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REVIEW ARTICLE

Preoperative pulmonary evaluation in patients scheduled for lung operations

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Summary

Preoperative pulmonary evaluation is essential in order to identify patients at risk for postoperative pulmonary complications (PPCs). Procedure and patient related risk factors should be assessed and modified if possible in order to reduce the incidence of PPCs. The extent of preoperative pulmonary evaluation testing required depends on whether the operation to be performed is thoracic or non-thoracic, in addition with patients' coexisting diseases and risk factors. Lung cancer resection surgery also requires extended preoperative evaluation, which is guided by functional pulmonary testing, including spirometry, diffusing capacity of the lung to carbon monoxide (DLCO) measurement, split function testing, exercise testing and arterial blood gas analysis according to published guidelines. Strategies to reduce the risk of PPCs should always be applied in patients at risk, beginning preoperatively and continuing during intraoperative and postoperative period.

Key words: complications, lung cancer, lung surgery, preoperative evaluation, pulmonary function testing

Introduction

Adequate preoperative pulmonary evaluation of patients undergoing thoracic or non-thoracic operations is essential in order to reduce the incidence of postoperative pulmonary complications. PPCs are among the most common causes of morbidity and mortality in patients undergoing major surgery. The occurrence of PPCs and their contribution to morbidity and mortality correlates with pathophysiologic changes occurring perioperatively. The first step in the preoperative management is to identify patients at risk, and the second is to examine the degree of reversibility of these factors and plan a modification strategy [1-3].

The exact definition of pulmonary complications varies, but most recent studies generally include complications which prolong hospital stay, or significantly contribute to morbidity and mortality [4]. The most important PPCs which occur after thoracic or non-thoracic surgery include pneumonia, respiratory failure and prolonged mechanical ventilation, bronchospasm, atelectasis, and exacerbation of underlying chronic lung disease (Table 1) [3-5].

Causes and pathophysiology of postoperative pulmonary complications

Breathing is a complex function requiring coordination of multiple groups of respiratory muscles in the chest wall and upper airway tract. Most PPCs occur as a result of respiratory muscle dysfunction, which begins with induction of anaesthesia and continues throughout the whole postoperative period. It is well established that anaesthetic agents interfere with central regulation of breathing by altering neural drive to respiratory muscles, mainly the diaphragm. When used in high doses, anaesthetics attenuate the activity of all respiratory muscles, but in moderate doses they cause a coordination of distribution and timing of neural drive in various muscle groups [6,7].

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Table 1. Postoperative pulmonary complications

Respiratory failure	Pulmonary edema
Pneumonia	ALI/ARDS
Atelectasis	Pneumothorax
Bronchospasm	Infiltrates
Exacerbation of chronic lung disease	Fever
Increased length of stay (ICU, HDU)	Aspiration
Postopneumonectomy syndrome	Pulmonary embolism

ICU: intensive care unit, HDU: high dependency unit, ALI/ARDS: acute lung injury/acute respiratory distress syndrome

Induction of anaesthesia reduces the Functional Residual Capacity (FRC) by an additional 15-20% beyond the level which occurs in supine position alone, due to loss of end expiratory diaphragm tone. The reduction of FRC caused by anaesthetic agents is not related to anaesthetic depth, and may persist for several hours following anaesthesia [8]. The decrease in lung volume is more profound in dependent lung regions during long operations, causing atelectasis which persists for more than 24 hours in 50% of the patients [9]. In addition, reflex stimulation of the upper airway during laryngoscopy and instrumentation can cause bronchoconstriction. This rise in airway resistance limits the expiratory flow through the lung, and increases the risk of overinflation and abnormal gas exchange. Furthermore, recent studies suggest that prolonged anaesthesia can impair the function of inflammatory lung cells, increasing the risk for developing PPCs [6]. Another important factor in the pathophysiology of pulmonary complications is the closing volume, which under normal circumstances is about 30% of the total lung capacity. In parallel with FRC reduction, closing volume increases, leading to premature airway closure during expiration and atelectasis. The resulting ventilation-perfusion mismatch contributes to hypoxaemia, trapping of secretions and pneumonitis [6].

Abdominal and thoracic surgical procedures cause a large reduction in vital capacity, and a smaller but rather crucial reduction in FRC. Reduction in FRC in non-abdominal, non-thoracic operations is about 10-15%, while in upper abdominal operations and thoracotomy can be 30% and 35%, respectively [3]. FRC reduction after upper abdominal procedures is maximal on the first postoperative day, but it can last 7-10 days postoperatively. Surgical trauma, especially after vertical incisions, which involve intercostal or abdominal muscles, can significantly impair respiratory function. In addition, postoperative pain causes rapid shallow breathing and ineffective cough, a decrease in the number of sighs and impaired mucociliary clearance, leading to microatelectasis and further reduction of lung volume [8]. Residual anaesthetic effects, positioning, sedation from opioid analgesics, abdominal distention and restriction by dressings also contribute to respiratory dysfunction during the early postoperative period (Figure 1).

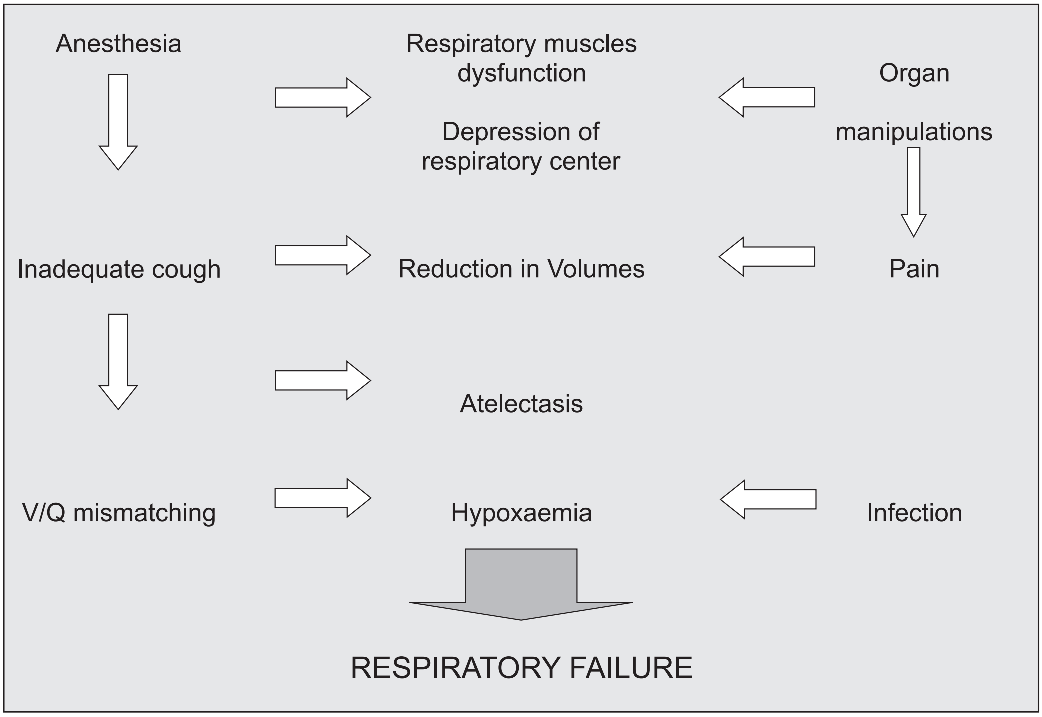

Figure 1. Pathophysiology of postoperative respiratory failure.

Identifying risk factors

Patient-related risk factors

There are many studies which evaluated the correlation between patients' risk factors and the development of PPCs. These factors can be divided in modifiable and non-modifiable, according to the possibility of reversibility guided by preoperative evaluation and management.

The main risk factors include age, chronic pulmonary disease, smoking and the general health status of the patient.

Age was not believed to be an independent risk factor, because of coexisting disorders due to chronological condition. The latest reviews state that age (especially patients over 70 years old) is a predictor of PPCs, even if other diseases coexist [10-12]. Smetana et al. [10] state that PPCs occurred in 4-45% of patients over 75 years of age, with a median rate of 15%.

Chronic obstructive pulmonary disease (COPD) seems to be the most frequently identified risk factor. Physical examination findings can be helpful in assessing the risk magnitude. Decreased breath sounds, prolonged expiration, rales, wheezing and rhonchi are associated with a six-fold increase in pulmonary complications after elective abdominal procedures [2,10]. However, patients should be aggressively treated in order to optimize pulmonary function preoperatively with combination of bronchodilators, physical therapy, antibiotics, smoking cessation and corticosteroids. In contrast to COPD, well-controlled asthma does not seem to be a risk factor for PPCs [2]. Patients preoperatively should be free of wheezing and with a peak flow at least 80% of the predicted personal value [10]. On the other hand, patients with symptomatic asthma at the time of operation have an increased risk of morbidity from anaesthesia [1], thus ideally only symptom-free asthmatic patients can have elective surgery. Regarding restrictive pulmonary disease or restrictive physiology due to chest wall deformities, there are not enough data to determine the exact ratio of postoperative risk for pulmonary complications.

Cigarette smoking is also associated with an increase in pulmonary complications, even among patients with no coexisting COPD. The relative risk of complications for smokers compared to non-smokers has been reported to increase from 1.4 to 4.3-fold [13]. It is rather interesting that patients who attempted to quit smoking shortly before elective surgery were more likely to develop a PPC compared with those who continued [10]. This risk decreases significantly after 8 weeks of smoking cessation, due to improvement of tracheobronchial clearance and function of small airways, and it should be encouraged in all patients during the preoperative evaluation [14]. Heavy smokers with increased levels of carboxyhaemoglobin (half-life approximately 6 hours), theoretically benefit from smoking cessation even a day before surgery [1].

Obesity can potentially lead to a restrictive ventilatory pattern and atelectasis after surgery, however no studies have proved a clear correlation among obesity and PPCs [1,2]. Studies report a 10% rate of pulmonary complications in patients with a body mass index (BMI) < 43 kg/m^3, and a 12% rate in patients with BMI > 43 kg/m^3, with no statistically significant difference among them [10]. However, a common coexisting condition is *obstructive sleep apnoea*, which is associated with increased risk for PPCs, in addition with difficulties in airway management perioperatively. Further studies are needed in order to determine the risk regarding these conditions.

The general health status of the patient, which is evaluated preoperatively with certain measuring scores, can predict the occurrence of PPCs. The American Society of Anesthesiologists (ASA) classification (Table 2) can predict not only perioperative mortality rates, but also PPCs and cardiac complications. Patients who are graded higher than class 2 have a 2 to 3-fold increased risk of PPCs compared with patients with better general health status [2,10]. In addition to ASA classification, the Goldman cardiac risk index also includes multiple factors from the patient's history, physical examination and laboratory findings, and predicts both pulmonary and cardiac complications [4]. Poor exercise capacity and functional dependence (inability to perform common daily activities) also identify patients at risk [2], while coexisting congestive heart failure is an independent risk factor for development of PPCs. Other conditions related with increased risk are impaired sensorium (acutely confused or delirious

Table 2. American Society of Anesthesiologists physical status classification for surgical candidates

Class 1	Normal healthy patient
Class 2	Patient with mild systemic disease and no functional limitations
Class 3	Patient with severe systemic disease that results in some functional limitation
Class 4	Patient with severe systemic disease that is a constant threat to life and functionally incapacitating
Class 5	Moribund patient who is not expected to survive 24 hours with or without an operation
Class 6	A brain dead patient whose organs are being harvested
Class E	If a procedure is an emergency the physical status is followed by an "E" (ie. 2E)

patients who cannot respond to verbal or mild tactile stimulation, or patients with mental status changes, delirium or both in the context of current illness), diabetes mellitus and HIV infection, although more data are needed in order to define the exact correlation ratio of these conditions with PPCs [10].

Procedure-related risk factors

Procedure-related risk factors are very important in predicting PPCs

The surgical site is significantly related to the occurrence of PPCs. Aortic and thoracic operations carry the highest risk, followed by upper abdominal procedures, vascular surgery, as well as head and neck surgery [2,10]. Low risk procedures include hip surgery and gynaecologic or urologic procedures.

The duration of the operation, defined as longer than 2.5-4 hours according to various studies, also correlates with increased incidence or PPCs [10]. Whenever possible, surgery in patients with non modifiable risk factors should be shorter in order to place them in lower risk.

The anaesthetic technique as a risk factor remains controversial. Several studies state a lower incidence of PPCs in patients who received spinal or epidural anaesthesia compared with general anaesthesia [4,7,10], but more data are needed in order to prove such a correlation. Residual neuromuscular blockade due to muscle relaxants used intraoperatively has also been studied. Pancuronium (a long acting muscle relaxant) has been proven to correlate with increased incidence of PPCs, compared with shorter-acting drugs such as atracurium or vecuronium [15]. Nevertheless, regional anaesthesia (i.e. brachial plexus blockade for arm procedures) should be preferred whenever possible.

Emergency surgery also correlates with PPCs, but not as an independent factor [10].

Preoperative evaluation for non cardiothoracic operations

History and clinical evaluation

Medical history of the patient and physical examination are very important during the preoperative evaluation. Chronic cough, exercise intolerance, dyspnea, chest pain or excessive sputum production, are common symptoms of underlying pulmonary disease. Physical evaluation can identify decreased breath sounds, wheezing, rhonchi or prolonged expiratory phase, all of which may increase the risk of pulmonary complications. Obstructive sleep apnoea should also be recognized by asking specific questions to the patient as well as to the sleep partner. Finally, frequent hospitalization, ICU admissions, steroid use and recent upper respiratory infection should be elucidated.

Chest radiographs

Chest radiographs are not a routine preoperative evaluation test and most of the studies agree that they do not correlate significantly with PPCs. Evidence suggests that chest radiographs rarely influence the preoperative management, except in patients with known cardiopulmonary disease, or patients older than 50 years, scheduled for upper abdominal, thoracic, or aortic aneurysm procedures [10,16].

Spirometry

Preoperative spirometry in patients undergoing non cardiothoracic operations is controversial. Studies have shown that clinicians can identify patients at risk using clinical criteria and that spirometry can not modify the risk assessment [2]. However, spirometry can be helpful in situations with an uncertain degree of risk, or in patients with COPD or asthma in order to estimate if lung function is in its best baseline condition [10,16].

Serum albumin measurements and blood urea nitrogen (BUN)

Recent studies have shown that both low serum albumin (< 3 g/dl) and BUN > 30 mg/dl are significant predictors of PPCs [2,16].

Arterial blood gas analysis

Latest studies have shown that preoperative hypercapnia ($PaCO_2 > 45$ mm Hg) is not an independent risk factor for perioperative complications, but it is advisable that additional testing should be performed. Hypoxaemia, with $SaO_2 < 90\%$, indicates an increased risk for PPCs, and further testing should also be performed [17].

Preoperative evaluation for lung cancer resection

The preoperative evaluation of patients scheduled for lung cancer resection includes careful history and physical examination, arterial blood gas analysis, spirometry, serum albumin and BUN measurement, but also more specific testing in order to assess the functioning parameters of the remaining lung. The prognosis of lung cancer is poor, even if it is found at an early stage. Surgical resection is the treatment of choice for non-small cell lung cancer, but only 20-25% of patients have resectable disease. The mortality rate after lung resection is reported to be 7-11% [18]. Pulmonary function is greatly affected by lung resection, depending on the degree of tissue removal and functioning capacity of the remaining lung. In pneumonectomy, forced expiratory volume in 1 second (FEV_1) has been shown to reduce by an average of 34-36% and the oxygen consumption (VO_2) max by 20-28%. After lobectomy, FEV_1 decreases by an average of 9-17% and VO_2 max by 0-13% [18]. Therefore, it is very important to evaluate the risk factors and to modify them if possible, in order to reduce morbidity and mortality from lung resection.

Spirometry

Spirometry is indicated in all patients scheduled for lung resection, in order to estimate the postoperative FEV_1 and suitability for resection. Spirometry should be performed when the patient is in clinically stable condition, and after having received maximal bronchodilator therapy. Several studies were carried out in order to define the minimum absolute values of FEV_1, which would predict suitability for pneumonectomy or lobectomy. However, a review of the literature suggests that an FEV_1 >2 L is the lower limit for pneumonectomy and >1.5 L for lobectomy [17]. The difficulty in accepting these recommendations is that they might not be suitable for patients with small stature, or older patients who might tolerate lower levels of lung function. According to the guidelines of the British Thoracic Society, patients are suitable for resection including pneumonectomy if FEV_1 is > 80% of the predicted normal value, or >2 L, without further evaluation. If FEV_1 is > 1.5 L, the patient is suitable for lobectomy without further evaluation [17]. If there is evidence of coexisting interstitial lung disease, DLCO should also be measured. Finally, in patients scheduled for lung cancer resection who have FEV_1 and DLCO < 80% of the predicted values, additional testing should be performed.

Diffusing capacity of the lung to carbon monoxide (DLCO)

DLCO has been shown to be an independent risk predictor regarding PPCs. Patients with low DLCO showed increased pulmonary complications after major lung resection [19]. A low DLCO characterizes patients with significant emphysema and reduced pulmonary capillary vascular bed. The preoperative value of DLCO, expressed as a percentage of the predicted value, has a higher correlation to postoperative mortality compared with the preoperative FEV_1 value [16]. Recent studies state that a DLCO < 60% of the predicted is associated with increased mortality, and the risk of PPCs increases 2 to 3-fold in patients with DLCO < 80% [17]. The guidelines of the British Thoracic Society state that in patients considered for lung cancer resection, wherever there is evidence of interstitial lung disease on radiographic studies, or dyspnea on exertion despite an adequate FEV_1, DLCO should also be measured. In cases where either FEV_1 or DLCO are < 80% of the predicted values, additional testing should be performed in order to evaluate the postoperative lung function [17].

Split function studies

The calculation of postoperative predictive values (ppo) for spirometry parameters as well as the percentage of the predicted values have increased the accuracy of lung function tests in the preoperative evaluation of patients [20]. Split function testing allows calculation of the relative contribution of the tissue to be removed to lung function. There are 3 different methods of measuring ppo: first, the split perfusion scan with intravenous Tc-99m; second, the quantitative computed tomographic scan; and third, the anatomic calculations comparing the number of segments/subsegments to be removed with the total number of segments/subsegments [21]. Recommended approaches include the radionuclide perfusion scan with Tc in order to estimate the ppo FEV_1 and DLCO after pneumonectomy, and also the number of the segments remaining.

% ppo for FEV_1 (or DLCO) is calculated using the formula:

$$ppoFEV_1 = \text{preoperative } FEV_1 \times (1 - \text{fraction of total perfusion for the resected lung})$$

The preoperative FEV_1 is taken as the best measurement after bronchodilation therapy. In addition, a quantitative radionuclide perfusion scan is performed, in order to measure the relative function of each lung.

Calculating the value of $ppoFEV_1$ after lobectomy is similar to the method used for perfusion scan, using the formula:

$$ppoFEV_1 = \text{preoperative } FEV_1 \times (\text{no. of segments remaining/total no. of segments})$$

This method can also be applied to segmentectomies, as well as in DLCO calculation. [17]. According to the guidelines of the British Thoracic Society, in patients with lung cancer being considered for surgical resection, a value of % ppo FEV_1 < 40%, or a % ppo DLCO < 40%, indicate a high risk for perioperative death and cardiopulmonary complications, and these patients should also have exercise testing. In addition, patients with a product of % ppo FEV_1 and % ppo DLCO < 1650 or % ppo FEV_1 < 30% are at very high risk of perioperative death and cardiopulmonary complications and they should be counseled for nonoperative treatment options [17,18].

Exercise testing

Since VO_2 of the lungs is representative of VO_2 in cellular level, any increase in cellular respiration during exercise can predictably increase VO_2. Age, sex, weight, and type of exercise performed, all correlate with VO_2. An exercise testing, according to the British Thoracic Society guidelines, should be performed in patients with borderline calculations of % ppo for FEV_1 and DLCO preoperatively (< 40%). The formula used to estimate VO_2 is:

$$\text{Predicted } VO_2 = 5.8 \times \text{weight in kg} + 151 + 10.1\ (W)$$

Two major types of exercise testing are usually performed during preoperative evaluation:

1. Fixed exercise challenge, during which the patient performs a sustained level of work.
2. Incremental exercise testing, during which the patient performs an increasing work, until reaching a desired endpoint [18].

In addition to the above mentioned tests, stairs climbing has been widely used in order to assess exercise capacity. Patients able to climb 3 flights of stairs are being considered suitable for lobectomy. Pneumonectomy requires the ability to climb 5 flights of stairs. This approach has been found to correlate with FEV_1, but it is not performed in a standardized manner [17].

Patients with a preoperative VO_2 max of > 25 ml/kg/min are not at increased risk of perioperative complications or death. On the other hand, patients with VO_2 max of < 10 ml/kg/min, have a very high risk for postoperative complications. These patients should be counseled for other, non surgical, therapeutic options for lung cancer. The same applies in patients with VO_2 max < 15 ml/kg/min and both % ppo of FEV_1 and DLCO < 40%, or patients who can climb < 1 flight of stairs preoperatively [17].

A simplified algorithm for the preoperative evaluation of patients scheduled for lung cancer resection is presented in Figure 2.

Strategies for reducing the risk

Strategies to reduce the risk of PPCs begin preoperatively after evaluation of the patient, and continue intraoperatively and during the postoperative period (Table 3).

Optimize chronic lung condition

All patients with symptomatic COPD and asthma should have bronchodilating therapy preoperatively, in order to reverse and prevent further bronchospasm. B-agonists are the first-line treatment, with additional steroids in patients with severe COPD or asthma. Steroids are used for a short period and they should be given at least 12 hours before the operation due to their long onset time [1]. Theophylline should be continued if used chronically, but it should not be initiated shortly before surgery. The main goal of preoperative preparation is a peak flow of at least 80% of the patient's personal best value. Antibiotics should be used only if there is evidence of pulmonary infection [2].

Smoking cessation

Opinions about smoking cessation preoperatively are controversial, since there is evidence of greater percentage of PPCs in patients who quit smoking shortly before surgery (< 8 weeks) [2,17], but further studies are needed in order to define the best timing for smoking cessation.

Table 3. Risk reduction strategies

Preoperatively
Cessation of cigarette smoking > 8 weeks
Treatment of airflow obstruction in patients with COPD or asthma
Antibiotics in case of respiratory infection (and delay surgery)
Education of patients for lung expansion maneuvers
Intraoperatively
Limitation of surgical procedure < 3 hours
Regional anaesthesia when appropriate
Short acting neuromuscular blocking agents (avoid pancuronium)
Laparoscopic techniques when appropriate
Postoperatively
Deep breathing exercises, incentive spirometry
CPAP when appropriate
Adequate pain control

COPD: chronic obstructive pulmonary disease, CPAP: continuous positive airway pressure

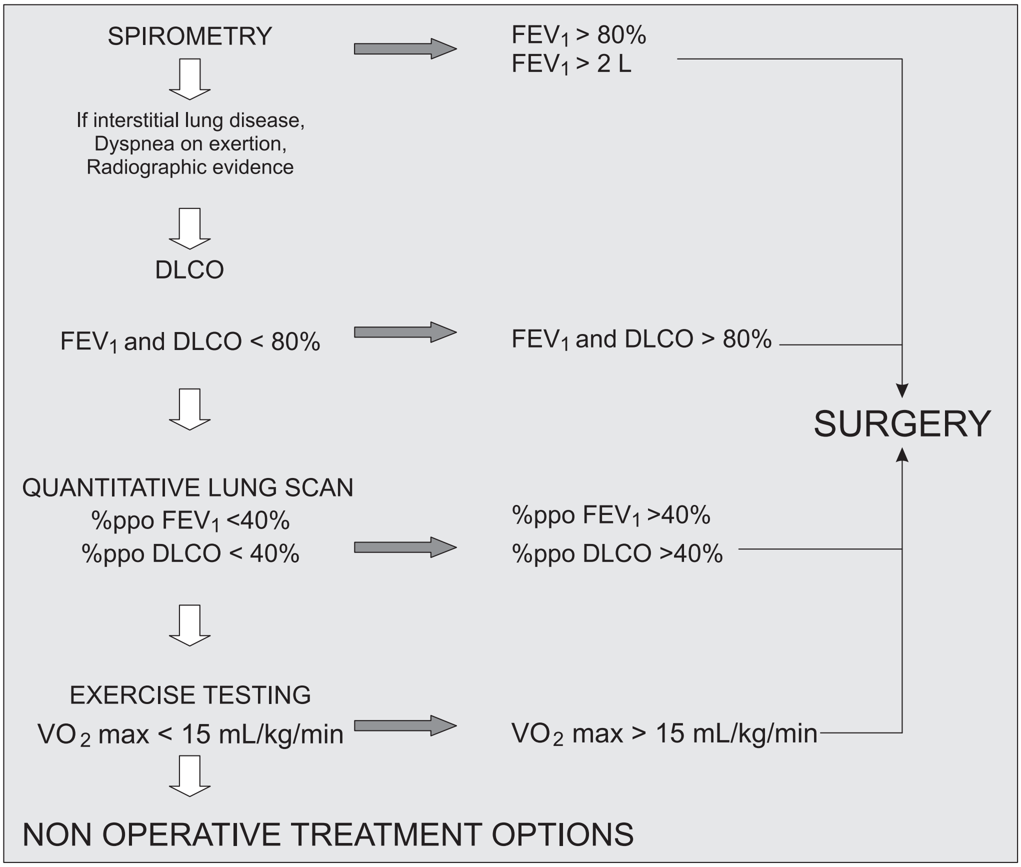

Figure 2. Simplified algorithm for preoperative evaluation of patients scheduled for lung cancer resection surgery, according to the British Thoracic Society. For abbreviations see text.

Anaesthesia and analgesia

Anaesthetic techniques with short-acting neuromuscular blocking drugs are associated with less PPCs [16]. Adequate postoperative analgesia is also essential in reducing pulmonary complications. Regional anaesthetic techniques, such as epidural anaesthesia/analgesia, when properly applied, can inhibit pain and therefore improve respiratory muscle function [2].

Surgical technique

Regarding lung cancer, the state of the art technique is still a thoracotomy with careful intraoperative assessment of lymph nodes. However, there is increasing evidence that video-assisted thoracoscopy is technically feasible and it can reduce PPCs. Lung volume reduction surgery (LVRS) is another recent development in thoracic surgery, which can improve pulmonary function in patients with severe emphysema. Some patients can have a combination of LVRS and cancer surgery, even if they do not meet the standard criteria. Combining LVRS and lung cancer resection, according to the British Thoracic Society guidelines, should be limited to patients with heterogeneous emphysema, especially if limited to the lobe containing the tumor [17,22].

Lung expansion maneuvers

Postoperative lung expansion maneuvers can prevent the decline of lung volumes after major surgery, especially in the abdominal or thoracic region [2]. Continuous positive airway pressure (CPAP) is also an effective measure in selected patients, although it carries the risk of aspiration and barotrauma. Chest physiotherapy, including deep breathing exercises in conjunction with chest percussion, postural drainage and incentive spirometry can also reduce the risk of PPCs [1].

Selective nasogastric decompression

Selective compared with routine use of nasogastric tubes seems to correlate with lower rate of postoperative pneumonia and atelectasis after abdominal surgery [2,16].

Table 4. Summary of recommendations of the British Thoracic Society and the American College of Physicians regarding thoracic and non-cardiothoracic operations [16,17]

British Thoracic Society **Lung Cancer Surgery**	**American College of Physicians** **Non Cardiothoracic Surgery**
▪ Patients with lung cancer should be evaluated by physicians interested in this disease ▪ Patients with lung cancer should be evaluated by a multidisciplinary team for their suitability for surgery (chest physician, thoracic surgical team, oncologist) ▪ Patients with lung cancer should not be denied lung resection surgery on the grounds of age alone	▪ All patients undergoing non cardiothoracic surgery should be evaluated for the presence of the following significant risk factors for PPCs: chronic obstructive pulmonary disease, age > 60 years, ASA physical status > 2, functionally dependent and congestive heart failure
▪ Patients with lung cancer scheduled for surgery should have preoperative cardiologic evaluation ▪ Every patient scheduled for lung cancer surgery should have preoperative spirometry. If FEV_1 > 80% predicted normal, or > 2 L, the patient is suitable for resection including pneumonectomy without further evaluation. If FEV_1 >1.5 L the patient is suitable for lobectomy without further evaluation	▪ Patients undergoing the following procedures are at higher risk for PPCs and should be evaluated for concomitant risk factors and receive pre/postoperative interventions to reduce risk: prolonged surgery > 3 hours, abdominal surgery, thoracic surgery, neurosurgery, head and neck surgery, vascular surgery, aortic aneurysm repair, emergency surgery, general anaesthesia
▪ If there is evidence of interstitial lung disease or radiographic studies or undue dyspnea on exertion, DLCO should be measured even if FEV_1 is adequate ▪ If either FEV_1 or DLCO are < 80% predicted, additional testing is required to predict postoperative lung function ▪ If patients have either %ppo FEV_1 < 40% or %ppo DLCO < 40%, there is a high risk of PPCs. These patients need further evaluation with exercise testing	▪ A low serum albumin level (<35 g/L) is a powerful marker of increased risk for PPCs and should be measured in all patients with suspected hypoalbuminaemia. Measurement should be considered in patients with > 1 risk factors for PPCs
▪ If patients have either a product of %ppo FEV_1 and %ppo DLCO < 1650 or % ppo FEV_1 < 30%, there is a very high risk for perioperative death and cardiopulmonary complications. These patients should be counseled about non-operative treatment options ▪ If VO_2 max < 10 ml/kg/min there is a very high risk for perioperative death and cardiopulmonary complications. These patients should be counseled about non-operative treatment options	▪ All patients who, after preoperative evaluation are found to be at high risk for PPCs, should receive the following postoperative procedures: 1) deep breathing exercises or incentive spirometry and 2) selective use of a nasogastric tube (as needed for postoperative nausea and vomiting, inability to tolerate oral intake, or sumptomatic abdominal distension)
▪ If VO_2 max < 15 ml/kg/min and both %ppo FEV_1 and DLCO < 40%, there is a very high risk for perioperative death and cardiopulmonary complications. These patients should be counseled about non-operative treatment options ▪ If patients walk < 25 shuttles on two shuttle walks or < 1 flight of stairs, there is a very high risk of perioperative death and cardiopulmonary complications. These patients should be counseled about non-operative treatment options	▪ Preoperative spirometry and chest radiography should not be used in all patients routinely. They may be appropriate in patients with evidence of chronic obstructive pulmonary disease or asthma
▪ $PaCO_2$ > 45 mmHg is not an independent risk factor for increase PPCs. Further physiologic testing is advised ▪ SaO_2 < 90% indicates increased risk for PPCs. Further physiologic testing is advised ▪ In patients with very poor lung function, combination of LVRS and lung cancer resection may be considered if emphysema is heterogeneous and involves primarily the lobe to be resected	▪ The following procedures should not be used solely for reducing PPCs: 1) right heart catheterization and 2) total parenteral nutrition or total enteric nutrition (for patients with low albumin levels or malnutrition)

For abbreviations see text

Conclusions

In conclusion, preoperative pulmonary evaluation is a very important part of perioperative management of patients scheduled either for thoracic or non-thoracic operations. Guidelines of the British Thoracic Society (regarding lung cancer resection surgery), as well as of the American College of Physicians (regarding patients with pulmonary disease undergoing non-thoracic operations) (Table 4) should always be followed, in addition with proper risk modification strategies, in order to reduce the possibility of PPCs and improve patients' outcome after major surgery.

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