Thoracic Surgery Highlight: Understanding the Terminology with Preoperative Pulmonary Function Tests in Lung Resection Candidates
Margaret Holland, PA-C
Director of Education

Lung cancer remains the leading cause of cancer death in the United States, with an estimated 234,030 new cases of lung cancer expected to be diagnosed in the US in 2018.\(^1\) Surgery remains the mainstay of treatment for early-stage non-small cell lung cancers with procedures such as the wedge resection (segmentectomy), lobectomy, and pneumonectomy. Currently, surgical mortality rates are typically estimated between 1-5% depending on the procedure performed. Due to the proximity of the lungs to the diaphragm, use of volatile anesthetic agents, and pain from surgery, patients undergoing lung resections are at high risk for postoperative pulmonary complications. When planning for surgery, lung function testing is valuable when considering the risk of mortality and decreased postoperative lung function.

It is recommended by the American College of Chest Physicians (ACCP) and the British Thoracic Society (CTS) that preoperative pulmonary function be assessed in all patients with lung cancer being considered for resectional surgery. The initial assessment should include spirometry to measure the forced expiratory volume in one second (FEV\(_1\)) and the diffusion capacity for carbon monoxide, which is abbreviated DLCO.\(^2\) The predicted postoperative values should also be calculated. These are the least invasive tests available that can be utilized to assess risk of both preoperative complications and long-term disability from surgical intervention.

The terminology and meaning associated with these tests can be confusing, especially if we do not regularly utilize them in daily practice. The following is a clarification of these terms and acronyms, and how they help guide our management of the patient undergoing preoperative evaluation for lung resection.
Spirometry

Spirometry is a measure of the volumes of air moved by a patient over time and assesses the mechanics of ventilation. Lung plethysmography also measures the change of volume of the lungs. The volumes measured in spirometry and plethysmography include the following:

- **Vital capacity (VC):** air displaced by maximal exhalation and inhalation
- **Total lung capacity (TLC):** maximal inspiration and maximal expiration
- **Forced vital capacity (FVC):** total volume of air exhaled with maximal effort
- **Functional residual capacity (FRC):** the volume of air remaining after expiration
- **Forced expiratory volume in the first second to the FVC maneuver (FEV₁):** total volume exhaled with maximal effort in one second

**FEV₁**

The FEV₁ is assessed by spirometry and is useful in determining restrictive or obstructive lung disorders. Many patients with lung cancer have comorbid conditions affecting their lung function such as COPD and asthma. The percent predicted FEV₁ is most often utilized in preoperative assessment. This percent predicted accounts for patient variables of age, sex, and height. An FEV₁ value of less than 50% of predicted is associated with increased risk of preoperative pulmonary complications.³

The FEV₁ and FVC are also often displayed as an FEV₁/FVC ratio, which means the percentage of the FVC that is exhaled in one second. It is mainly assessing airflow and any limitations in that airflow through the respiratory tract. An FEV₁/FVC ration of <70% is typically found in obstructive disorders (i.e. COPD). The reversibility of an obstructive defect is determined after a bronchodilator treatment (an increase of more than 12% and 200 mL demonstrates reversible).
Of note, although it is not utilized to assess risk for complications, the FRC may be affected by surgery. The FRC may decline a significant percentage after thoracotomy and lung resection, which will predispose patients to atelectasis, impaired gas exchange, and infectious complications. Decreased inspiratory capacity and expiratory reserve volume from the lost lung volume will also contribute to ineffective cough and clearing of secretions.

**DLCO**

DLCO, the diffusion capacity for carbon monoxide, helps us assess the function of the lung at the alveolar capillary membrane level. Most commonly, the single breath test is utilized. The actual test involves inhaling very small amounts of carbon monoxide with a tracer gas (methane or helium) through a tightly fitting mouthpiece with nose clips. After inhaling, the patient holds their breath for 10 seconds and then rapidly exhales. The tracer gas is measured after exhalation and is used to determine how much was absorbed during the breath. Carbon monoxide is used because it is highly diffusible and identifies utilization of alveolar gases.

The DLCO values are useful in identifying the severity of underlying lung disease, which contributes to postoperative complications. A DLCO higher than 60% predicted is considered low risk for postoperative pulmonary complications.

**PPO**

PPO stands for predicted postoperative lung function. These values can be calculated using different formulas for pneumonectomy and lobectomy; these formulas include use of the preoperative value and the remainder of functional lung segments (lobectomy) or total perfusion of the resected lung (pneumonectomy). Calculating the total perfusion of the resected lung requires a perfusion scan and is most appropriate for patients undergoing a pneumonectomy.

To calculate the PPO FEV₁, the following equations are used: 

\[ \text{PPO FEV}_1 = \text{Preoperative FEV}_1 + \text{Remainder of Functional Lung Segments} \]

\[ \text{PPO FEV}_1 = \text{Preoperative FEV}_1 + \text{Total Perfusion of Resected Lung} \]
\[ \text{PPO FEV}_1 = \text{preoperative FEV}_1 \times \left(1 - \frac{\# \text{ of unobstructed segments to be resected}}{\text{total \# of unobstructed segments}}\right) \]

\[ \text{PPO FEV}_1 \text{ or PPO DLCO} = \text{baseline value} \times \left(100 - \frac{\text{percent perfusion in the region of planned resection}}{100}\right) \]

Patients are considered low risk for perioperative death and cardiopulmonary complications, if the PPO FEV\(_1\) and PPO DLCO are > 60%. No further testing is typically done in these patients. Where the PPO FEV\(_1\) and PPO DLCO are < 60%, further testing such as exercise testing is recommended.

**Exercise Capacity**
Tests for exercise capacity include stair-climbing and the cardiopulmonary exercise test (CPET) and are performed when the ppo FEV\(_1\) and ppo DLCO are < 60% predicted. These are usually used in a sequential pattern, with CPET being utilized as the last option. Stair-climbing is performed simply by having the patient climb stairs while symptoms and pulse oximetry are monitored. Stair-climbing is useful in determining the risk for perioperative mortality and the number of lights of stairs may correlate with level of risk. The ACCP uses a cutoff of 22 m on the test, and below this cutoff, patients have shown to be at increased risk for complications post-surgically.

Cardiopulmonary exercise testing (CPET) is recommended for patients where the PPO FEV\(_1\) is <30% predicted or PPO DLCO <30%. The CPET measures oxygen uptake per minute, minute ventilation, along with electrocardiogram and heart rate response to exercise. The maximal oxygen uptake is measured as (MV\(\text{O}_2\)) and an acceptable level for surgical resection is 10-20 mg/kg/minute or >20 mg/kg/minute for a pneumonectomy.\(^7\)

It should be noted that specific cutoff numbers have not been identified below which surgical resection should not be performed.
Conclusion

Spirometry, diffusion capacity, and exercise capacity are practical, non-invasive tests available to clinicians for assessing risk of both preoperative complications and long-term disability from surgical intervention. Using these resources with an understanding of the terminology will empower the surgical PA to assess risk and make the best decision for patients that will optimize outcomes.


1. Which of the following tests are recommended by the American College of Chest Physicians (ACCP) and the British Thoracic Society (CTS) for initial assessment of preoperative pulmonary function in patients with lung cancer being considered for resectional surgery?
   A. Spirometry, Forced expiratory volume (FEV₁)
   B. Diffusion capacity for carbon monoxide (DLCO)
   C. Cardiopulmonary exercise testing (CPET)
   D. A & B
   E. A, B, & C

2. Patients are considered to be at low risk for cardiopulmonary complications if their predicted post-operative (PPO) FEV₁ and PPO DLCO values are:
   A. < 60%
   B. > 60%
   C. < 50%
   D. < 30%
   E. None of the above

3. The percent predicted FEV₁ includes the following patient variables:
   A. Gender
   B. Age
   C. Tobacco use
   D. Height
   E. A, B, & C
   F. A, B, & D
4. The DLCO, which helps us assess the function of the lung at the alveolar capillary membrane level, most commonly utilizes measurement of which gas
   A. carbon dioxide
   B. carbon monoxide
   C. oxygen
   D. nitrous oxide

5. When is it appropriate to utilize cardiopulmonary exercise testing (CPET) in patients undergoing lung resection
   A. PPO FEV₁ is >30% predicted or PPO DLCO >30%
   B. PPO FEV₁ is >60% predicted or PPO DLCO >60%
   C. PPO FEV₁ is <30% predicted or PPO DLCO <30%
   D. None of the above

6. True/False: The most appropriate equation used in calculation of PPO FEV₁ for a pneumonectomy takes into account the percent perfusion in the region of planned resection.
   A. True
   B. False

7. Mr. Martinez is a 70-year-old man with a history of COPD who is a 50-pack-year smoker. On CT scan of the chest, there are multiple pulmonary nodules suspicious for lung cancer noted in his right upper lobe, and he is being evaluated for potential right upper lobectomy. Initial spirometry testing reveals an FEV₁ 58% predicted, and calculated PPO FEV₁ of 49%. What would be an appropriate next step in the preoperative testing be when determining surgical candidacy and risk of postoperative complications?
   A. Complete metabolic panel (CMP)
   B. Chest X-ray
   C. Arterial blood gas (ABG)
8. Mrs. Smith is a 50-year-old non-smoking woman with no significant history of lung disease who has a suspicious mass noted on a recent chest xray. She underwent further imaging studies and is planning for potential surgical removal of the mass. Preoperative spirometry shows her FEV₁ 80% predicted and diffusion capacity PPO DLCO 89%. In this absence of any other comorbidities, Mrs. Smith has what level of risk for postoperative pulmonary complications?
   A. Low
   B. Intermediate
   C. High
   D. Surgery should not be performed

Answers: 1) D; 2) B; 3) F; 4) B; 5) C; 6) A; 7) D; 8) A