Preoperative assessment for pulmonary resection

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Abstract
Adequate preoperative assessment is important to stratify and therefore minimize the risk associated with pulmonary resection. It is a multidisciplinary process but should focus on selecting those with surgically resectable disease who will tolerate surgery with an acceptable risk. Anaesthetic assessment focuses on cardiovascular fitness and lung function, in particular evaluating the effects of resection on postoperative lung function. Predicted postoperative values of forced expiratory volume in 1 second (ppo FEV₁) and the diffusing capacity of the lung for carbon monoxide (ppo DLCO) can be estimated. These values are used to estimate risk of perioperative morbidity and mortality. Patients with ppo FEV₁ and ppo DLCO greater than 40% are deemed low risk. Patients with values less than these should undergo further cardiorespiratory evaluation to measure maximal oxygen consumption (V̇o₂max). Only those with ppo FEV₁ and ppo DLCO less than 40% and V̇o₂max less than 15 ml/kg/min should be considered too high a risk for conventional pulmonary resection. Risk assessment should always hold in context that surgery is the most effective treatment for early-stage lung cancer.

Keywords cardiopulmonary exercise test; early-stage lung cancer; postoperative lung function; pulmonary resection

Careful preoperative evaluation to select patients suitable for thoracic surgery is vital as surgery may carry significant risk (e.g. mortality for pneumonectomy is 5–9% and for lobectomy is 1–3%). Risk assessment must place in context that surgery for early-stage lung cancer is the most effective treatment for this disease. Patients should be denied surgery only if the risks are prohibitive. Assessment should be undertaken by a multidisciplinary team selecting those with surgically resectable disease who will tolerate surgery with an acceptable risk. Factors taken into account include the effect of surgery on postoperative lung function, comorbidity, performance status, nutrition and age. The anaesthetist’s role is to evaluate risk for perioperative complications and long-term disability (e.g. ventilator dependence) and allow planning of anaesthetic technique and postoperative care. This is done by physiological testing focusing on cardiovascular fitness and lung function, in particular evaluating the effects of resection on postoperative lung function. The following summarizes the guidelines produced on this subject by the American College of Chest Physicians and the British Thoracic Society (Figure 1).

Respiratory assessment
No single test has sufficient sensitivity and specificity to predict outcome for all patients undergoing lung resection. Slinger et al summarized the assessment of respiratory function in three related but independent areas: respiratory mechanics, parenchymal function and cardiopulmonary interaction (Figure 2).

Using this system, transport of oxygen to the lungs correlates with respiratory mechanics; transport into the blood with parenchymal function; and transport to the tissues with cardiopulmonary interaction.

Respiratory mechanics
Basic spirometry to measure post-bronchodilator forced expiratory volume in 1 second (FEV₁) and forced vital capacity (FVC) should be performed on all patients. Threshold preoperative FEV₁ values of greater than 1.5 litres for lobectomy and 2 litres for pneumonectomy have historically been used to indicate suitability for lung resection. However, absolute values may negatively bias certain patients (e.g. women and the elderly); therefore, using percentage predicted values based on tables of normal values is preferred. In patients with an FEV₁ less than 80% of the predicted value, formal lung function tests should be performed and the diffusing capacity of the lung for carbon monoxide (DLCO) should be measured to assess parenchymal function. Postoperative pulmonary reserve should then be estimated by predicting postoperative values of FEV₁ and DLCO (ppo FEV₁ and ppo DLCO). This is done by estimating the amount of functioning lung tissue that would be lost with surgical resection. Methods used to do this include anatomic estimation, ventilation–perfusion (V/Q) scans, and quantitative computerized tomography (CT) scans. Anatomic estimation strongly correlates with actual postoperative values after lobectomy and perfusion estimation (from V/Q scan) correlates well with actual values after pneumonectomy (Figure 3).

Parenchymal function
If diffuse parenchymal lung disease is present on radiographic studies, the DLCO should be measured. In patients with a DLCO less than 80% of the predicted value, ppo DLCO should be estimated: ppo DLCO is calculated using the same formula as ppo FEV₁.

Resting peripheral oxygen saturation (S₉O₂) in air should be measured in all patients. Preoperative arterial blood gas analysis is not usually indicated in the fittest patients but must be performed if spirometry values are below threshold.
values, if there is evidence of interstitial disease or if the patient experiences dyspnoea. Preoperative hypoxaemia ($S_dO_2/S_pO_2$ less than 90%) is associated with an increased risk of complications but hypercapnia, although associated with poor lung function, is not an independent risk factor for increased perioperative complications.

Cardiopulmonary interaction

A cardiopulmonary exercise test is used to measure maximal oxygen consumption ($V_{O2max}$). A $V_{O2max}$ value of less than 15 ml/kg/min confers high risk. Other tests of cardiopulmonary reserve include the 6 minute walk and the shuttle walk test. Exercise oximetry can be simultaneously carried out during these tests,

The 'three-legged stool' of prethoracotomy respiratory assessment

Respiratory mechanics
- Predictive postoperative FEV$_1$ > 40%
- Maximal voluntary ventilation, forced vital capacity
- Residual volume/total lung capacity

Cardiopulmonary reserve
- VO$_2$max > 15 ml/kg/min
- Stair climb > 2 flights 6 min walk
- Exercise $Sp_{O2}$ (pulse oximetry) fails < 4%

Parenchymal function
- Predictive postoperative diffusing capacity of the lung for carbon monoxide > 40%
- $PaO_2$ > 8.3 kPa
- $PaCO_2$ < 6.3 kPa

*Represents most valid test. The most valid tests and the results above represent the threshold below which patients are at increased risk. Slinger et al.*
Calculation of predicted postoperative FEV₁ (ppoFEV₁)

**Anatomic method (with the knowledge that the lungs contain 19 segments)**

\[
\text{ppoFEV₁} = \text{preoperative FEV₁} \times \frac{(19 - \text{segments to be removed})}{19}
\]

**Segments – right:** upper lobe, 3; middle lobe, 2; lower lobe, 5

**left:** upper lobe, 3; lingula, 2; lower lobe, 4

**Perfusion method**

\[
\text{ppoFEV₁} = \frac{\text{preoperative FEV₁} \times (1 - \text{fraction of total perfusion of resected lung})}{1}
\]

**Figure 3**

and a desaturation of greater than 4% has been associated with increased perioperative cardiopulmonary risk. Stair climbing has traditionally been used as a surrogate for estimating cardiopulmonary reserve with those who are able to climb five flights of stairs having a \( V_{O2\text{max}} \) greater than 20 ml/kg/min and those unable to climb one flight of stairs having a \( V_{O2\text{max}} \) less than 10 ml/kg/min.

**Cardiovascular assessment**

The guidelines from the American College of Cardiology/American Heart Association on perioperative cardiovascular evaluation for non-cardiac surgery should be used as the basis for assessment. Cardiac risk should be stratified by history, examination and basic investigations so that high-risk patients can be identified and evaluated further. Risk assessment is essentially based on clinical predictors, exercise tolerance and type of surgery planned (Figure 4).

All patients should have an ECG. Patients with a cardiac murmur should undergo at least transthoracic echocardiography. It is recommended that patients who have had a myocardial infarction in the last 6 months should have a cardiology opinion. Those who have had a recent myocardial infarction should wait at least 6 weeks before surgery for lung resection. However, coronary revascularization is indicated only in those likely to benefit from coronary revascularization independent of non-cardiac surgery. Patients with severe valvular heart disease are at increased risk of peri-operative events, and valve surgery should be undertaken before thoracic surgery if indicated on standard cardiological grounds.

**Predictors and further assessment of cardiac risk factors**

<table>
<thead>
<tr>
<th>Minor risk</th>
<th>Intermediate risk</th>
<th>Major risk</th>
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<tbody>
<tr>
<td>Age over 80 years</td>
<td>Mild angina</td>
<td>Unstable coronary syndrome</td>
</tr>
<tr>
<td>ECG: right bundle branch block, left ventricular hypertrophy</td>
<td>Previous myocardial infarction</td>
<td>Recent myocardial infarction (1/12)</td>
</tr>
<tr>
<td>Non-sinus rhythm</td>
<td>Compensated congestive heart failure</td>
<td>Decompensated congestive heart failure</td>
</tr>
<tr>
<td>Poor effort tolerance (&lt; two flights stairs)</td>
<td>Diabetes</td>
<td>Significant arrhythmia: high-grade atrioventricular block or any ventricular arrhythmia</td>
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<tr>
<td>Previous cardiovascular accident</td>
<td></td>
<td>Severe valvular disease</td>
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<td>Uncontrolled hypertension</td>
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</tbody>
</table>

**Figure 4**


If cardiac surgery is undertaken, it is usual to delay thoracic surgery for 4–6 weeks. The optimum timing of surgery after percutaneous coronary intervention is a very complicated issue related to the use of clopidogrel as anti-platelet therapy. It is usual to delay surgery at least 4 weeks if bare metal stents are deployed, after which time clopidogrel may be stopped (though aspirin continued) to allow surgery. Current clinical practice with drug-eluting stents entails clopidogrel therapy without cessation for at least a year; thus, the need for thoracic surgery may affect the choice of stent deployed or even the choice of percutaneous intervention versus coronary revascularization surgery. More guidance on this difficult issue may be forthcoming in the next UK guidelines on operability for pulmonary resection (see below).

Suitability for surgery

Historically, a threshold postoperative value FEV₁ of less than 0.8 litres was considered to leave patients at high risk of ventilator dependency and therefore not suitable for surgery. However, absolute values may negatively bias certain patients.

If the %ppo FEV₁ and the %ppo DLCO are greater than 40%, this represents average risk and surgery should proceed. A %ppo FEV₁ and %ppo DLCO less than 40% should be used to identify those at high risk. These high-risk patients should undergo cardiopulmonary exercise testing (CPET) to further evaluate cardiopulmonary reserve. Indications for CPET are described in Figure 1. Those patients with a $V_{O2}\text{max}$ less than 15 ml/kg/min and %ppo FEV₁ and DLCO less than 40% should be counselled about non-standard surgery and non-operative treatments for their lung cancer.

The British Thoracic Society and the Society of Cardiothoracic Surgeons of Great Britain and Ireland have convened a working party to re-examine the Guidelines on the selection of patients with lung cancer for surgery. It is likely that this report will be published in late 2008, more than 2 years before this topic will be re-visited in Anaesthesia and Intensive Care Medicine. The report will be accessible to interested readers at www.brit-thoracic.org.uk and www.scts.org.

REFERENCES