Preoperative Evaluation of Patients for Thoracic Surgery

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1. Introduction

Lung cancer is the most common cancer in the world with 1.61 million new cases diagnosed every year (1). The vast majority of lung cancers are caused by cigarette smoking. It has been estimated that the lifetime risk of developing lung cancer in 2008 is 1 in 14 for men and 1 in 19 for women in the UK.

Approximately 2400 Lobectomies and 500 Pneumonectomies are undertaken in the UK annually, the majority for malignancy. For this group of patients, in-hospital mortality rates are 2-4% and 6-8% respectively in the UK, although world mortality rates as high as 11% have been cited for Pneumonectomy(2)

To guide decisions, one must not only consider the extremely poor prognosis for inoperable patients but also be familiar with the operative risks, and understand how surgery impacts on pulmonary function both in short term and long term.

The aim of the preoperative pulmonary assessment is to identify patients who are at increased risk of having peri-operative complications and long term disability from surgical resection using the least tests available. The purpose of this preoperative physiologic assessment is to enable adequate counselling of the patient on treatment options and risks so that they can make a truly informed decision (3)

Preoperative evaluation of a patient with lung cancer involves answering three questions: 1) is the neoplasm resectable? (Anatomic resectability), 2) Does the patient have adequate pulmonary reserve to tolerate pulmonary resection? (Operability or physiologic resectability); 3) is there any major medical contraindication to the proposed surgery?

2. Anatomical resectability

After a tissue diagnosis of lung cancer has been made, the neoplasm should first be assessed for anatomic resectability. A neoplasm is considered resectable if the entire tumour can be removed by surgery. Knowing the extent of tumour both within and outside the thorax is the key in determining resectability. Surgical resection is considered the treatment of choice in physiologically operable patients with up to stage IIIA tumour. (4)

2.1 Operability (physiologic resectability)

2.1.1 Physiologic alterations after thoracotomy and lung resection

If, after adequate staging, the tumour is found to be anatomically resectable, the next step is determination of operability or physiological resectability. To understand operability the physiologic changes due to surgery and the pulmonary reserve require discussion. When thoracic surgery is performed, several physiological effects occur which can be discussed under changes in Lung volume, compliance and pulmonary blood flow.

2.1.1.1 Changes in lung volume

Even if no lung is resected, vital capacity declines by approximately 25% in the early postoperative period and slowly returns to baseline in a few weeks. In patients with underlying lung disease, the reduction in vital capacity by lung surgery may result in acute and chronic respiratory failure, or even death. However, it should be noted that while in most circumstances lung resection leads to reduction in lung function; this is not always the case. Patients who undergo resection of large bullae may actually have improvement in lung function postoperatively because of better lung mechanics. On occasion, lung resection only involves removal of non-functioning lung parenchyma and there is little or no change in resultant lung function after recovery. Moreover, in some highly selected cases, in particular upper lobe tumours in patients with centrilobular emphysema, there may be a lung volume reduction surgery (LVRS)-like effect. In these selected circumstances, the resultant lung function after recovery from resection is actually better than the preoperative measurements. This effect is difficult to anticipate given the obvious important differences between lobectomy and LVRS protocols, but it has been noticed in anecdotal cases (8).

2.1.1.2 Changes in lung compliance

Chest wall compliance also decreases to less than 50% and work of breathing increases to more than 140% of the preoperative level. The cough pressure is reduced to 30% of the preoperative value and increases to 50% by 1 week (5–7).

2.1.1.3 Changes in pulmonary blood flow

Removal of lung parenchyma results in reduction of the pulmonary capillary bed. The decrease in pulmonary capillary bed is well tolerated by patients with otherwise normal lungs but in patients with pulmonary dysfunction this may result in postoperative pulmonary hypertension.

Unlike most general surgical procedures where cardiovascular complications are the major cause of perioperative morbidity and mortality, in thoracic surgical population respiratory complications are the predominant cause of perioperative morbidity and mortality (9,10).

The principles described will apply to all other types of non-malignant pulmonary resections and to other chest surgery. The major difference is that in patients with malignancy the risk/benefit ratio of cancelling or delaying surgery pending other investigation/therapy is always complicated by the risk of further spread of cancer during any extended interval prior to resection. This is never completely “elective” surgery (10).

3. Assessment of patients for lung resection

Each patient’s management requires planning by a multi-disciplinary team (MDT), which includes a respiratory physician, a thoracic surgeon, an oncologist and other staff such as physiotherapists and respiratory nurses. If the MDT feels that surgery is appropriate, then the surgeon will decide if the tumour is technically resectable based on chest X-ray and CT scan images (Figure 1).

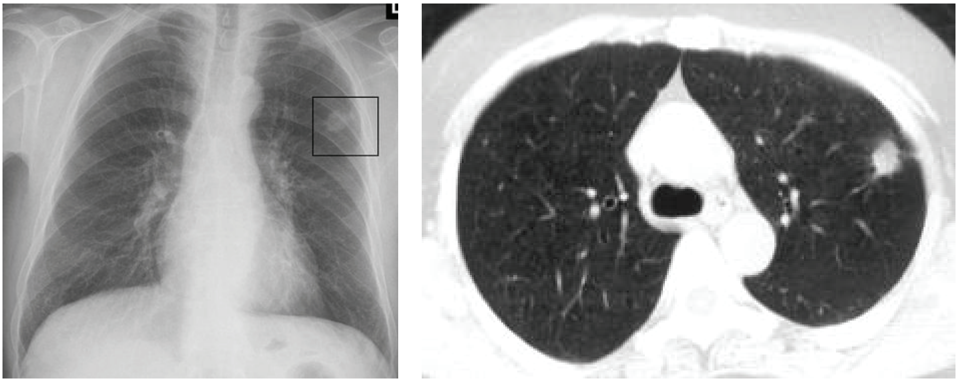


Fig. 1. Chest X ray and CT scan showing Lung Cancer in Left Lung.

4. General assessment

Prevention of postoperative complications requires a detailed medical history and examination. History should address the presence of dyspnoea, exercise tolerance, cough, and expectoration, wheezing, and smoking status. Examination should also focus on respiratory rate, pattern of breathing, wheezing, and body habitus.

4.1 Assessment of risks of the surgery

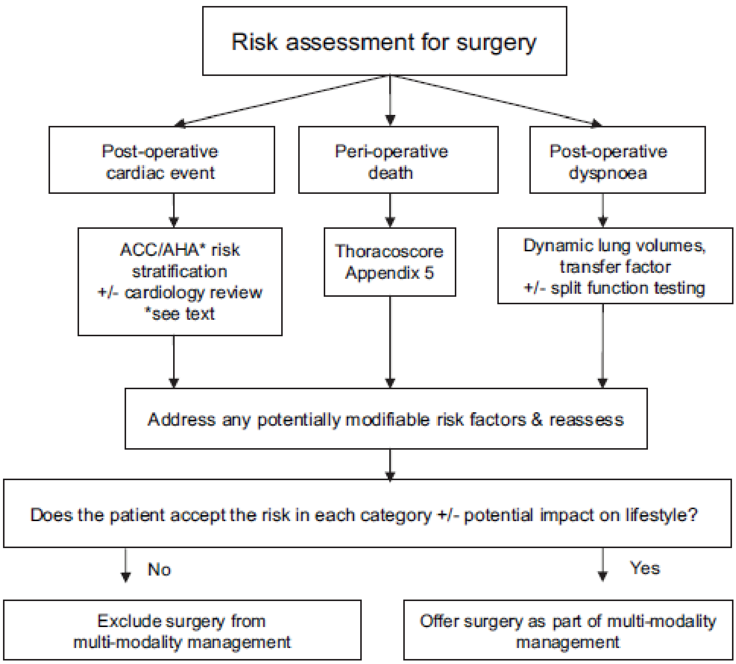


Fig. 2. Tripartite Risk Assessment.

Recent British Thoracic Society guidelines 2010 (BTS) presents a Tripartite risk assessment model that considers risk of operative mortality, risks of perioperative myocardial events and risk of postoperative dyspnoea.
This model facilitate the calculation and assessment of individual outcomes that may be discussed by the MDT and enables the patient to make truly informed decision.

4.2 Assessment of risks of the surgery

Estimating the risk of in-hospital death is one of the most important considerations for surgeons and patients when they evaluate the option of surgery for lung cancer.The 30 day mortality for lobectomy and pneumonectomy in England from National Lung Cancer Audit is 2.3% and 5.8% respectively.
Thoracoscore is currently the largest and most validated global risk score . It is a logistic regression derived model which is based on nine variables like Age, sex, ASA score, performance status, dyspnoea score, priority of suregry, extent of surgery, malignant diagnosis and a composite comorbidity score(11).

Thoracoscore

Variable	Value	Code	β-coefficient
Age	<55 years	0	
	55–65 years	1	0.7679
	>65 years	2	1.0073
Sex	Female	0	
	Male	1	0.4505
ASA score	≤2	0	
	≥ 3	1	0.6057
Performance status	≤2	0	
	≥3	1	0.689
Dyspnoea score	≤2	0	
	≥3	1	0.9075
Priority of surgery	Elective	0	
	Urgent or emergency	1	0.8443
Procedure class	Other	0	
	Pneumonectomy	1	1.2176
Diagnosis group	Benign	0	
	Malignant	1	1.2423
Comorbidity score	0	0	
	≤2	1	0.7447
	≥3	2	0.9065
Constant			−7.3737

Table 1.

Methods for using the logistic regression model to predict the risk of in-hospital death:

1. Odds are calculated with the patient values and the coefficients are determined from the regression equation:

$$\text{Odds} = \exp\,[\text{e}7.3737 + (0.7679 \text{ if code of age is 1 or } 1.0073 \text{ if code of age is 2})$$
$$+(0.4505\ 3 \text{ sex score}) + (0.6057\ 3 \text{ ASA score}) + (0.6890\ 3 \text{ performance status Classification})$$
$$+(0.9075\ 3 \text{ dyspnoea score}) + (0.8443\ 3 \text{ code for priority ofsurgery})$$
$$+(1.2176\ 3 \text{ procedure class}) + (1.2423\ 3 \text{ diagnosis group})$$
$$+(0.7447 \text{ ifcode of comorbidity is 1 or } 0.9065 \text{ if code of comorbidity is 2})].$$

2. The odds for the predicted probability of in-hospital death are calculated: probablity + odds/(1 + odds).

ASA, American Society of Anesthesiologists.

4.3 Age

All patients should have equal access to lung cancer services regardless of age(12). British Thoracic Society (BTS) guideline recommendations with regards to age are:

1. Perioperative morbidity increases with advancing age. The rate of respiratory complications (40%) is double that expected in a younger population and the rate of cardiac complications (40%), particularly arrhythmias, triples that which should be seen in younger patients(10)
2. Elderly patients undergoing lung resection are more likely to require intensive perioperative support. Preoperatively, a careful assessment of co-morbidity needs to be made. (13)
3. Surgery for clinically stage I and II disease can be as effective in patients over 70 years as in younger patients. Such patients should be considered for surgical treatment regardless of age. (13,14)
4. Age over 80 alone is not a contraindication to lobectomy or wedge resection for clinically stage I disease.
5. Pneumonectomy is associated with a higher mortality risk in the elderly. Age should be a factor in deciding suitability for pneumonectomy

4.4 Weight loss, performance status and nutrition

Weight loss>10%, a low BMI or serum albumin may indicate more advanced disease or an increased risk of postoperative complications.(16) The National VA Surgical Risk Study reported that a low serum albumin level was also the most important predictor of 30-day perioperative morbidity and mortality. Mortality increased steadily from less than 1.0% to 29% as albumin declined from values greater than 4.6 g/dl to values less than 2.1 g/dl.(17)

4.5 Cardiovascular assessment

Cardiac complications are the second most common cause of perioperative morbidity and mortality in the thoracic surgical population. As with any planned major operation, especially in a population that is predisposed to atherosclerotic cardiovascular disease due to cigarette smoking, a preoperative cardiovascular risk assessment should be performed.

The European Respiratory Society/European Society of Thoracic Surgery (ERS/ESTS) provides an algorithm based on a well validated score system, the revised cardiac risk index (RCRI), to estimate the patient's risk (18). The calculation of this index is simple, since it is based on the medical history, physical examination baseline ECG and plasma creatinine measurement.

Calculating the revised cardiac risk index (RCRI) based on history, physical examination, baseline ECG and serum Creatinine:

Each item is assigned 1 point.
• High Risk Surgery (including Pneumonectomy or Lobectomy) • History of Ischemic Heart disease (Prior MI or Angina pectoris) • History of Heart failure • Insulin dependent Diabetes • Previous Stroke or Transient ischemic attacks • Pre-operative Serum Creatinine 2 mg/dl.
If
• RCRI is ≥ 2 • The patient has any cardiac conditions requiring medications • The patient has a newly suspected cardiac condition • The patient is unable to climb 2 flight of stairs
A cardiological consultation is needed.

Table 2.

Algorithm for cardiac assessment before lung resection for lung cancer patients:

RCRI: Revised cardiac Risk Index; ECG: electrocardiogram;
AHA: American Heart Association; ACC: American College of Cardiology;
CABG: coronary artery bypass graft; PCI: primary coronary intervention;
TIA: transient ischaemic attack

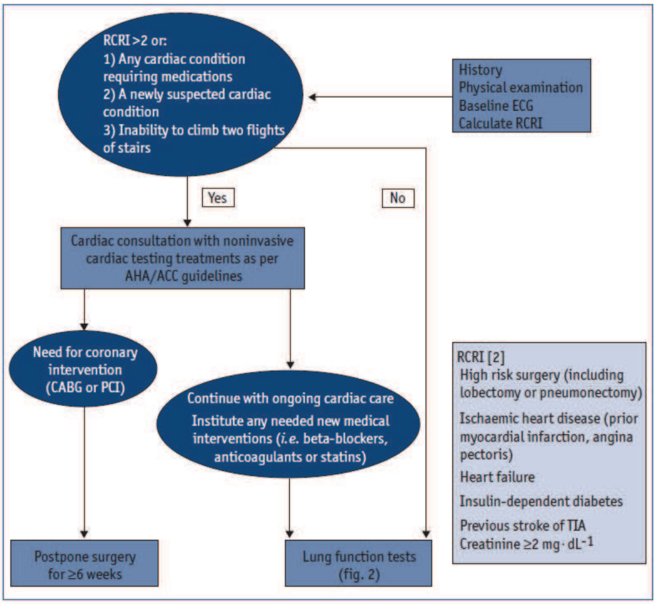


Fig. 3.

Adapted from ERS/ESTS clinical guidelines on fitness for radical therapy in lung cancer patients (14)

4.6 Arrhythmias

Dysrhythmias, particularly atrial fibrillation, are a frequent complication of pulmonary resection surgery (8,15). Factors known to correlate with an increased incidence of arrhythmia are the amount of lung tissue resected, age, intraoperative blood loss, and intrapericardial dissection (16). Prophylactic therapy with Digoxin has not been shown to prevent these arrhythmias. Diltiazem has been shown to be effective (22).

4.7 Smoking

Smoking cessation should be advised to all patients. Abstinence from smoking will decrease carboxyhemoglobin acutely but improvement in mucociliary function and small airway obstruction may take up to 10 weeks (21). Stein and Cassara established that 3 weeks of smoking cessation combined with perioperative incentive spirometry in a group of patients undergoing nonthoracic general surgery improved outcomes (23,24). Three weeks of smoking cessation should be considered standard for all non-emergent major surgical procedures.

4.8 COPD

COPD patients have 6 fold increased risk of post-operative pulmonary complications like atelectasis, pneumonia, exacerbation of COPD and Respiratory failure. Inhaled anesthetic depresses the respiratory drive in response to both hypoxia and hypercapnia even at sub-anaesthetic doses. Many COPD patients have an elevated Paco2 at rest. To identify these patients preoperatively, all moderate-to-severe COPD patients need arterial blood gas analysis. COPD patients desaturate more frequently and severely than normal patients during sleep (9).

As many as 50% of COPD patients will have RV dysfunction mostly due to chronic hypoxemia. The dysfunctional RV is poorly tolerant of sudden increases in afterload such as the change from spontaneous to controlled ventilation (9,15). Pneumonectomy candidates with a ppoFEV1 ≤40% should have transthoracic echocardiography to assess right heart function (23).

Overall medical condition of patients with COPD who are scheduled for surgery should be optimized. Patients with evidence of suboptimal reduction in symptoms, physical examination demonstrating airflow obstruction, or submaximal exercise tolerance warrant aggressive therapy.

Use of bronchodilators and glucocorticoid agents, and cessation of smoking, aggressive chest physiotherapy are paramount. Antibiotic therapy should be administered if there is evidence of pulmonary infection.

4.9 Renal dysfunction

Renal dysfunction after pulmonary resection surgery is associated with a very high incidence of mortality (19%) (25). History of previous renal dysfunction, concurrent diuretic therapy, Pneumonectomy surgery, postoperative infection, and blood transfusion are all associated with high risk for perioperative renal dysfunction. Fair evidence supports serum blood urea nitrogen levels of 7.5 mmol/L as a risk factor. However, the magnitude of the risk seems to be lower than that for low levels of serum albumin.

5. Specific assessment

5.1 Pulmonary function tests & lung resection

The best assessment of respiratory function comes from a history of the patient's quality of life (9). A unique consideration in patients considered for thoracotomy is the effect of pulmonary parenchymal resection on postoperative pulmonary function and exercise capacity. There is no single test that can reliably predict the patients' likelihood of tolerating thoracotomy and lung resection without excessive postoperative morbidity and mortality.

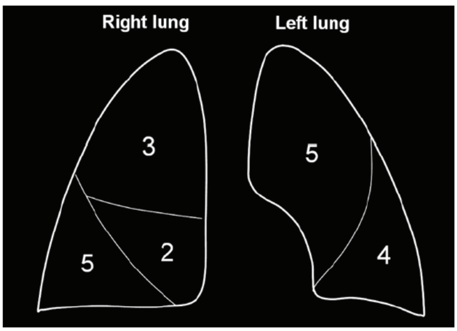
5.2 Current guidelines

Guidelines from the American College of Chest Physicians and the British Thoracic Society suggest that patients with a preoperative Forced Expiratory volume in 1 second (FEV1) in excess of 2 L (or >80 percent predicted) generally tolerate pneumonectomy, whereas those with a preoperative FEV1 greater than 1.5 L tolerate lobectomy (4,15) However, if there is either undue exertional dyspnea or coexistent interstitial lung disease, then measurement of Diffusing capacity(DLCO) should also be performed (2). Patients with preoperative results for FEV1 and DLCO that are both >80 percent predicted do not need further physiological testing.
Although pulmonary function that is better than the aforementioned threshold levels predicts a good surgical outcome, it has been difficult to identify a single absolute value of preoperative FEV1 below which the risk of surgical intervention should be considered prohibitive for all patients. Responsible factors for this lack of a single value include the following:

- Differences in the amount of lung tissue to be resected, as the extent of the planned resection will affect the choice of an acceptable preoperative FEV1.
- Differences in the severity of underlying lung disease and the contribution to total lung function of the portion of lung to be resected.
- Differences in size, age, gender, and race of patients undergoing lung resection.

Below these values further interpretation of the spirometry readings is needed and a value for the predicted postoperative (ppo-) FEV1 should be calculated. As the FEV1 decreases, the risk of respiratory and cardiac complications increases, mortality increases and patients are more likely to require postoperative ventilation.

5.3 Calculating the predicted postoperative FEV1(ppo FEV1) & TLCO (ppo TLCO)



Courtesy from Portch & McCormick.

Fig. 4.

Radiological imaging (usually a CT scan) identifies the area of the lung that requires resection. There are five lung lobes containing nineteen segments in total with the division of each lobe (shown in figure 2).
Knowledge of the number of segments of lung that will be lost by resection allows the surgeon and anaesthetist to estimate the post resection spirometry and TLCO values. These can then be used to estimate the risk to the patient of undergoing the procedure (22). Predicted postoperative function is calculated using preoperative values of FEV1 or DLCO and measurement of lobar or whole lung fractional contribution to function as determined by quantitative perfusion lung scanning, ventilation, or CT lung scanning.

$$\mathbf{ppo\ FEV1 = Preoperative\ FEV1 \times \frac{no.\ of\ segments\ left\ after\ resection}{18}}$$

The value obtained is then compared to the predicted value for FEV1 for that individual's height, age, and gender to obtain the percent predicted postoperative FEV1.

$$\mathbf{ppoDLCO = preoperative\ DLCO \times \left(1 - \%functional\ lung\ tissue\ removed\ /\ 100\right)}$$

Predicted post-operative DLCO is the single strongest predictor of complications and mortality after lung resection, although it is important to note that DLCO is NOT predictive of long term survival,only perioperative mortality (28). Interestingly, ppoDLCO and ppoFEV1 are poorly correlated, and thus should be assessed independently (29)
A patient is considered to be at increased risk for lung resection with predicted postoperative values for either FEV1 or DLCO <40 percent predicted. Nakahara et al. (10) found that patients with a ppoFEV1 ≥40% had no or minor post-resection respiratory complications. Major respiratory complications were only seen in the subgroup with ppoFEV1 ≤40% and patients with ppoFEV1 ≤30% required postoperative mechanical ventilatory support. The use of epidural analgesia has decreased the incidence of complications in the high-risk group
The European Respiratory Society and the European Society of Thoracic Surgery (ERS/ESTS) advise that the cutoff value for predicted postoperative FEV1 or DLCO may be lowered to 30 percent rather than 40 percent, due to improvements in surgical technique and the belief that removal of hyperinflated, poorly functioning lung tissue during surgery ameliorates the calculated loss in lung function through a "lung volume reduction effect" (15,16). However, evaluation with cardiopulmonary exercise testing (CPET) is needed prior to making a final decision on operability.

5.4 Exercise tests

5.4.1 Formal cardiopulmonary exercise tests

Exercise tests are thought to mimic the postoperative increase in oxygen consumption and have been used to select patients at high risk of cardiopulmonary complications after thoracic, but also abdominal surgery. The aim of exercise tests is to stress the whole cardiopulmonary system and estimate the physiological reserve that may be available after lung resection. The most used and best validated exercise parameter is V'O2, max. In the literature, V'O2, max appears to be a very strong predictor of postoperative complications, as well as a good predictor of long-term post-operative exercise capacity.
Patients with a preoperative V'O2, max of 15 to 20 mL/kg/min can undergo curative-intent lung cancer surgery with an acceptably low mortality rate. In several case series, patients with a V'O2, max of ≤ 10 mL/kg/min had a very high risk for postoperative death (3,16).

Interpreting the VO_2 Max	
20 ml/kg/min or > 15ml/kg/min and FEV1 >40% predicted	- No increased risk of complications or death.
<15ml/kg/min	- High Risk
<10ml/kg/min	- 40-50% mortality consider non surgical treatment

Table 3.

5.5 Low technology exercise tests

Formal CPET with VO2'max measurements may not be readily available in all centres. Therefore, low-technology tests have been used to evaluate fitness before lung resection, including the 6-min walk test (6MWT), the shuttle test and the stair climbing test.

5.5.1 6MWT

The 6MWT is the most used low-technology test, but the distance walked does not correlate with the VO_2, max in all (especially in fit) patients. Moreover, post-operative complications have been found to be associated with the distance walked in some but not all studies. As a result, the 6MWT is not recommended to select patients for lung resection (3,19).

5.5.2 Shuttle walk test

The shuttle walk test is the distance measured by walking a 10 m distance usually between two cones at a pace that is progressively increased. This test has good reproducibility and correlates well with formal cardiopulmonary exercising testing (VO2max) (44,45) Previous BTS recommendations that the inability to walk 25 shuttles classifies patients as high risk has not been reproduced by prospective study(46) Some authors report that shuttle walk distance may be useful to stratify low-risk groups (ability to walk >400 m) who would not need further formal cardiopulmonary exercise testing.(47)

5.5.3 Stair climbing test

Because calculation of VO2 max is expensive, stair climbing has been proposed as an alternative. It is commonly cited that the ability to climb five flights of stairs without stopping (20 x 6″ steps) is equivalent to a VO2 max of 15 mL/kg/min, and two flights correspond to 12 mL/kg/min.] However, the data are difficult to interpret as there is a lack of standardisation of the height of the stairs, the ceiling heights, different parameters used in the assessment (eg, oxygen saturations, extent of lung resection) and different outcomes.

5.6 Blood gas tension and oxygen saturation at rest

Recent studies have shown that hypercapnia in itself is not predictive of complications after resection, particularly if patients are able to exercise adequate(28) However, such patients are often precluded because of other adverse factors—for example, postoperative FEV1 and TLCO <40% predicted.
Ninan *et al* found that there was a higher risk of postoperative complications among patients who either had oxygen saturation (SaO2) on air at rest of <90% or desaturated by >4% from baseline during exercise (34).

6. Effects of lung cancer

Lung cancer patients should be assessed for “4Ms”.

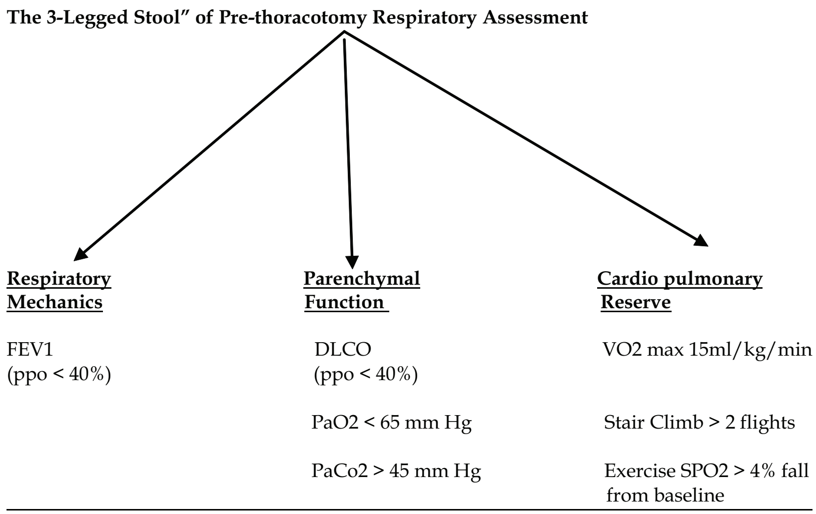
- Mass effects (SVC, Pancoast, obstructive pneumonia, laryngeal nerve paralysis, phrenic paresis)
- Metabolic effects (hypercalcemia, hyponatremia, Cushing’s, Lambert-Eaton)
- Metastases to brain, bone, liver& adrenal
- Medications (bleomycin [avoid high FiO2], cisplatin [avoid NSAIDs])

7. Effects of incisions

FEV1 and FVC are decreased by up to 65% on the first postoperative day after thoracotomy. Resolution of these changes takes up to 2 months. The effects can be mitigated somewhat through use of appropriate incisions.

8. Combination of tests

No single test of respiratory function has shown adequate validity as a sole preoperative assessment. Before surgery an estimate of respiratory function in all three areas: lung mechanics, parenchymal function, and cardiopulmonary interaction should be made for each patient (9).
Slinger et al has described “The 3-Legged Stool” of Pre-thoracotomy Respiratory assessment.



Courtesy of Slinger and Johnson

Fig. 5.

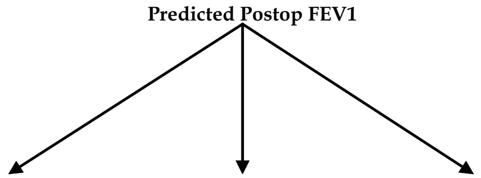
9. Methods of altering the perioperative risks

The following are the risk-reduction strategies which can be considered to reduce the risks in patients undergoing lung resection

- Cardiopulmonary rehabilitation
- Permit recovery from induction therapy
- Nutritional repletion
- Smoking cessation
- DVT and arrhythmia prophylaxis
- Perioperative pulmonary physiotherapy
- Changing extent of or approach to operation

Postoperatively, use of deep-breathing exercises or incentive spirometry, use of continuous positive airway pressure, use of epidural analgesia ,use of intercostals nerve blocks where applicable helps to reduce the postoperative pulmonary complications.

10. Post thoracotomy anaesthetic management based on predicted postop FEV1



>40 %	40-30%	30-20%
Extubate in OR	Extubate if other factors are favourable	Consider Extubation If all are favourable with Thoracic Epidural Analgesia
If Alert, warm Comfortable	Exercise Tolerance, DLCO V/Q Scan, Associated diseases	other patients: Staged wean of Ventilation.

Courtesy of Slinger and Johnson

Fig. 6.

11. Imaging studies

Assessment of patient anatomy is important in order to anticipate a difficult endotracheal, or endobronchial intubation. Any deviation of the trachea from the midline should alert the anaesthetists to a potentially difficult intubation or to the possibility of airway obstruction during induction of anaesthesia. In addition to the physical exam, Chest X-rays, CT scans, and bronchoscopy reports can all be of use. Important factors include tumour that impinges on the chest wall, traverses the fissures between lobes or is in close proximity to major vessels. In some cases, and where available, a PET scan (positron emission tomography) may be performed to further identify the anatomy of the tumour and to clarify whether nodal spread or metastasis has occurred (Figure2). As an anaesthetist it is important to view these scans in order to understand the planned surgery(27). For example:

- chest wall resection may be necessary,
- close proximity to the pleura with pleural resection may make paravertebral analgesia impossible,
- proximity to the pulmonary vessels or aorta makes major blood loss more likely.

12. Algorithm for preoperative evaluation of patients for lung resection

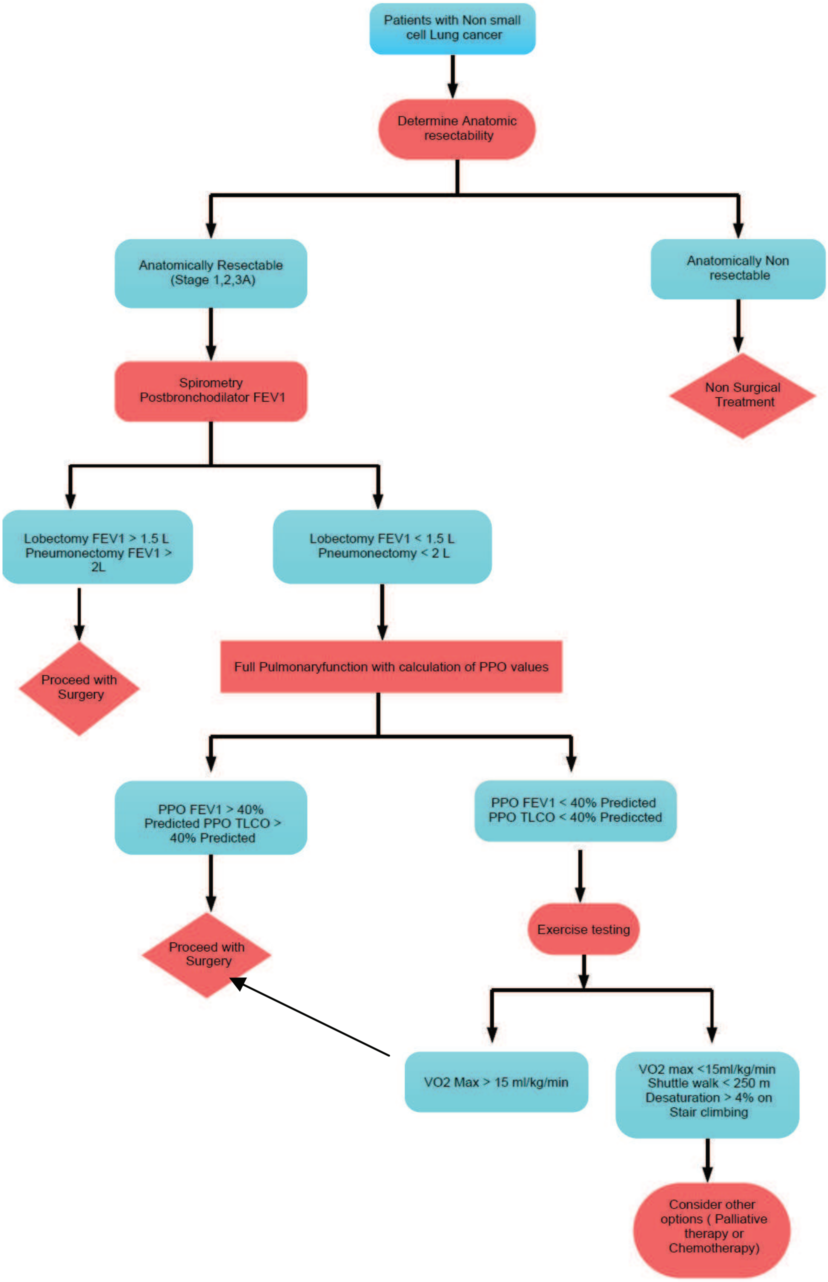


Fig. 7.

13. Summary

Surgical pulmonary resection and chemo radiotherapy both induce significant mortality and morbidity in lung cancer patients. A targeted preoperative assessment combined with multidisciplinary approach can help individualize the morbidity and mortality risk of surgery for each patient and provide the surgeon and patient with the information needed for operative decision making.

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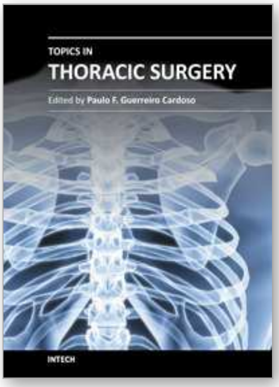

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