Review Article

Lung cancer resection in high-risk patients: a narrative review

Akshay J. Patel[1,2], Ehab S. Bishay[1], Babu Naidu[1,3]

[1]Department of Thoracic Surgery, University Hospitals Birmingham, England, UK; [2]Institute of Immunology and Immunotherapy, University of Birmingham, England, UK; [3]Institute of Inflammation and Ageing, University of Birmingham, England, UK

Contributions: (I) Conception and design: AJ Patel; (II) Administrative support: None; (III) Provision of study materials or patients: None; (IV) Collection and assembly of data: AJ Patel; (V) Data analysis and interpretation: All authors; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

Correspondence to: Akshay J. Patel. Department of Thoracic Surgery, Queen Elizabeth Hospital, University Hospitals Birmingham, NHS Foundation Trust, Mindelsohn Way, Edgbaston, B15 2GW, England, UK. Email: ajp.788@gmail.com.

Background and Objective: The National Lung Cancer Audit (NLCA) 2022 report showed that for England in 2019, the curative treatment rates of non-small cell lung cancer (NSCLC) patients with stage I/II disease and good performance status were 81%, this metric fell to 73% in 2020 with resection rates falling from 20% to 15%. The impact of COVID-19 could well have influenced this and indeed lung cancer patients diagnosed in 2020 were more likely to have a worse performance status, diagnosed as emergency presentations and less likely to have a pathological diagnosis. Assessing risk in the current era and defining which patients are high-risk needs formal exploration and definition if we are to improve resection rates in a safe and equitable manner.

Methods: We conducted a narrative literature review to explore the paradigm of risk in thoracic surgery and in particular address the concept of what is considered to be "high risk" for surgery. We searched MEDLINE, EMBASE and Cochrane Library databases using the OVID interface. We reviewed articles between January 1, 2000, and December 31, 2021 and restricted this to full text papers only in the English language. Conference abstracts were not considered.

Key Content and Findings: A delineation must be made between the assessment of risk for an individual patient (usually peri-operative complication and death) and the assessment of risk for an entire cohort, i.e., determining safety, efficacy, and feasibility of an intervention for a particular group. Both components are necessary when communicating risk. There is no fixed model of the high-risk patient, but instead an individualised risk profile which should serve to employ pre-operative optimisation strategies, pulmonary rehabilitation, smoking cessation programmes, exercise rehabilitation and post-operative rehabilitation.

Conclusions: By understanding risk and benchmarking patients appropriately and in a uniform way, one can be more objective and scientific in assessing suitability for resection. This is but one pillar of a multi-faceted approach to help inform patients and healthcare providers in a constructive way and increase surgical rates in an appropriate and safe way.

Keywords: Thoracic surgery; "high risk"; lobectomy; risk profiling; rehabilitation

Received: 07 March 2022; Accepted: 27 June 2022; Published: 30 July 2022.

doi: 10.21037/shc-22-16

View this article at: https://dx.doi.org/10.21037/shc-22-16

Introduction

Lung cancer is the commonest cause of cancer death in the United Kingdom (UK) accounting for 21% of all cancer deaths (1). In the UK, lung cancer survival rates are poor compared to other European countries, with the UK ranked 26th out of 29 countries (2). Surgical resection is seen as the optimal curative-intent treatment for early stage lung cancer and optimising surgical resection rates is a key intervention to improve long-term survival and to ensure

Table 1 The search strategy summary

Items	Specification
Date of search	January 1, 2022, onwards
Databases and other sources searched	MEDLINE, EMBASE and Cochrane Library databases using OVID interface
Search terms used	"risk", "high-risk", "thoracic surgery", "lung resection"
Timeframe	Between January 1, 2000, to December 31, 2021
Inclusion and exclusion criteria	Inclusion and exclusion criteria: (I) articles in English languages; (II) full-text articles are available; (III) article types were not conference abstracts
Selection process	Two reviewers conducted the study screening and selection independently. Any conflicts regarding inclusion were resolved by a third senior reviewer

the UK has outcomes comparable with other European countries (1,3-5). Improved lung cancer survival is seen in high volume surgical centres which supports the drive towards higher surgical resection rates across the UK (6). The number of lung cancer resections performed in the UK is increasing year on year; for example there was a 15% increase between 2014 (n=5,750) and 2017 (n=6,641) and this was achieved whilst at the same time maintaining a high 30-day and one-year survival at 98.1% and 88.7% respectively (5,6). This suggests surgery can be offered to more patients without compromising safety and, perhaps, further increases in surgical volume are possible. Despite this, significant variability exists in surgical resection rates for non-small cell lung cancer (NSCLC) across different trusts in the UK (10–37%), meaning that some centres do not actually reach the National Lung Cancer Audit (NLCA) standard of 17% (5). Suggested reasons for this include variability in pre-operative physiological work-up, access to surgery and adherence to recognised best practices & national guidelines (5). The Cardiothoracic Surgery Getting It Right First Time (GIRFT) Programme National Specialty Report makes recommendations that thoracic surgical centres establish collective responsibility for high-risk and complex cases supported by a National policy (7).

Understanding surgical risk and in particular what this "risk" relates to is a vehicle through which the pre-operative assessment process can be standardised, adherence to best practice and maximise access to surgical care through collective responsibility. We present the following article in accordance with the Narrative Review reporting checklist (available at https://shc.amegroups.com/article/view/10.21037/shc-22-16/rc).

Methods

We interrogated the literature to determine how risk is assessed and managed in surgical patients and specifically thoracic surgical patients. We searched MEDLINE, EMBASE and Cochrane Library databases using the OVID interface. We reviewed articles between January 1, 2000, and December 31, 2021 and restricted this to full text papers only in the English language. Conference abstracts were not considered. The search strategy included only terms relating to or describing the condition. The search strategy was determined in conjunction with a medical librarian. The MEDLINE search terms were adapted for use with the other bibliographic databases in combination with database-specific filters. Terms such as "risk", "high-risk", "thoracic surgery" and "lung resection" were employed. We searched all databases from their inception to the present. Please see an example of the independent search strategy in *Table 1*.

What is risk?

All patients regardless of status should be discussed in a multi-disciplinary team (MDT) meeting. Robust physiological assessment as detailed above allows us to stratify those patients at highest risk of peri-operative morbidity and mortality. Moreover, areas which need optimisation can be identified and communicated to the patient and other members of the MDT to facilitate shared decision making.

However, in working up patients, we must ask ourselves, what is risk? As this is a relative entity and it means different things to care-givers and to patients. A risk of 10% peri-operative mortality from a lobectomy in the current era is

incredibly high to a surgeon but to a patient it seems quite reasonable. Managing expectations is the absolute key to communicating risk more so in the high-risk patient.

Our ability to assess risk can be quite poor as in spite of robust prediction models and physiological parameters used to guide us, our own fears and hopes can play just as much as a guiding role (8). The discussion of risk can be open to misinterpretation as a result from all parties involved.

A delineation must be made between the assessment of risk for an individual patient (usually peri-operative complication and death) and the assessment of risk for an entire cohort, i.e., determining safety, efficacy, and feasibility of an intervention for a particular group. Both components are necessary when communicating risk. As an example, counselling patients for a pneumonectomy would entail a discussion of the natural history of this procedure and associated average morbidity/mortality as well as an assessment of the individual's physiological status which together will determine overall risk of poor outcome.

All risk conversations tend to be outcome-driven and usually this relates to death, but we must also clarify what the outcome of interest is. Particularly for thoracic surgical patients, we must communicate a risk of peri-operative morbidity and mortality, post-operative breathlessness and poor quality of life, post-operative pain and specific to oncological cases, risk of post-operative recurrence. All these four parameters differ greatly according to the type of surgery being undertaken within the thoracic cavity. Considering risk as a multi-faceted entity helps to better communicate the paradigm and therefore enables thought processes on how risk can be altered or optimised for the healthcare clinician and allows patients to participate in their treatment pathway. From the clinician perspective, would a certain level of risk mean limited resection which has shown a degree of benefit at the randomised trial level (JCOG0802) (9,10) or post-operative high dependency unit (HDU) level care or ward bed. Furthermore, discussing alternative treatment options (non-surgical) is of paramount importance as it helps facilitate a shared decision-making process, and properly informed consent.

The high-risk thoracic surgical patient

In surgery, the National Confidential Enquiry into Peri-Operative Deaths (N-CEPOD) addressed the issue of where a baseline for risk might lie (8,11). There are between 2.8 million and 3.3 million operations per year in England, Wales, and Northern Ireland. The risk of death within 30 days of any operation has been estimated at between 0.7% and 1.7%. The N-CEPOD enquiry also showed that as a group, surgeons did not identify one third of patients who died as being high-risk for peri-operative death, suggesting that our perception of what is "high-risk" is somewhat inaccurate (11). Boyd *et al.* have intimated that high risk should be defined as an individual's risk of mortality is either >5% or twice the risk of the general population undergoing the same procedure (8). In lung cancer, Sancheti *et al.* (12) retrospectively assessed outcomes for high-risk and standard risk early stage lung cancer patients undergoing curative resection. As no consensus on high-risk surgery classification currently exists, identification of high-risk patients was done according to the ACOSOG z4032/z4099 criteria [forced expiratory volume in the first second (FEV1) <50%, diffusion capacity of the lung for carbon monoxide (DLco) <50%, age >75 years]. High-risk patients were more likely to undergo sublobar resection (P=0.001), they demonstrated a higher length of post-operative stay (5 versus 4 days, P<0.0001) however there was no difference in post-operative mortality (2% versus 1%, P=NS). Three-year survival was significantly lower in the high-risk group (59% versus 76%, P<0.0001) (12).

The American Association for Thoracic Surgery consensus panel reviewed the guidance around patients who are deemed high-risk and undergoing lobectomy for early-stage lung cancer. Various important physiological factors were identified (as detailed below) yet the key message was that factors used for risk assessment are evolving in light of an ageing population (13). Furthermore, as we continue to innovate and progress minimally invasive strategies, risk can be mitigated somewhat making what was once considered "high-risk" may not be the case in the next 5–10 years. The use of scoring systems such as Thoracoscore, EuroLung 1 and 2, the Revised Cardiac Risk Index (ThRCRI), the European Society Objective Score (ESOS) all have utility and are particularly important when comparing unit-specific and surgeon-specific outcomes however are a "broad brush" picture of the risk profile of a patient, individualised metrics and standardisation according to the patient must be considered (14).

The assessment model of pulmonary mechanical function, parenchymal function and cardiopulmonary reserve remains the cornerstone when considering what is "fit for thoracic surgery" however other peri-operative factors are critical, as suggested by the conventional Tripartite Risk Model (operative mortality, peri-operative adverse events and post-operative dyspnoea) (15). These include robust frailty

assessment (Clinical Frailty Scoring), whether multi-modality pre-habilitation is likely to be of benefit and balancing this with the access and extent of surgical resection planned. The latter is of particular importance as it challenges the whole paradigm of high-risk, making patients with predicted postoperative FEV1 (ppoFEV1) and DLco <30% potentially operable (16). As such there is no fixed model of the high-risk patient, but instead an individualised risk profile which should serve to employ pre-operative optimisation strategies, pulmonary rehabilitation, smoking cessation programmes, exercise rehabilitation and post-operative rehabilitation. Pre-habilitation has shown to increase exercise capacity and significantly enhance pulmonary function (17) and meta-analytical data has subsequently demonstrated a robust reduction in post-operative complications as a result (18).

Current approach to determining peri-operative risk

When evaluating a patient's fitness for surgery, as part of the tripartite assessment, evaluation of cardiopulmonary reserve and cardiac risk tends to be a key discriminator. Evaluation for coronary artery disease is not needed for patients with an acceptable exercise tolerance and cardiac interventions specifically for thoracic surgery are of limited value. Overall risk is more useful in this regard especially in the era of enhanced recovery. Nonetheless, it is recommended that a cardiology opinion be sought for patients with angina on minimal exertion (<100 m or climbing, <2 flights of stairs), breathlessness at rest attributed to cardiac failure, severe aortic stenosis, or severe atrioventricular (AV) conduction defect. Non-invasive stress testing (e.g., dobutamine stress echo) are only indicated in those patients with significant limitation to exercise tolerance due to suspected cardiac disease defined as less than 4 metabolic equivalents (METS) which is equivalent to <100 m walking distance as per the European guidelines (19). The medical optimisation of cardiac co-morbidity such as left ventricular dysfunction with initiation and up-titration of evidenced based interventions such as angiotensin converting enzyme (ACE) inhibitors and beta-blockers remain an important focus of pre-operative optimisation. For major thoracic surgery, the need for pre-operative echocardiography in patients with cardiac history is reasonable however large scale, propensity matched cohort data for patients undergoing elective intermediate to high risk non-cardiac surgery (n=264,823) did not demonstrate a survival benefit or a reduced post-operative complication rates in patients undergoing routine pre-operative echocardiography (20).

In terms of lung function parameters in the assessment for lung cancer resection, international guidelines define high-risk surgical candidates as those with a ppo lung function <40% with expert opinion suggesting those with ppo 30–40% can undergo surgical resection with acceptable peri-operative mortality and long-term survival (21-24). Acceptable outcomes have been demonstrated using these selection criteria in the context of an acceptable exercise tolerance by Puente-Maestú *et al.* (25) with a peri-operative mortality of 6% and Brunelli *et al.* at 4% (26). Furthermore, Puente-Maestú and colleagues did demonstrate that the 2-year survival of those patients in the resection group was 66% versus 19% in those patients that did not undergo surgery (25).

Numerous forms of functional exercise testing exist that range from very good accessibility but poor reproducibility (e.g., stair climbing test) to those that are far less accessible but demonstrate excellent reproducibility [e.g., cardiopulmonary exercise testing (CPET)]. The incremental shuttle walk (ISWT) has gained increasing support due to good accessibility (requirement for two shuttle cones 10 metres apart and an incremental pacing track) and good reproducibility. An ISWT greater than 40 shuttles (400 m) correlates well to a VO_2max >15 mL/kg/min (100% positive predictive value) however the shuttle walk appears to underestimate VO_2max at the lower ranges with more than half of patients with a shuttle walk <250 m having a VO_2max >15 mL/kg/min (22,27,28). More recent data demonstrated a shuttle walk of >25 shuttles (250 m) has a 90% positive predictive value for VO_2max >15 mL/kg/min (29).

CPET is considered the gold standard exercise test and has an extensive evidence base in vascular surgery particularly for the repair of abdominal aortic aneurysm assessment. However, for lung cancer resection, the British Thoracic Society (BTS) and Society of Cardiothoracic Surgery (UK and Ireland, SCTS) state "*The evidence for CPET in providing a useful definition of high risk is limited and there is no data to show how it can help predict unacceptable levels of post-operative dyspnoea*". In the largest case series study of CPET in lung cancer, where high risk was defined as a VO_2max <15 mL/kg/min, 68 high risk patients underwent surgical resection with an operative mortality of 4% and no difference in complication rate. The overall survival of high-risk patients that underwent surgery was 36 versus 15.8 months in high-risk patients that did not undergo surgery (30). The ERS/ESTS/ACCP generally consider a VO_2max <10 mL/kg/min prohibitive for surgery though

this is based on a total of 27 patients from 4 studies with a mortality of 26% (21-23,26).

Evidence is contradictory on the ability of desaturation during exercise to predict complications. National and international guidelines do not recommend desaturation during exercise as a robust measure for the risk of complications however recording it and review of the impact on outcomes of this metric could form part of a holistic risk assessment (21,22,24).

In summary, there is a clear rationale for standardised preoperative assessment protocols that identify higher risk patients through cardiac assessment, post-operative predicted lung function and functional testing. However, this higher risk status, rather than be an automatic marker for prohibitive surgery should form the basis of multi-disciplinary discussion and the presentation of risk to patients in a shared decision-making process. This standardised approach, on many occasions will provide the opportunity for objective evidence supporting surgical resection, e.g., shuttle walk test >250 m or using CPET to demonstrate better functional results in cases where the shuttle walk is <250 m, ensuring optimal access to surgery.

Risk prediction models

Numerous risk prediction models have been devised in thoracic surgery to try and determine one's risk of peri-operative and post-operative mortality. Each model has its own advantages and disadvantages, and the applicability of these risk prediction models on their own or in combination has still not been adopted into mainstream thoracic surgical practice. Moreover, none of the models specifically enable us to determine the type or extent of surgical resection let alone whether to resect or not. Robust systematic review data (31) from 2021, evaluated 22 risk prediction models in thoracic surgery and it was concluded that despite there being multiple risk prediction models to predict perioperative mortality after thoracic surgery, none could be described as appropriate for contemporary thoracic surgery. Furthermore, there was an overall lack of formalised external contemporary validation of available models to ensure that appropriate estimates of operative risk can be made available for contemporary thoracic surgical practice. The receiver operating characteristic (ROC) of these 22 models ranged from area under the curve (AUC) 0.74–0.85 in the test cohorts, however only four of these models demonstrated effective external validation (AUC 0.82–0.85). Owing to the large degree of heterogeneity in patient characteristics in these models as well as predictor heterogeneity, it is very difficult to confidently combine models for predictive purposes and evaluate any single model for current day use. Adopting machine learning methodology may be one approach to effectively evaluate robust predictors of mortality in large scale test and validation cohorts. The data from ACOSOG z4032 and z4033 prospectively characterised lung cancer patients as "high-risk"; prospective evaluation of these criteria showed that "high risk" status was not associated with peri-operative morbidity and despite a large proportion of said "high-risk" patients undergoing lobectomy, there were no differences in early outcomes between the two different risk groups (32). This again reinforces two points: firstly that risk stratification in line with current model data is not completely translatable to current day practice and secondly that an individualised patient-centric approach to risk assessment should remain to be the cornerstone of assessing suitability for thoracic surgical resection.

Conclusions

The determination of risk is a clinical decision and judgement, which should also take into consideration patient perspectives, values, preferences, and quality of life. The purpose of an effective scoring system is to highlight potentially high-risk and to act as a focus for generating a multidisciplinary risk/benefit discussion between various specialties. The concept of the high-risk patient in thoracic surgery is an evolving concept and there is no fixed criterion by which to assign this status to any one patient. Rather, an individualised risk profile predicated on a holistic approach will serve to inform patients better, facilitate shared decision making and divert patients to optimisation pathways throughout their operative process.

Acknowledgments

Funding: None.

Footnote

Provenance and Peer Review: This article was commissioned by the Guest Editors (Marcus Taylor and Felice Granato) for the series "Thoracic Surgery in High Risk Patients" published in *Shanghai Chest*. The article has undergone external peer review.

Reporting Checklist: The authors have completed the Narrative Review reporting checklist. Available at https://shc.amegroups.com/article/view/10.21037/shc-22-16/rc

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://shc.amegroups.com/article/view/10.21037/shc-22-16/coif). The series "Thoracic Surgery in High Risk Patients" was commissioned by the editorial office without any funding or sponsorship. The authors have no other conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

References

1. Lung cancer statistics | Cancer Research UK [Internet]. [cited 2022 Feb 23]. Available online: https://www.cancerresearchuk.org/health-professional/cancer-statistics/statistics-by-cancer-type/lung-cancer
2. Allemani C, Matsuda T, Di Carlo V, et al. Global surveillance of trends in cancer survival 2000-14 (CONCORD-3): analysis of individual records for 37 513 025 patients diagnosed with one of 18 cancers from 322 population-based registries in 71 countries. Lancet 2018;391:1023-75.
3. Overview | Lung cancer: diagnosis and management | Guidance | NICE [Internet]. [cited 2022 Feb 23]. Available online: https://www.nice.org.uk/guidance/ng122
4. Edwards BK, Noone AM, Mariotto AB, et al. Annual Report to the Nation on the status of cancer, 1975-2010, featuring prevalence of comorbidity and impact on survival among persons with lung, colorectal, breast, or prostate cancer. Cancer 2014;120:1290-314.
5. Lung cancer clinical outcomes publication 2019 (for the audit period 2017) [Internet]. RCP London. 2020 [cited 2022 Feb 23]. Available online: https://www.rcplondon.ac.uk/projects/outputs/lung-cancer-clinical-outcomes-publication-2019-audit-period-2017
6. Lüchtenborg M, Riaz SP, Coupland VH, et al. High procedure volume is strongly associated with improved survival after lung cancer surgery. J Clin Oncol 2013;31:3141-6.
7. Getting It Right First Time - GIRFT [Internet]. Getting It Right First Time - GIRFT. [cited 2022 Feb 23]. Available online: https://www.gettingitrightfirsttime.co.uk/
8. Boyd O, Jackson N. How is risk defined in high-risk surgical patient management? Crit Care 2005;9:390-6.
9. Nakamura K, Saji H, Nakajima R, et al. A phase III randomized trial of lobectomy versus limited resection for small-sized peripheral non-small cell lung cancer (JCOG0802/WJOG4607L). Jpn J Clin Oncol 2010;40:271-4.
10. 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;399:1607-17.
11. Ingram GS. The lessons of the National Confidential Enquiry into Perioperative Deaths. Best Pract Res Clin Anaesthesiol 1999;13:257-66.
12. Sancheti MS, Melvan JN, Medbery RL, et al. Outcomes After Surgery in High-Risk Patients With Early Stage Lung Cancer. Ann Thorac Surg 2016;101:1043-50; Discussion 1051.
13. 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.e6.
14. Irons JF, Martinez G. Complex, high-risk thoracic surgery—does risk always outweigh the benefit or can we manage it safely? Video-assist Thorac Surg 2017;2:63.
15. Keogh BF, Alexander D. Preoperative assessment for thoracic surgery. Anaesth Intensive Care Med 2011;12:518-21.
16. Hanley C, Donahoe L, Slinger P. "Fit for Surgery? What's New in Preoperative Assessment of the High-Risk Patient Undergoing Pulmonary Resection". J Cardiothorac Vasc Anesth 2021;35:3760-73.
17. Sanchez-Lorente D, Navarro-Ripoll R, Guzman R, et al. Prehabilitation in thoracic surgery. J Thorac Dis

2018;10:S2593-600.
18. Gravier FE, Smondack P, Prieur G, et al. Effects of exercise training in people with non-small cell lung cancer before lung resection: a systematic review and meta-analysis. Thorax 2022;77:486-96.
19. Poldermans D, Bax JJ, Boersma E, et al. Guidelines for pre-operative cardiac risk assessment and perioperative cardiac management in non-cardiac surgery: the Task Force for Preoperative Cardiac Risk Assessment and Perioperative Cardiac Management in Non-cardiac Surgery of the European Society of Cardiology (ESC) and endorsed by the European Society of Anaesthesiology (ESA). Eur J Anaesthesiol 2010;27:92-137.
20. Wijeysundera DN, Beattie WS, Karkouti K, et al. Association of echocardiography before major elective non-cardiac surgery with postoperative survival and length of hospital stay: population based cohort study. BMJ 2011;342:d3695.
21. Brunelli A, Gooseman MR, Pompili C. Evaluation of Risk for Thoracic Surgery. Surg Oncol Clin N Am 2020;29:497-508.
22. 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.
23. 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:e166S-90S.
24. Lim E, Baldwin D, Beckles M, et al. Guidelines on the radical management of patients with lung cancer. Thorax 2010;65 Suppl 3:iii1-27.
25. Puente-Maestú L, Villar F, González-Casurrán 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;139:1430-8.
26. 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.
27. Win T, Jackson A, Groves AM, et al. Relationship of shuttle walk test and lung cancer surgical outcome. Eur J Cardiothorac Surg 2004;26:1216-9.
28. 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.
29. Benzo RP, Sciurba FC. Oxygen consumption, shuttle walking test and the evaluation of lung resection. Respiration 2010;80:19-23.
30. Loewen GM, Watson D, Kohman L, et al. Preoperative exercise Vo2 measurement for lung resection candidates: results of Cancer and Leukemia Group B Protocol 9238. J Thorac Oncol 2007;2:619-25.
31. 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;32:333-42.
32. 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;97:1678-83; discussion 1683-5.

doi: 10.21037/shc-22-16
Cite this article as: Patel AJ, Bishay ES, Naidu B. Lung cancer resection in high-risk patients: a narrative review. Shanghai Chest 2022;6:23.