Decision making

Summary

Central to risk assessment for lung resection is the fact that surgery offers the only chance of long-term survival and cure in non-small carcinoma of the lung. The challenge is, therefore, to offer surgery to as many patients as possible, whilst avoiding the risk of death from postoperative respiratory failure. Risk assessment is based on careful evaluation of the patient's existing cardiac and respiratory disease. The use of a cardiac risk index, such as that described by Detsky, will ensure that cardiac risk factors are recognised and, where possible, ameliorated prior to surgery. Pre-existing respiratory disease may be assessed by arterial blood gas analysis, exercise testing, whole and regional lung function tests. Criteria based on these tests have been proposed to aid patient selection prior to lung resection. However, these criteria take no account of the beneficial influence on outcome of modern anaesthesia and postoperative care. The elimination of postoperative pain, along with techniques such as minitracheostomy and incentive spirometry have allowed surgery to be offered to many patients who would have been deemed unsuitable by standard criteria. Patients with potentially resectable lung cancer must never be arbitrarily excluded from surgery on the basis of any single criteria or test. Referral for assessment by an experienced team consisting of a thoracic physician, surgeon and anaesthetist will maximise the number of patients offered surgery for this otherwise incurable disease.

Keywords: lung cancer, thoracotomy, pre-operative assessment

Department of Anaesthesia, The
Cardiothoracic Centre, Liverpool
L14 3PE, UK
GN Russell

University Department of Anaesthesia,
Royal Liverpool University Hospital,
Liverpool, UK
SD Thomas
PD Berry

Correspondence to Dr GN Russell

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Is this patient fit for thoracotomy and resection of lung tissue?

Stephen D Thomas, Peter D Berry, Glenn N Russell

Introduction

This article will focus on risk assessment in the patient requiring lung resection for carcinoma. At least in non-small carcinoma, surgical intervention is the only therapeutic method that offers a chance of long-term survival, a fact that is central to any discussion of risk in this group of patients. The first step must therefore be in deciding the operability of the tumour. By a range of clinical, radiographic and invasive tests, staging should be possible with 75–80% accuracy.¹ Whilst the final selection of procedure will take place at the time of operation, it is useful to have some idea of the probable extent of surgery prior to risk assessment. The challenge in assessing patients for lung resection is to offer surgery to as many potentially curable patients as possible, whilst avoiding the misery of death by postoperative respiratory or cardiac failure.

Having decided that the patient is a surgical candidate, and with some idea of the proposed extent of resection, there are two remaining questions (box 1).

Evaluation of cardiac risk prior to lung resection

There have been a number of studies demonstrating risk factors for adverse cardiac outcome – usually defined as cardiac death, non-fatal myocardial infarction and pulmonary oedema – following surgery. Goldman² undertook a prospective study of 1001 patients over the age of 40 having non-cardiac surgery and was able to establish nine independent correlates of adverse cardiac outcome. The most important of these are shown in box 2.

Whilst it has generally stood the test of time, there have been two main criticisms of the Goldman index. Firstly, there may clearly be significantly different outcomes for the same operation performed in different institutions. This 'institutional' influence is a result of factors such as available surgical, nursing and anaesthetic skills. These factors are of prime importance when assessing risk to an individual patient. Secondly, in the Goldman study there were insufficient patients with severe class 3 or 4 angina to demonstrate a correlation with adverse cardiac outcome.

In order to address these specific deficiencies, Detsky³ modified the Goldman index. Before consideration of an individual patient's cardiac risk, the average risk of peri-operative cardiac complications in the institution planning the procedure is determined. This baseline institutional or *pre-test* risk will be a function of the patient population and how they are managed. An individual patient is then scored according to the presence of risk factors highlighted in the modified multifactorial index (box 3). A normogram (figure 2) is then used to demonstrate the individual patient's *post-test risk* – a combination of the institutional risk modified by the presence of additional cardiac risk factors.

The Detsky index also addressed the influence of angina as a risk factor. Whilst it is generally recognised that the presence of Canadian class 1 or 2 angina adds only a relatively small risk to the procedure, class 3 to 4 and unstable angina are associated with high risk and scored appropriately in the index (box 3). The presence of pre-operative cardiac failure has a high risk ranking in both the Goldman and Detsky indices. This has particular relevance to pulmonary resection. Recent evidence⁴ suggests that right ventricular ejection fraction is depressed for at least three weeks following lung resection, probably as a result of increased afterload. The imposition of these postoperative changes on the patient with pre-existing right ventricular dysfunction may be catastrophic.

It should be noted that although both Detsky and Goldman assign some additional risk to thoracic surgical procedures, there have been no studies dealing specifically with the patient having lung resection.

Decision making: thoracotomy

- is the patient at risk from pre-existing cardiac disease?
- is the patient at risk due to pre-existing respiratory disease?
- If either of these is true
- can the risk be reduced by pre-operative preparation?

Box 1

Figure 1 Chest X-ray showing bronchial carcinoma in the right lung

Goldman risk index

	<i>points</i>
• S3 gallop or jugular venous distension	11
• myocardial infarction in previous 6 months	10
• suspected critical aortic stenosis	3
• arrhythmias:	5
– > 5 premature ventricular contractions/min at any time prior to surgery	
– any rhythm other than sinus rhythm	

Box 2

Detsky risk index

	<i>points</i>
• Canadian Cardiovascular Society classification of angina*	
Class 3	10
Class 4	20
• unstable angina	10
• myocardial infarction in previous 6 months	10
• suspected critical aortic stenosis	20
• alveolar pulmonary oedema within 1 week	10
• arrhythmias:	5
– > 5 premature ventricular contractions/min at any time prior to surgery	
– any rhythm other than sinus rhythm	

*Class 3: angina on climbing stairs at normal pace

Class 4: angina on slightest physical activity
Unstable angina: increasing frequency and severity

Box 3

Can the cardiac risk be reduced?

Perhaps the major importance of these risk indices is not their arguable ability to predict specific outcome for an individual, but to highlight those features that must be sought and modified in the patient's preoperative assessment. Atypical chest pain should be assessed by exercise testing. Intravenous dipyridamole thallium imaging is useful in defining myocardial perfusion defects in patients unable to perform exercise treadmill tests.⁵ Patients with obvious class 3 or 4 angina or unstable angina require further assessment, usually incorporating coronary angiography. Angioplasty or coronary artery surgery may then be considered if appropriate. Thus, many of the risk factors common to both indices can be modified so as to reduce the risk of adverse cardiac outcome significantly.

Evaluation of risk with pre-existing respiratory disease

A number of investigations have been advocated to predict postoperative morbidity and mortality following lung resection (box 4).

EXERCISE TESTING

The 'flight of stairs' test is considered by many to be useful in assessing a patient for pneumonectomy. Elaborating on this concept, there have been a number of investigations into the role of preoperative exercise testing and outcome following pulmonary resection.^{6,7} The rationale of these tests is that exercise demands integrated cardiac, pulmonary, and cellular function. Several of these studies have suggested a correlation between poor exercise tolerance, as tested by incremental increases in exercise on a cycle ergometer, and adverse outcome following pulmonary resection. Other investigators have advised caution in disqualifying patients from surgery on the results of such tests as it can be difficult to exercise elderly patients with cardiopulmonary disease adequately. The approach of sub-maximal exercise testing described by Olsen *et al*⁸ may be more appropriate in such patients.

A recent review by Fishman *et al*⁹ reinforces the point that no clear consensus as to the value of exercise testing has yet emerged, but undoubtedly it is an area that warrants further study.

ARTERIAL BLOOD GAS ANALYSIS

Arterial blood gas estimation on breathing room air has been advocated as a screening test for pulmonary resection. However, the arterial PO₂ is generally a poor predictor of postoperative outcome. In some patients, the lung zone to be surgically removed may have little ventilation but persistent perfusion, thereby acting as a functional right to left intrapulmonary shunt. Resection of such an area may improve the postoperative PO₂, as has been reported following pneumonectomy.¹⁰ A PaCO₂ greater than 45 mmHg may be associated with an adverse outcome, but does not represent an absolute contraindication to surgery. In some patients, hypercapnoea may be due to a pulmonary infection and may be reversible if the infection is treated. Any reversible components of airway obstruction must be sought.¹¹ Patients with hypercapnoea are often those with the poorest pulmonary function tests¹² and so the investigation has low sensitivity and adds little information that cannot be gained non-invasively.

WHOLE LUNG FUNCTION TESTS

A large number of studies over the last three decades have attempted to predict outcome following lung resection based on pre-operative whole lung function tests. These studies have a number of defects (box 5), particularly when applied to an individual patient:

- Many of the studies describe a relatively small number of patients. With small samples, institutional factors such as patient population and quality of surgical and anaesthetic skills may be particularly important. The results from one institution may not readily be transferable to another.
- In many studies, arbitrary lung function limits are set, and the outcome of patients who meet these criteria is described. No mention is made of the number of otherwise curable patients who are excluded from surgery by the application of the criteria. This is particularly pertinent to lung cancer, where the only real chance of cure is surgery.
- Few papers describe the specific techniques used in the postoperative management of the patients. As described later, these may have a marked influence on outcome.

The whole lung function tests most frequently advocated are the maximum voluntary ventilation and the forced expiratory volume in one second (FEV₁). The table shows the values associated with minimal postoperative morbidity and

Figure 2 Detsky risk normogram. The 'pre-test risk' is initially assessed. The cardiac risk factors are then summated. A straight line is drawn through the pre-test value and the risk factor score, giving the 'post-test' probability of cardiac complications for an individual patient

Pre-operative assessment of lung function

- exercise testing
- arterial blood gas analysis
- whole lung function testing
- regional lung function testing

Box 4

Whole lung function criteria for pulmonary resection

- may exclude many otherwise curable patients
- fail to incorporate the influence of modern anaesthesia and postoperative care

Box 5

Table Suggested whole lung pulmonary function criteria for lung resection

Pulmonary function test	Normal	Pneumonectomy	Lobectomy	Wedge or segment	Inoperable
Maximum voluntary ventilation (% of predicted)	>80	>55	>40	>35	<35
FEV ₁ (l)	>2	>2	>1	>0.6	<0.6
(% of predicted)	100	>55	40–50	>40	<40

mortality as described by Miller *et al.*¹³ Whilst this study has many of the defects described above, it does have a sample size of 2340 patients covering an 18-year audit period.

The maximum voluntary ventilation has been advocated as the best screening test prior to pulmonary surgery by a number of authors.^{14–16} The unique value of this test may lie in its dependence on the intangible variables of patient co-operation, motivation, and stamina. Values of FEV₁ and FVC are variously presented as either absolute volumes, or as a percentage of the values predicted from a normogram based on height and age. Absolute volumes generally refer to the 'average' adult, and the use of the 'per cent of predicted' volumes probably has better prognostic value at extremes of patient age and size.¹⁷

In an attempt to improve on the sensitivity of whole lung function tests, particularly for pneumonectomy, regional lung function tests have been advocated.

REGIONAL LUNG FUNCTION TESTS

Multiplication of whole lung function by the percentage of lung to be removed, as determined by radioactive scanning radiospirrometry, has been used to predict postoperative pulmonary function.¹⁸ A postoperative FEV₁ of 0.8 l or more has been associated with an acceptable outcome and this may be a useful adjunct in patients who fail to meet the criteria as described in the table. It should be noted that there is no universal agreement on the ability to predict accurately post resection pulmonary function. In a prospective study of high-risk patients having lung resection for carcinoma, Murphy *et al.*¹⁸ noted that patients with the poorest pre-operative pulmonary function often had the least change post-operatively, and this is demonstrated by our case history (box 6). In some cases, they even showed improvement in pulmonary function. This is the group which, if existing guidelines are followed, are most likely to be denied surgery.

It should be clear from the above that no patients should be excluded from surgery on the basis of a single lung function test. The value of published criteria such as those set by Miller *et al.*¹³ is that they do not represent absolute exclusion criteria, but targets that should be considered during pre-operative pulmonary preparation of the patient.

Can the risk associated with pre-existing disease be reduced?

SMOKING

The chronic pulmonary changes associated with smoking are well described and continued smoking up to the time of the procedure is associated with significant mortality.¹⁹ For maximum risk reduction, the patient should stop smoking at least two months prior to surgery.²⁰ However, some improvement in respiratory symptoms and function may be seen within one month of cessation, and even a short abstinence may see an improvement in mucociliary clearance in the critical peri-operative period.²¹

PRE-OPERATIVE PULMONARY PREPARATION

It is well recognised that pre-operative pulmonary preparation, incorporating the use of physiotherapy, bronchodilators, and antibiotic therapy can dramatically reduce the risk of postoperative infection.²²

In addition to this regime, there is increasing awareness of the influence of modern anaesthetic techniques in reducing the immediate postoperative risk posed by pre-existing respiratory disease. This area has been the subject of much research over recent years, particularly with greater understanding of the physiological changes associated with thoracotomy and the advent of effective management of postoperative pain.

MODERN ANAESTHETIC TECHNIQUES

There are two main physiological consequences of thoracotomy (box 7). Firstly, operations on the chest wall produce clinically significant alterations in

Case history

- female aged 77 years
- carcinoma involving left upper lobe
- pre-operative findings:
no symptoms of cardiovascular disease
spirometry following ventolin nebuliser
FVC 1.44 l (51% of predicted)
FEV₁ 0.92 l (43% of predicted)
- operation:
lymphadenopathy precluded lobectomy
left pneumonectomy performed
- postoperative management:
thoracic epidural opioid/local anaesthetic infusion
mini-tracheostomy for secretions
incentive spirometry
3 days stay in high dependency unit
spirometry 10 days following surgery
FVC 1.28 l (45% of predicted)
FEV₁ 0.88 l (41% of predicted)

Box 6**Pain following thoracotomy is associated with:**

- changes in pulmonary mechanics promoting atelectasis
- chest wall splinting and the inability to cough

Box 7**Summary points**

- in non-small cell carcinomas of the lung, surgery offers the only chance of long-term survival or cure
- no patient with lung cancer should be excluded from surgery on the basis of a single lung function test
- modern anaesthesia and postoperative care may allow pulmonary resection in some patients who do not meet standard lung function criteria
- patients with potentially resectable lung cancer should be assessed by an experienced team (surgeon, physician and anaesthetist)

Box 8

- 1 Miller JL, Mansour KA, Hatcher CR. Carcinoma of the lung: five year experience in a university hospital. *Am J Surg* 1980; **46**: 147–53.
- 2 Goldman L, Caldern DL, Nussbaum S. Multifactorial index of cardiac risk in non-cardiac surgical procedures. *N Engl J Med* 1977; **297**: 845–50.
- 3 Detsky AS, Abrams HB, Forbath N, Scott JG, Hillard JR. Cardiac assessment for patients undergoing noncardiac surgery. *Arch Intern Med* 1986; **146**: 2131–4.

ventilatory mechanics and pulmonary gas exchange that start following induction of anaesthesia and persist well into the postoperative period. The functional residual capacity falls by about 18%, and with little change in the closing volume, atelectasis in the dependent segments is inevitable.²³ The aetiology of these changes in pulmonary mechanics remain the subject of investigation, although changes in chest wall elastic recoil and loss of tonic activity in the diaphragm are certainly implicated.

Secondly, severe postoperative pain may cause chest wall splinting.²⁴ An understandable unwillingness to inspire deeply will greatly reduce the patient's ability to cough. The previously described physiological changes promoting atelectasis, combined with the inability to clear secretions, are synergistic factors promoting postoperative infection.

There are now a number of techniques available to manage postoperative pain. Epidural analgesia, particularly with mixtures of opioids and local anaesthetics, can dramatically reduce postoperative pain.²⁵ Similar results have been reported with continuous paravertebral analgesia.²⁶ The extent to which these pain management techniques reverse the specific changes in pulmonary mechanics promoting atelectasis has been the subject of debate. There is some evidence that epidural analgesia may reverse postoperative diaphragmatic dysfunction, perhaps by reducing reflex inhibition of the diaphragm due to chest wall efferent activity.²⁷ More importantly, the abolition of postoperative pain will allow effective clearing of secretions and permit the use of physiotherapy techniques which in themselves are designed to reduce postoperative atelectasis. It is not surprising that these techniques have been reported to improve outcome following surgery, particularly in high risk patients.²⁸

In parallel with the development of techniques to manage postoperative pain has been the development of well equipped high dependency units with a high nurse-to-patient ratios. These units greatly facilitate the management of the high-risk patient, with the availability of proven techniques such as a mini-tracheostomy and high frequency jet ventilation.

As described earlier, the additional benefit of this sophisticated approach to postoperative care is not generally considered in the studies of pulmonary function criteria for lung resection. It has been our experience, and this is demonstrated by the not unusual case history presented in box 6, that the application of these techniques may permit pulmonary resection in selected patients who do not meet the criteria in the table.

Conclusions

Is this patient fit for thoracotomy and resection of lung tissue? Risk is inherently a relative term. Of fundamental importance is the realisation that surgery offers the only real possibility of cure in non-small cell carcinoma of the lung. This dilemma is summarised by the pertinent question posed by Glass and Olsen,²⁹ 'What is an acceptable surgical mortality in a disease with 100% mortality?'.

THE TEAM APPROACH

Faced with this scenario, pre-operative assessment prior to lung resection calls on the entire resources of the surgeon, physician and anaesthetist.

The *surgeon* must make every effort to assess accurately the operability of the tumour and define the probable extent of resection that will be required.

The *physician* must recognise and make every effort to modify the cardiac and respiratory risk factors highlighted in this article. Good pre-operative preparation is the cornerstone of risk reduction prior to lung resection.

The *anaesthetist* must ensure that he or she is fully conversant with the modern anaesthetic techniques that are pivotal to the successful management of the high-risk patient.

An additional value to the patient of this tripartite approach is the awareness within the team of the strengths and weakness of individual members.³⁰ Patients with potentially curable lung cancer must never be arbitrarily excluded from lung resection on the basis of any single criteria, and should always be offered the benefit of a team approach to pre-operative assessment.

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Medical Anniversary

THOMAS CECIL HUNT, 5 JUNE 1901

Thomas Cecil Hunt (1901-1980) was born at Guildford, Surrey, UK, and educated at St Paul's, Magdalen, Oxford, and St Mary's, graduating in medicine in 1926. He became senior physician at St Mary's and President in turn of the British Society of Gastroenterology and Medical Society of London. He died in London on 22 December 1980.