez les greffés d'organe solide [Lung cancer surgery in solid organ transplanted patients]. *Rev Pneumol Clin* 2014; 70: 315–321.
381 Drevet G, Duruisseaux M, Maury JM, *et al.* Lung cancer surgical treatment after solid organ transplantation: a single center 30-year experience. *Lung Cancer* 2020; 139: 55–59.
382 Bahig H, Filion E, Vu T, *et al.* Severe radiation pneumonitis after lung stereotactic ablative radiation therapy in patients with interstitial lung disease. *Pract Radiat Oncol* 2016; 6: 367–374.
383 Liu Y, Zhu Y, Wu R, *et al.* Stereotactic body radiotherapy for early stage non-small cell lung cancer in patients with subclinical interstitial lung disease. *Transl Lung Cancer Res* 2020; 9: 2328–2336.
384 Tsurugai Y, Takeda A, Sanuki N, *et al.* Stereotactic body radiotherapy for lung cancer patients with idiopathic interstitial pneumonias. *Radiother Oncol* 2017; 125: 310–316.
385 Ueki N, Matsuo Y, Togashi Y, *et al.* Impact of pretreatment interstitial lung disease on radiation pneumonitis and survival after stereotactic body radiation therapy for lung cancer. *J Thorac Oncol* 2015; 10: 116–125.
386 Chen H, Senan S, Nossent EJ, *et al.* Treatment-related toxicity in patients with early-stage non-small cell lung cancer and coexisting interstitial lung disease: a systematic review. *Int J Radiat Oncol Biol Phys* 2017; 98: 622–631.
387 Doi H, Nakamatsu K, Nishimura Y. Stereotactic body radiotherapy in patients with chronic obstructive pulmonary disease and interstitial pneumonia: a review. *Int J Clin Oncol* 2019; 24: 899–909.
388 Hagiwara Y, Nakayama Y, Kudo S, *et al.* Nationwide survey of radiation therapy in Japan for lung cancer complicated with interstitial lung disease. *J Radiat Res* 2020; 61: 563–574.
389 Higo H, Kubo T, Makimoto S, *et al.* Chemoradiotherapy for locally advanced lung cancer patients with interstitial lung abnormalities. *Jpn J Clin Oncol* 2019; 49: 458–464.
390 Li F, Zhou Z, Wu A, *et al.* Preexisting radiological interstitial lung abnormalities are a risk factor for severe radiation pneumonitis in patients with small-cell lung cancer after thoracic radiation therapy. *Radiat Oncol* 2018; 13: 82.
391 Ozawa Y, Abe T, Omae M, *et al.* Impact of preexisting interstitial lung disease on acute, extensive radiation pneumonitis: retrospective analysis of patients with lung cancer. *PLoS ONE* 2015; 10: e0140437.
392 Altan M, Soto F, Xu T, *et al.* Pneumonitis after concurrent chemoradiation and immune checkpoint inhibition in patients with locally advanced non-small cell lung cancer. *Clin Oncol (R Coll Radiol)* 2023; 35: 630–639.
393 Aoki S, Ishikawa H, Nakajima M, *et al.* Safety and efficacy of single-fraction carbon-ion radiotherapy for early-stage lung cancer with interstitial pneumonia. *Cancers (Basel)* 2024; 16: 562.
394 Jeong WG, Kim YH, Ahn SJ, *et al.* Effect of interstitial lung abnormality on concurrent chemoradiotherapy-treated stage III non-small cell lung cancer patients. *Anticancer Res* 2023; 43: 1797–1807.
395 Park SH, Lim JK, Kang MK, *et al.* Predictive factors for severe radiation-induced lung injury in patients with lung cancer and coexisting interstitial lung disease. *Radiother Oncol* 2024; 192: 110053.
396 Walls GM, McMahon M, Moore N, *et al.* Clinicoradiological outcomes after radical radiotherapy for lung cancer in patients with interstitial lung disease. *BJR Open* 2023; 5: 20220049.
397 Chida M, Ono S, Hoshikawa Y, *et al.* Subclinical idiopathic pulmonary fibrosis is also a risk factor of postoperative acute respiratory distress syndrome following thoracic surgery. *Eur J Cardiothorac Surg* 2008; 34: 878–881.
398 Chiyo M, Sekine Y, Iwata T, *et al.* Impact of interstitial lung disease on surgical morbidity and mortality for lung cancer: analyses of short-term and long-term outcomes. *J Thorac Cardiovasc Surg* 2003; 126: 1141–1146.
399 Fukui M, Takamochi K, Suzuki K, *et al.* Lobe-specific outcomes of surgery for lung cancer patients with idiopathic interstitial pneumonias. *Gen Thorac Cardiovasc Surg* 2020; 68: 812–819.
400 Ito H, Nakayama H, Yokose T, *et al.* A prophylaxis study of acute exacerbation of interstitial pneumonia after lung cancer surgery. *Jpn J Clin Oncol* 2020; 50: 198–205.
401 Ito H, Nakayama H, Yokose T, *et al.* Prophylaxis for acute exacerbation of interstitial pneumonia after lung resection. *Asian Cardiovasc Thorac Ann* 2014; 22: 948–954.
402 Iwata T, Yoshida S, Fujiwara T, *et al.* Effect of perioperative pirfenidone treatment in lung cancer patients with idiopathic pulmonary fibrosis. *Ann Thorac Surg* 2016; 102: 1905–1910.
403 Kanayama M, Osaki T, Nishizawa N, *et al.* Modified risk scoring system for acute exacerbation of interstitial lung disease. *Asian Cardiovasc Thorac Ann* 2019; 27: 18–22.
404 Kanzaki M, Kikkawa T, Maeda H, *et al.* Acute exacerbation of idiopathic interstitial pneumonias after surgical resection of lung cancer. *Interact Cardiovasc Thorac Surg* 2011; 13: 16–20.
405 Koizumi K, Hirata T, Hirai K, *et al.* Surgical treatment of lung cancer combined with interstitial pneumonia: the effect of surgical approach on postoperative acute exacerbation. *Ann Thorac Cardiovasc Surg* 2004; 10: 340–346.
406 Kumar P, Goldstraw P, Yamada K, *et al.* Pulmonary fibrosis and lung cancer: risk and benefit analysis of pulmonary resection. *J Thorac Cardiovasc Surg* 2003; 125: 1321–1327.

407 Maniwa T, Endo M, Isaka M, *et al.* Acute exacerbation of interstitial lung disease with lung cancer after surgery: evaluation with 2-[18]-fluoro-2-deoxy-D-glucose positron emission tomography. *Surg Today* 2014; 44: 494–498.

408 Maniwa T, Kondo H, Mori K, *et al.* Outcomes in surgically managed non-small-cell lung cancer patients with evidence of interstitial pneumonia identified on preoperative radiology or incidentally on postoperative histology. *Interact Cardiovasc Thorac Surg* 2015; 20: 641–646.

409 Mimae T, Suzuki K, Tsuboi M, *et al.* Surgical outcomes of lung cancer in patients with combined pulmonary fibrosis and emphysema. *Ann Surg Oncol* 2015; 22: Suppl. 3, S1371–S1379.

410 Miyajima M, Watanabe A, Sato T, *et al.* What factors determine the survival of patients with an acute exacerbation of interstitial lung disease after lung cancer resection? *Surg Today* 2018; 48: 404–415.

411 Mizuno Y, Iwata H, Shirahashi K, *et al.* The importance of intraoperative fluid balance for the prevention of postoperative acute exacerbation of idiopathic pulmonary fibrosis after pulmonary resection for primary lung cancer. *Eur J Cardiothorac Surg* 2012; 41: e161–e165.

412 Omori T, Tajiri M, Baba T, *et al.* Pulmonary resection for lung cancer in patients with idiopathic interstitial pneumonia. *Ann Thorac Surg* 2015; 100: 954–960.

413 Park JS, Kim HK, Kim K, *et al.* Prediction of acute pulmonary complications after resection of lung cancer in patients with preexisting interstitial lung disease. *Thorac Cardiovasc Surg* 2011; 59: 148–152.

414 Saito H, Minamiya Y, Nanjo H, *et al.* Pathological finding of subclinical interstitial pneumonia as a predictor of postoperative acute respiratory distress syndrome after pulmonary resection. *Eur J Cardiothorac Surg* 2011; 39: 190–194.

415 Sakamoto S, Homma S, Mun M, *et al.* Acute exacerbation of idiopathic interstitial pneumonia following lung surgery in 3 of 68 consecutive patients: a retrospective study. *Intern Med* 2011; 50: 77–85.

416 Sato S, Koike T, Hashimoto T, *et al.* Surgical outcomes of lung cancer patients with combined pulmonary fibrosis and emphysema and those with idiopathic pulmonary fibrosis without emphysema. *Ann Thorac Cardiovasc Surg* 2016; 22: 216–223.

417 Sato T, Teramukai S, Kondo H, *et al.* Impact and predictors of acute exacerbation of interstitial lung diseases after pulmonary resection for lung cancer. *J Thorac Cardiovasc Surg* 2014; 147: 1604–1611.e1603.

418 Sekihara K, Aokage K, Oki T, *et al.* Long-term survival after complete resection of non-small-cell lung cancer in patients with interstitial lung disease. *Interact Cardiovasc Thorac Surg* 2018; 26: 638–643.

419 Shintani Y, Ohta M, Iwasaki T, *et al.* Predictive factors for postoperative acute exacerbation of interstitial pneumonia combined with lung cancer. *Gen Thorac Cardiovasc Surg* 2010; 58: 182–185.

420 Sugiura H, Takeda A, Hoshi T, *et al.* Acute exacerbation of usual interstitial pneumonia after resection of lung cancer. *Ann Thorac Surg* 2012; 93: 937–943.

421 Takeda S, Maeda H, Sawabata N, *et al.* Clinical impact of interstitial pneumonia following surgery for lung cancer. *Thorac Cardiovasc Surg* 2006; 54: 268–272.

422 Tang H, Ren Y, She Y, *et al.* Is operation safe for lung cancer patients with interstitial lung disease on computed tomography? *Ther Adv Respir Dis* 2020; 14: 1753466620971137.

423 Taniguchi D, Yamasaki N, Miyazaki T, *et al.* The surgical outcomes of lung cancer combined with interstitial pneumonia: a single-institution report. *Surg Today* 2017; 47: 1397–1404.

424 Tao H, Onoda H, Okabe K, *et al.* The impact of coexisting lung diseases on outcomes in patients with pathological stage I non-small-cell lung cancer. *Interact Cardiovasc Thorac Surg* 2018; 26: 1009–1015.

425 Tsutani Y, Mimura T, Kai Y, *et al.* Outcomes after lobar *versus* sublobar resection for clinical stage I non-small cell lung cancer in patients with interstitial lung disease. *J Thorac Cardiovasc Surg* 2017; 154: 1089–1096.e1081.

426 Voltolini L, Bongiolatti S, Luzzi L, *et al.* Impact of interstitial lung disease on short-term and long-term survival of patients undergoing surgery for non-small-cell lung cancer: analysis of risk factors. *Eur J Cardiothorac Surg* 2013; 43: e17–e23.

427 Yamamichi T, Shimada Y, Masuno R, *et al.* Association between F-18 fluorodeoxyglucose uptake of noncancerous lung area and acute exacerbation of interstitial pneumonia in patients with lung cancer after resection. *J Thorac Cardiovasc Surg* 2020; 159: 1111–1118.e1112.

428 Yano M, Sasaki H, Moriyama S, *et al.* Post-operative acute exacerbation of pulmonary fibrosis in lung cancer patients undergoing lung resection. *Interact Cardiovasc Thorac Surg* 2012; 14: 146–150.

429 Hata A, Sekine Y, Kota O, *et al.* Impact of combined pulmonary fibrosis and emphysema on surgical complications and long-term survival in patients undergoing surgery for non-small-cell lung cancer. *Int J Chron Obstruct Pulmon Dis* 2016; 11: 1261–1268.

430 Kobayashi S, Matsumura Y, Karube Y, *et al.* Inflammation-based prognostic score predicts postoperative survival of patients with interstitial pneumonia after undergoing lung cancer resection. *World J Surg* 2018; 42: 2143–2152.

431 Chida M, Kobayashi S, Karube Y, *et al.* Incidence of acute exacerbation of interstitial pneumonia in operated lung cancer: institutional report and review. *Ann Thorac Cardiovasc Surg* 2012; 18: 314–317.

432 Axtell AL, David EA, Block MI, *et al.* Association between interstitial lung disease and outcomes after lung cancer resection. *Ann Thorac Surg* 2023; 116: 533–541.

433 Ki MS, Kim SY, Kim EY, *et al.* Clinical outcomes and prognosis of patients with interstitial lung disease undergoing lung cancer surgery: a propensity score matching study. *Clin Lung Cancer* 2023; 24: e27–e38.

434 Hyun DG, Han SJ, Ji W, *et al.* Clinical characteristics and prognostic impact of acute exacerbations in patients with interstitial lung disease and lung cancer: a single-center, retrospective cohort study. *Thorac Cancer* 2023; 14: 3323–3330.

435 Patel AJ, Walters GI, Watkins S, *et al.* Lung cancer resection in patients with underlying usual interstitial pneumonia: a meta-analysis. *BMJ Open Respir Res* 2023; 10: e001529.

436 Shao C, Zhi X, Mao S, *et al.* Efficacy and safety of local ablative therapy for patients with NSCLC and coexisting interstitial lung disease. *Thorac Cancer* 2024; 15: 778–787.

437 Caini S, Del Riccio M, Vettori V, *et al.* Quitting smoking at or around diagnosis improves the overall survival of lung cancer patients: a systematic review and meta-analysis. *J Thorac Oncol* 2022; 17: 623–636.

438 Yoong S, Tursan d'Espaignet E, Wiggers J, *et al.* Tobacco and Postsurgical Outcomes: WHO Tobacco Knowledge Summaries. Geneva, World Health Organization, 2020.

439 Zaman M, Bilal H, Mahmood S, *et al.* Does getting smokers to stop smoking before lung resections reduce their risk? *Interact Cardiovasc Thorac Surg* 2012; 14: 320–323.

440 Napolitano MA, Rosenfeld ES, Chen SW, *et al.* Impact of timing of smoking cessation on 30-day outcomes in veterans undergoing lobectomy for cancer. *Semin Thorac Cardiovasc Surg* 2021; 33: 860–868.

441 Yamamichi T, Ichinose J, Iwamoto N, *et al.* Correlation between smoking status and short-term outcome of thoracoscopic surgery for lung cancer. *Ann Thorac Surg* 2022; 113: 459–465.