Literature Review

# Preoperative Assessment Prior to Lung Resection: How to Eliminate the Risk

**Dian Megawati*, Menaldi Rasmin, Budhi Antariksa, Faisal Yunus**

Department of Pulmonology and Respiratory Medicine Faculty of Medicine, Universitas Indonesia, Persahabatan National Respiratory Referral Hospital, Jakarta

**Corresponding Author:**
*Dian Megawati* | Department of Pulmonology and Respiratory Medicine Faculty of Medicine, Universitas Universitas Indonesia, Persahabatan National Respiratory Referral Hospital, Jakarta | mega.efendi89@gmail.com

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## Abstract

Lung resection is part of the treatment of various lung diseases, both malignancy and infection. Although it has great benefits, lung resection can result in a variety of functional disorders that can affect the whole cardiopulmonary system. The mortality of these procedures is 2-4% in segmentectomy and 6-8% in lobectomy, while the mortality of pneumonectomy in the world is 11%. Good preoperative assessment of patients has been reported to have reduced mortality and morbidity after lung resection. Things that need to be considered to assess preoperative eligibility include age, lung function, cardiovascular fitness, nutrition, and performance status. The preoperative pulmonary tolerance assessment is divided into three stages: the first stage is the assessment of lung function and blood gas analysis, the second stage is to assess postoperative prediction of pulmonary function, and the third stage is to assess the maximum oxygen consumption per minute by doing a cardiopulmonary exercise test. Patients who have a good tolerance for lung resection are patients who have predictive postoperative force expiration volume one second (ppoFEV$_1$) values more than 40%, predictive postoperative diffusion capacity of the lung for carbon monoxide (ppoDLCO) more than 50%, and maximum oxygen consumption ($VO_2$ max) more than 15ml/kg/min.

**Keywords:** lung resection, pulmonary tolerance, tolerance assessment

## INTRODUCTION

Lung resection is part of the treatment of various lung diseases, both malignancy and infection. There are several types of lung resection, including wedge resection, segmentectomy, lobectomy, and pneumonectomy. The choice of technique depends on the size of the lesion or the extent of the damage.[1] The lung resection procedure has been carried out since 1933 by Evarts A. Graham, who successfully performed a pneumonectomy in lung cancer patients.[2] In 1940, Blades and Kent reported performing the first lobectomy in a patient with bronchiectasis.[3] The benefits of surgical therapy for various lung diseases are well known. Life expectancy in patients with early-stage non-small-cell

lung carcinoma increased to 48 months. In addition, in cases of bronchiectasis, surgical therapy improves the quality of life and survival.[4]

Despite its great benefits, lung resection can cause a variety of functional disorders that can affect the whole cardiopulmonary system.[5] Patients undergoing lung resection are at high risk for postoperative pulmonary complications. Francois et al reported that the incidence of postoperative pulmonary complications was 49%.[6]

Many factors affect the incidence and types of complications that occur. These include age, the physical status of the patient, such as cardiorespiratory functional status, type, and extent of the procedure, course of the disease, and other therapeutic modalities given.[7] In 2006 in England, it was reported that there were 2400 lobectomies and 500 pneumonectomies performed annually, with the most common indication being lung cancer. In these patients, the mortality is 2–4% for segmentectomy, 6–8% for lobectomy, and 11% for pneumonectomy.[8]

Before lung resection is performed, assessment of tolerance, patient capacity, and postoperative complications is very important. The greatest challenge in conducting a preoperative evaluation is identifying the patient's increased risk of complications and mortality.[9] The British Thoracic Society (BTS) and the Society of Cardiothoracic Surgeons of Great Britain and Ireland (SCTS) have published a guideline for selecting candidates for surgery in malignancy patients. The things that are important factors to assess are age, functional status of the cardiorespiratory system, nutrition, and functional status.[10] Good preoperative assessment of patients has been reported can reduced mortality and morbidity after lung resection.[7]

## PREOPERATIVE ASSESSMENT PRIOR TO LUNG RESECTION

The main causes of postoperative mortality and morbidity in thoracic surgery, especially lung resection, are respiratory complications, including atelectasis, pneumonia, and respiratory failure, which occur in 15-20% of cases.[11] Good preoperative assessment of patients has been reported to have reduced mortality and morbidity after lung resection.[7] The main concerns to assessing preoperative eligibility include age, lung function, cardiovascular fitness, nutrition, and performance status.[10] This assessment is related to the risk that the patient will experience during and after the procedure, such as postoperative cardiac complications, intraoperative death, and postoperative dyspnea.[12]

### Age

Age is a risk factor for postoperative complications, although there is no specific age limit that is a contraindication to lung resection. Based on data collected by the Society of Thoracic Surgeons (STS), it is estimated that around 30 - 35% of patients who are candidates for lung resection in lung cancer cases are over 70 years old.[13]

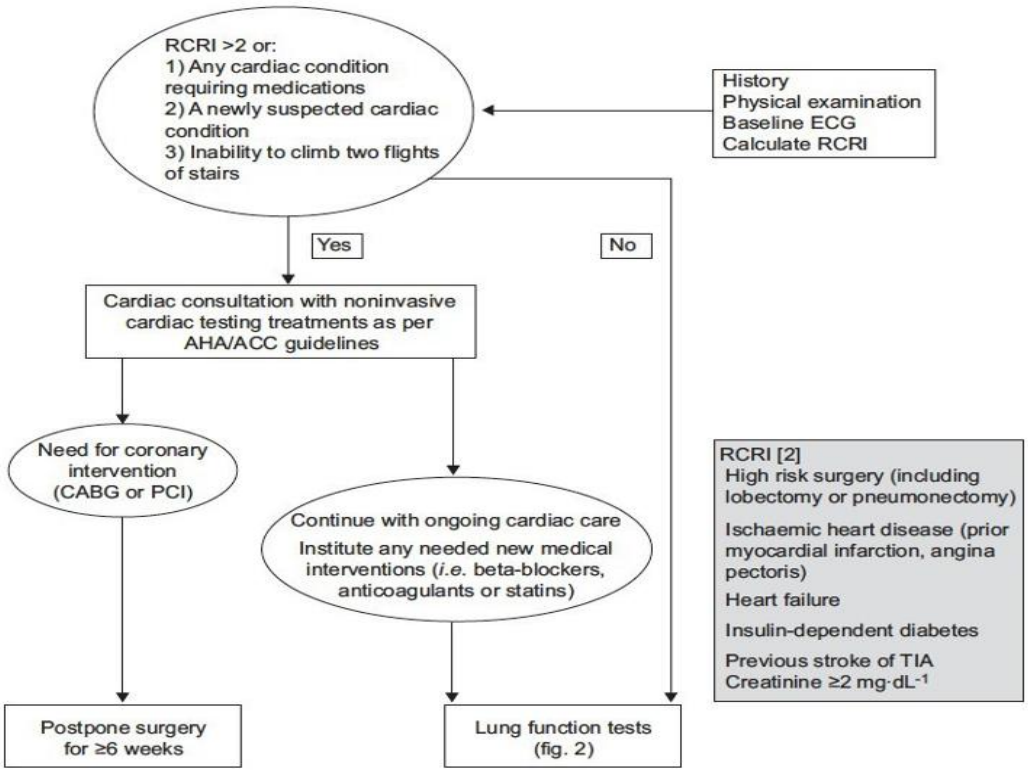


Figure 1. Algorithm for assessing cardiovascular status before lung resection[14]

Fernandes et al stated that patients aged over 65 years were at a 2,6 times greater risk of post-resection pulmonary complications.[4] This is related to physiological changes in the respiratory system caused by aging. In the elderly, there is a decrease in the compliance of the chest cavity, which can reduce vital lung capacity due to degeneration of elastin fibers around the alveolus, and a decrease in the amount of supporting tissue around the alveolus, causing premature closure of the airways, thereby increasing the amount of trapped air and residual volume.[15]

## Cardiovascular Status

Patients who will undergo lung resection have a 2-3% risk of developing cardiovascular complications during and after the procedure. The major risks that may occur include myocardial infarction, pulmonary edema, arrhythmias, and cardiac arrest. Therefore, cardiovascular status assessment is very important to predict the risk of complications that may occur. The American Heart Association (AHA) has a score to assess the risk of cardiovascular complications in patients undergoing lung resection, called the Thoracic Revised Cardiac Risk Index (ThRCRI). The score consists of a history of ischemic heart disease, a history of stroke/transient ischemic attack, and a creatinine level greater than 2mg/dL.[14]

Other tests that need to be done to assess cardiovascular status are electrocardiography, echocardiography, exercise testing, and invasive tests such as primary coronary intervention (PCI) (figure 1).[16]

## Lung Function Test

Spirometry and Diffusing Capacity of the Lung for Carbon Monoxide (DLCO) are the two main modalities of preoperative pulmonary evaluation that should be performed in patients prior to lung resection. These two tests can also be used to estimate ppoFEV$_1$ and ppoDLCO values, which are important indicators for selecting the follow-up tests that need to be performed and can even be used as a basis for excluding patients from surgery.[16]

Spirometry has good sensitivity and specificity in predicting the outcome of patients who will undergo lung resection. Indicators of mechanical function and lung volume showed a correlation with postoperative outcomes, such as FEV1, forced vital capacity (FVC), maximal voluntary ventilation (MVV) and residual volume/total lung capacity ratio (RV/TLC).[17]

The BTS guideline on surgical therapy for lung cancer patients states that the combined examination of spirometry and DLCO is considered more meaningful for predicting postoperative morbidity and mortality.[18] The ppoFEV$_1$ value is obtained by multiplying the preoperative FEV$_1$ value by the number of segments left after surgery divided by 19. Nineteen is the total number of lung segments in normal people.[17]

Many studies state that ppoFEV$_1$ of less than 40% significantly increased the risk of mortality, and ppoFEV$_1$ values of greater than 70% were associated with a lower incidence of postoperative complications. A low-risk patient has a postoperative mortality risk of less than 1% and pulmonary resection is recommended. A moderate-risk patient has a mortality risk of less than 10%, and a high-risk patient has a mortality risk of more than 10% and other treatment strategies are recommended.[19]

## Blood Gas Analysis

Blood gas analysis provides a complete picture of respiratory function, which is influenced by central mechanisms, cardiac function, and metabolism as lung function affects it.[20] Blood gas analysis is used to assess lung function before resection and as an effort to prevent respiratory insufficiency. Hypercapnia and hypoxia have been reported to be risk factors for postoperative complications. One indicator to exclude candidates for lung resection is hypercapnia.[21]

Table 1. Interpretation of ppoFEV1 and ppoDLCO[17]

| ppoFEV1 (% prediction) | Interpretation |
|---|---|
| > 40 | No or minor respiratory complications that need to be anticipated |
| < 40 | Increased risk of perioperative death and cardiopulmonary complications |
| < 30 | Possible need for postoperative ventilation assistance and increased risk of death and complications. Nonsurgical therapy should be considered. |
| >40%, ppoFEV1 >40% and $SpO_2$ room air >90% | Moderate risk, does not require further pulmonary examination |
| <40% | Increased risk of cardiopulmonary complications |
| <40% and ppoFEV1 <30% | High risk, requires cardiopulmonary exercise test |
| <30% | The patient is likely to develop hypoxia without supplemental oxygen |

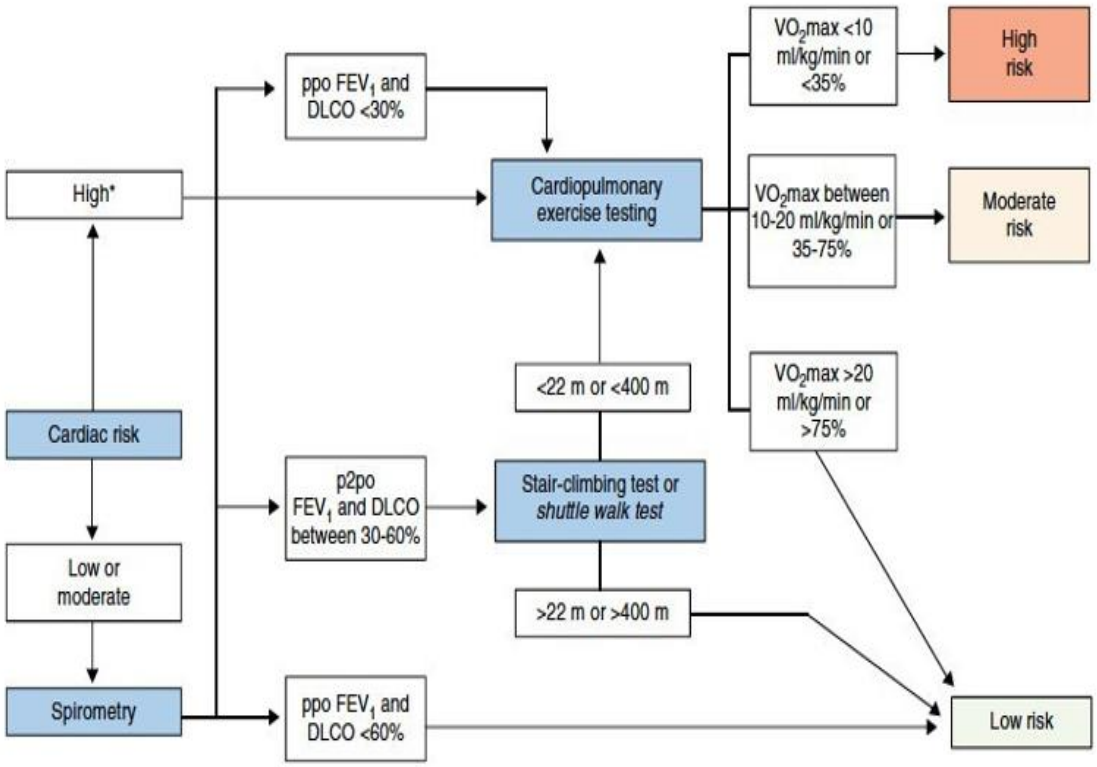


Figure 2. Algorithm for risk assessment of lung resection candidate patients[14]

The results of the study by Saleem et al in 2018 stated that patients with preoperative $CO_2$ partial pressure ($PaCO_2$) more than 45 mmHg were more likely to experience complications when compared to patients who had a preoperative $PaCO_2$ less than 45 mmHg.[22]

## Exercise Test

There are several types of exercise tests that are recommended to assess preoperative tolerance, including the six-minute walking test (6MW), shuttle walk test (SWT), stairs climbing test (SCT), and cardiopulmonary exercise test (CPET). The exercise test is the third stage of pulmonary tolerance assessment before lung resection is performed. This test is indicated for patients with stage I and II assessment results having moderate or doubtful risk. The purpose of this examination is to provide stimulation and pressure to the entire cardiopulmonary system and to estimate postoperative physiological function. During exercise, there is an increase in ventilation, oxygen uptake, carbon dioxide removal, and blood flow in the respiratory system, which correlates with what occurs after surgery.[10,16]

## Six-minute Walking Test (6MW)

The six-minute walking test is a test to assess a person's activity capacity by measuring the distance the patient can walk for six minutes on a flat surface. This test has a good correlation with the values of $FEV_1$ and DLCO.[18] The six-minute walking test is also considered to be able to describe the value of $VO_2$ max. The European Respiratory Society (ERS) recommends this examination as an initial

screening for lung resection candidates even though it is considered less able to describe the risk of postoperative complications. The cut off value recommended by ERS is 400 meters, which can be covered in six minutes, representing a $VO_2$ max 15 ml/kg/minute.[16]

**Shuttle Walk Test (SWT)**

In the shuttle walk test, the patient is asked to walk between two marking funnels that are approximately 10 meters apart. The patient walks according to the given rhythm, which is getting faster and faster. The examination is carried out for 12 minutes or until the patient feels unable to continue the examination. This examination is considered to be significantly correlated with the value of $VO_2$ max. If the distance traveled by the patient is less than 250 meters or there is a decrease in $O_2$ saturation greater than 4%, then the patient is included in the high-risk group.[17] The patient's ability to walk as far as 250 meters is associated with a $VO_2$ max 10 ml/kg/min and 400 meters is associated with $VO_2$ max more than 15 ml/kg/min.[16]

**Stairs Climbing Test**

This examination technique involves asking the patient to climb several levels of stairs at a speed that is adjusted to the patient's ability. Examination is stopped when the patient has reached the maximum level, the patient is tired, short of breath, or chest pain. Parameters observed before and immediately after the examination included blood pressure, pulse, respiration rate, and oxygen saturation. Parameters related to postoperative risk are O2 saturation less than 90% or desaturation occurring more than 4% after exercise. Interpretation of examination results was also correlated with VO2 max (table 2).[17,18] Brunelli et al stated that a decrease in O2 saturation of more than 4% after exercise was associated with postoperative complications, and the incidence of complications in these patients was 36%.[19]

**Cardiopulmonary Exercise Test (CPET)**

Cardiopulmonary exercise test is a high-tech examination carried out using a static bicycle or treadmill. It is carried out in an environment that is regulated in such a way as to ensure good standards and results. The $VO_2$ max is an important parameter that can directly assess exercise capacity.[16] The workload on the examination is set to reach a maximum of 8 - 12 minutes. When symptoms occur, fatigue, an abnormal ECG, or the patient's pulse reach their maximum, the examination is terminated.[11]

Cardiopulmonary exercise test is not performed in all lung resection candidates. This examination is indicated in patients who have a high-risk cardiovascular status, $ppoFEV_1$ and ppoDLCO less than 30%, climbing stairs test less than 22 meters, and shuttle walk test less than 400 meters. The cut-off value for the CPET is $VO_2$ max more than 75% predicted or more than 20 ml/kg/min for pneumonectomy, and a $VO_2$

max value of less than 15 ml/kg/minute indicates a high risk.[10]

## OPTIMIZATION OF PRESURGICAL LUNG FUNCTION

### Smoking Cessation

Various studies have assessed the relationship of smoking status in patients undergoing lung resection with the incidence of complications. Motono et al stated that the incidence of postoperative complications occurred in 33% patients who smoked. This result is greater than the incidence of complications in patients who do not smoke, which is 17%.[21]

Nakagawa et al conducted a study that assessed the relationship between the duration of smoking cessation and the incidence of pulmonary complications after lung resection in 2001. The results of this study indicated that the smoker must have quit more than five weeks before surgery.[23] The European Respiratory Society recommends that patients undergoing lung resection stop smoking at least four weeks before the procedure.[16]

Table 2. Interpretation of stairs climbing test[17]

| Test results | $VO_2$ max conversion | Interpretation |
|---|---|---|
| > 5 levels | > 20 ml/kg/min | Correlated with $FEV_1$ >2 l and low risk of death after pneumonectomy |
| > 3 levels | - | Correlated with $FEV_1$ 1,7 l and low risk of death after lobectomy |
| < 2 levels | - | Correlated with a high risk of death |
| < 1 level | < 10 ml/kg/min | Correlated with a high risk of death |

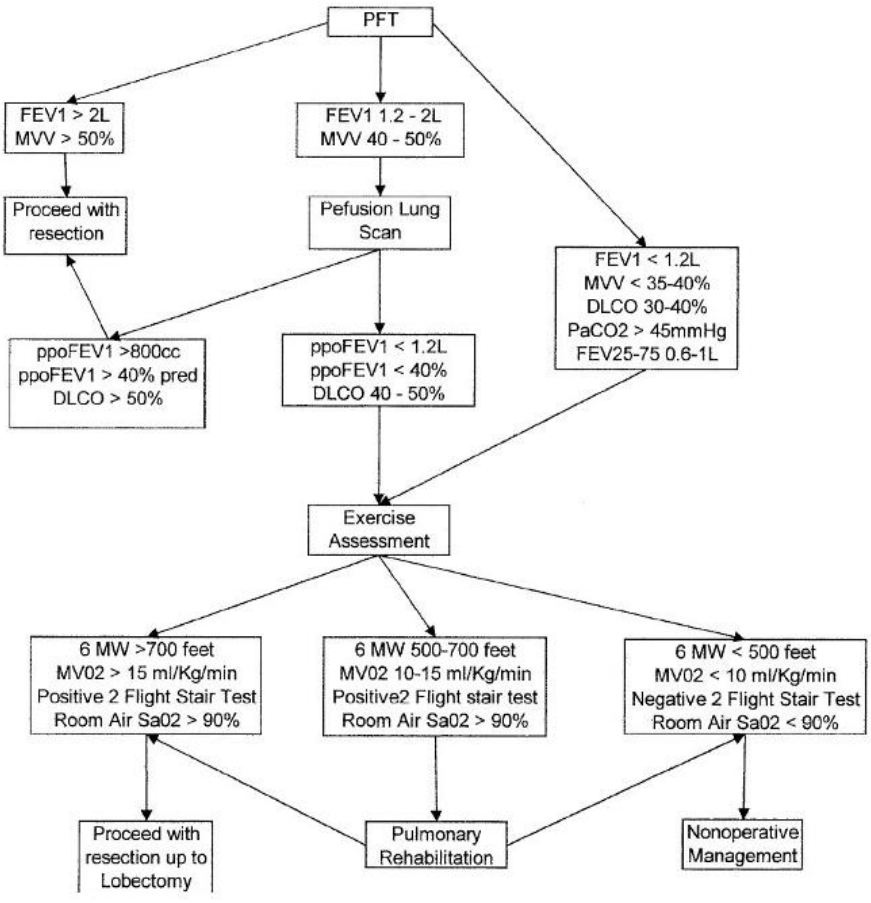


Figure 3. Algorithm for evaluation of pulmonary function for resection[20]

## Pulmonary Rehabilitation

Associated respiratory muscle dysfunction can be caused by the administration of anesthetic drugs from the beginning to the postoperative period. This is considered to increase the risk of postoperative complications, especially pulmonary complications. Optimization of respiratory muscle function can be achieved by performing pulmonary rehabilitation prior to surgery.[24]

Some of the methods that can be used include inspiratory muscle training, chest physiotherapy, and incentive spirometry.[24] Meta-analysis showed 50% of postoperative complications can be reduced by performing incentive spirometry and deep breathing exercises.[25] The ERS guidelines recommend pulmonary rehabilitation before and after surgery because it has benefits in the recovery process and prevents complications.[16]

## Aminophylline Treatment

The function of the respiratory muscles after surgery, especially thoracic surgery, can be caused by direct effects of damage to the muscles or conditions due to the incision or indirectly as a result of mechanical changes in the respiratory system. Research has also shown that lung resection, especially in patients older than 70 years, can reduce the maximum inspiratory pressure (MIP) and maximum expiratory pressure (MEP) and can cause diaphragmatic paralysis.[26]

The effects of anesthetics on respiratory function are affected by a number of factors, including the agent, dose, the subject's consciousness, and the specific muscle group. Sedation, anesthesia, opioids, and endogenous consciousness impairment all reduce respiratory arousal during the perioperative period. As a result, the total level of stimulation to the respiratory muscles decreases, making the upper airway more susceptible to collapse and respiratory failure.[26]

An effort to reduce the risk is made by giving aminophylline. Aminophylline stimulates the central nervous system, myocardium, and muscles by increasing intracellular cAMP (cyclic adenosine monophosphate) and calcium. Aminophylline is also used to stimulate respiratory muscles and reduce the risk of apnea by blocking adenosine A1 and A2a receptors.[27] Yokoba et al stated that aminophylline can increase inspiratory and expiratory muscle activity. In addition, aminophylline is also considered to increase diaphragmatic muscle strength and slow muscle fatigue in patients with hypoxia and hypercapnia.[28]

## CONCLUSION

Lung resection is a modality of choice in the treatment of various lung diseases, but this action can result in various functional disorders that can affect the whole cardiopulmonary system. Assessment of preoperative tolerance is very important and has been reported to reduce mortality and morbidity after lung resection. The main concerns to preoperative tolerance assessment include

age, lung function, cardiovascular fitness, nutrition, and functional status. Preoperative pulmonary assessment includes pulmonary function tests using spirometry and DLCO, blood gas analysis, and exercise testing. Patients who have good tolerance for lung resection are patients who have low cardiovascular risk, ppo$FEV_1$ values more than 40%, ppoDLCO more than 50% and $VO_2$ max more than 15 ml/kg/min. Preoperative lung function can be optimized by smoking cessation, pulmonary rehabilitation, and intravenous administration of aminophylline.

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