Preoperative Pulmonary Evaluation

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Educational Objectives:
1. Define perioperative pulmonary risk.
2. Review the risk factors associated with respiratory complications from non-thoracic and thoracic surgery.
3. Understand the evaluation of patients undergoing non-thoracic surgery
4. Review the objective determination of risk for patients with lung disease undergoing pulmonary resection.

Background
Perioperative pulmonary complications (PPC) are common and may contribute significantly to perioperative morbidity and mortality, hospital length of stay, and associated cost of care. Current literature varies widely in criteria to label a PPC, so incidence ranges are wide. A common definition of PPC used in several articles is the following: any pulmonary abnormality occurring in the postoperative period that produces identifiable disease or dysfunction which is clinically significant and adversely affects the clinical course.

Common PPCs:
- Respiratory infection: pneumonia or bronchitis
- Atelectasis
- Respiratory failure: hypoxemia or hypercapnia (may lead to prolonged mechanical ventilation or reintubation, use of non-invasive ventilation, use of increased F_iO_2)
- Pulmonary embolism
- Pleural effusion and pulmonary edema
- Pneumothorax
- Exacerbation of underlying lung disease

Scenario:
Ms. R. is a 35-year-old woman referred for evaluation of preoperative pulmonary risk before elective open cholecystectomy. She has cholelithiasis and has had 2 prior episodes of acute cholecystitis. Because of a previous abdominal gunshot wound and subsequent adhesions, she was advised to undergo open rather than laparoscopic cholecystectomy.

Past medical history is notable for moderate persistent asthma. She has approximately 3 exacerbations per year, requiring a course of oral corticosteroids. She was hospitalized one year ago with a severe exacerbation but did not require intubation. She is currently on high-dose inhaled corticosteroids, a long-acting beta-agonist, and a rescue short-acting beta agonist as needed. Currently, she needs to use her rescue inhaler 2-3 times per week. She is a non-smoker.

On examination, she is obese, with a BMI of 35. Vital signs are normal; O_2 saturation by pulse oximetry is 91% on ambient air. On chest examination, there are some scattered expiratory wheezes in both lungs. A cardiac examination is unremarkable. Abdominal examination is notable for mild right upper quadrant tenderness. The liver is not enlarged, and the gallbladder is not palpable.

Question 1: What are the potential risk factors of concern for Ms. R?

1. Site of surgery: Upper abdominal (including abdominal aortic aneurysm) and thoracic surgical procedures have the highest risk for postoperative pulmonary complications (Brooks-Brun, Chest 1997). Inspiratory pain, splinting, and diaphragm dysfunction are of particular concern with upper abdominal surgery, leading to decreased FRC and tidal volume (with subsequent atelectasis and hypoxemia) and impaired cough (with subsequent infection). These problems may also be complicated by the respiratory depressant effect of opioids for postoperative pain. Vital capacity may be reduced 50-60% postoperatively in these patients, and the reduction may persist for days. Other types of surgery pose less of a problem: lower abdominal surgery is associated with less reduction in VC, and extremity surgery is not associated with changes in pulmonary function. The laparoscopic approach decreases risk of postoperative complications relative to open cholecystectomy (Coccolini F, Int J Surg. 2015).

2. Underlying disease: Although COPD is associated with approximately a 2 to 6-fold increase in the risk of postoperative pulmonary complications (depending upon the severity of the COPD), the risk in patients with asthma appears to be less, and may not be increased if the asthma is well-controlled at the time of surgery (Gupta et al. Chest 2013). Other important comorbid conditions increasing the risk of postoperative pulmonary complications include:
    a. **Pulmonary hypertension** (PH) – In cardiac surgery, the negative impact of PH has been well described. In non-cardiac surgery, the perioperative risk is less clearly defined. The American Heart Association/American College of Cardiology Foundation Practice Guideline does not list PH as a risk factor. Despite the limited evidence, elective surgery in these patients is not recommended due to reported incidence of early and sudden post-operative death. The preoperative evaluation must be carefully planned among PH specialists, anesthesiology, and surgical teams. (Minai. Chest 2013)

b. **Heart failure** – associated with increased risk, OR 2.93 (CI, 1.02 to 8.43) (Smetana, Ann Intern Med 2006). It also has been shown to be a significant risk factor for postoperative respiratory failure and reintubation (OR, 2.36 [1.58-5.92]; p= 0.005). (Subramani. Anesthesiology Clinics 2018)
c. **Obstructive sleep apnea**: adds a 2 – 4 fold increased risk. Higher risk if there is also hypoventilation syndrome with daytime hypercapnia. Consider testing and initiating treatment if clinical suspicion is high (i.e., STOPBANG score ≥5) (Abdelsattar, ZM et al, Sleep 2015, Raveendran R et al., Curr Opin Anaesthesiol 2017).
d. **Interstitial lung disease**: FVC and DLCO were not predictive of increased risk for PPC in studies; however, those with low BMI (< 23 kg/m^2) and/or those undergoing emergency surgery or lung cancer resection had increased risk of PCCs (Patel. Chest 2019).
e. **Upper respiratory tract infection**: This is not clearly associated with an increased risk, but may be wise to defer elective surgery until treatment is complete/acute symptoms resolve.
f. **Neuromuscular disease**, including scoliosis and neuromuscular weakness: likely increases perioperative pulmonary risk but robust data are lacking. Preoperative inspiratory muscle training may benefit, but randomized-controlled data are lacking.

3. Obesity: Obesity has not been consistently shown to increase the risk of postoperative pulmonary complications except in patients undergoing emergency abdominal surgery (Serejo L.G.G., et al., Respiratory Medicine, 2006). Delaying elective surgery until patients have achieved weight loss may reduce risk of PPC. However, both high and low BMI can be problematic--lower BMI in patients with COPD was associated with a poorer prognosis, independent of disease severity (Subramani. Anesthesiology Clinics. 2018).

4. Other issues:
   a. **Age**: >50 years is associated with higher risk (OR of 1.5 (CI 1.31-1.71)), and the relative risk increases with each decade above 50. Age greater than 80 years was associated with 5.6 times increased risk of PCCs (Subramani. Anesthesiology Clinics. 2018).
   b. **Duration of surgery**: Longer duration (typically > 2 hours) is associated with higher risk than shorter surgery.
   c. **Anesthetic type**: General anesthesia is associated with higher risk than spinal/epidural anesthesia. The decision of anesthetic approach is usually driven by other factors. Hypoalbuminemia is a risk factor for postoperative respiratory failure.
   d. **Underlying general health status**: American Society of Anesthesiologists Classification (ASA Class). ASA class of ≥ 2 and ≥ 3 were respectively associated with a 4.87 [CI, 3.34 to 7.10] and 2.55 [CI, 1.73 to 3.76] fold increase in risk (Smetana GW et al, Ann Intern Med 2006).
   e. Smoking will be specifically addressed later in this script.

Question 2: What testing should be done before surgery that does not involve lung resection or cardiothoracic surgery?

1. Indications for spirometry: Data are conflicting about whether preoperative spirometry predicts risk for postoperative pulmonary complications. It does not appear to be as important as the site and the length of surgery. The American College of Physicians guideline from 2006 recommends that preoperative spirometry not be routinely performed. Suppose it is unclear whether patients with COPD or asthma are at their baseline. In that case, spirometry is reasonable to assess whether they are at baseline and whether they need more intensive treatment prior to surgery. There is no absolute spirometric cutoff indicating that surgery is contraindicated. There is also no expert consensus on using spirometry to risk stratify restrictive lung or neuromuscular disease, as no studies exist for this patient population (Ann Intern Med 2006).

2. Other testing: Preoperative hypoxemia or hypercapnia is not clearly associated with postoperative risk, and preoperative arterial blood gases are not generally indicated. Routine preoperative chest X-rays in the absence of known or suggested cardiothoracic disease are not indicated. There are no clear guidelines about preoperative chest X-rays in patients with known lung or heart disease. Still, they are reasonable to perform if the patients are not clinically at baseline or if there are unexplained respiratory symptoms that could indicate underlying cardiorespiratory disease.

Question 3: Are there scoring systems to predict postoperative risk?

Yes, there are, but they are not routinely used. Examples of scores include:

ARISCAT Risk Index:

Factor	Parameters	Points
Age	≤50yrs old	0
	51-80 yrs old	3
	>80 yrs old	16
Pre-operative oxygen saturation	≥96%	0
	91-95%	8
	≤90%	24
Other clinical risk factors	Respiratory infection in the last month	17
	Preoperative anemia with Hgb ≤10 g/dL	11
	Emergency surgery	8
Surgical Incision	Upper abdominal	15
	Intrathoracic	24
Duration of Surgery	≤2 hrs	0
	2-3 hrs	16
	>3 hrs	23

0-25 points: LOW risk; 1.6% pulmonary complication rate
26-44 points: INTERMEDIATE risk; 13.3% pulmonary complication rate
45-123 points: HIGH risk; 42.1% pulmonary complication rate
From Canet, et al, Anesthesiology 2010.

ARISCAT was found to be superior to ASA at predicting pulmonary postoperative risk.

Additional scoring systems to calculate postoperative risk:
1. Arozullah respiratory failure index (Arozullah et al, Ann Surg 2000 - note women were excluded)
2. Gupta calculators for postoperative respiratory failure or postoperative pneumonia (available at http://www.surgicalriskcalculator.com/prf-risk-calculator).

Scenario:
Mr. C. is a 67-year-old man with longstanding COPD and recently diagnosed non-small cell lung cancer that presented as a 4 cm RUL mass. CT-PET scan was negative for mediastinal lymph node involvement. He has a 90-pack year smoking history. He tried unsuccessfully on multiple occasions to stop smoking, and he is currently smoking ½ pack per day.

On examination, he is thin, and he breathes with pursed lips during expiration. Vital signs are normal except for an O_2 saturation of 90% on ambient air. There is no cervical or supraclavicular adenopathy. Chest examination shows diffusely decreased breath sounds with mild expiratory wheezing. Cardiac examination is notable for distant heart sounds but no murmur or gallop. There is no clubbing or peripheral edema.

Mr. C. has a thoracic surgery consultation, and the recommendation is for him to undergo thoracotomy with probable lobectomy. However, given the position of the tumor, it is possible he may need to have a pneumonectomy.

Question 4: What functional studies should be done as part of the preoperative evaluation to assess whether he has sufficient reserve to undergo lobectomy (and possibly pneumonectomy)?

The most important studies predictive of operative risk and surgical outcome are FEV1 and DLCO. Therefore, he should have preoperative spirometry and measurement of DLCO. A preoperative FEV_1 <60% is the strongest predictor of postoperative complications. Both preoperative DLCO and predicted postoperative DLCO (see Question 5) are also correlated with postoperative complications and mortality. However, ACCP guidelines do not specify an absolute threshold for preoperative FEV_1 or DLCO below which surgery should not be performed (Brunelli, et al. Chest, 2013). The British Thoracic Society (BTS) guidelines consider an FEV_1>2 L or >80% predicted to be acceptable for pneumonectomy, and an FEV_1>1.5 L to be acceptable for lobectomy. However, there is no clearly accepted lower threshold for FEV_1. In addition, the BTS guidelines were based on relatively old outcomes data, and surgical care has improved since then (BTS Guidelines, 2001).

Question 5: When is there value in predicting postoperative pulmonary function, and how is it done?

If patients do not fall into the low risk category noted above (both FEV_1 and DLCO>80%), then it may be helpful to estimate postoperative pulmonary function based upon the preoperative values, how much lung is being resected, and what is its likely contribution to

pulmonary function. The contribution of resected lung to pulmonary function can be estimated by number of segments to be removed or by perfusion lung scanning, which quantifies the perfusion to the resected area of lung relative to perfusion of the lung that will be remaining postoperatively. The perfusion method is recommended for predicting postoperative lung function after pneumonectomy, whereas the anatomic method (using the number of segments to be removed) is recommended for lobectomy.

Although a predicted postoperative FEV_1>0.8 L has been used in the past as a threshold value, using an absolute FEV_1 level can be problematic depending upon size of the patient, gender, etc (Miller JI, J Thorac Cardiovasc Surg 1993). A better option is to use a threshold value that is a percent of the patient's predicted pulmonary function. In one study, a predicted postoperative FEV1 value of 40% predicted appeared to be a good cutoff that separated low from high risk outcomes. A predicted postoperative DLCO of 40% predicted has also been used as a potential cutoff (Markos, et al. Am Rev Respir Dis, 1989).

Question 6: When does further testing need to be done?

The ACCP recommends that no further testing needs to be done if both predicted postoperative FEV_1 and predicted postoperative DLCO are >60% of the predicted normal value. If one or the other is <60% but >30%, then a "low technology exercise test" (either a stair climb or an incremental shuttle walk test) is recommended. If either FEV_1 or DLCO is <30%, then a formal cardiopulmonary exercise test is recommended with measurement of maximal O_2 consumption (a.k.a., VO_2max).

Question 7: How are the stair climb and the incremental shuttle walk tests performed?

Stair climb: ACCP uses a cutoff of 22 meters of stair climbing as predictive of high risk. If the patient is unable to climb 22 meters, then a cardiopulmonary exercise test is recommended.

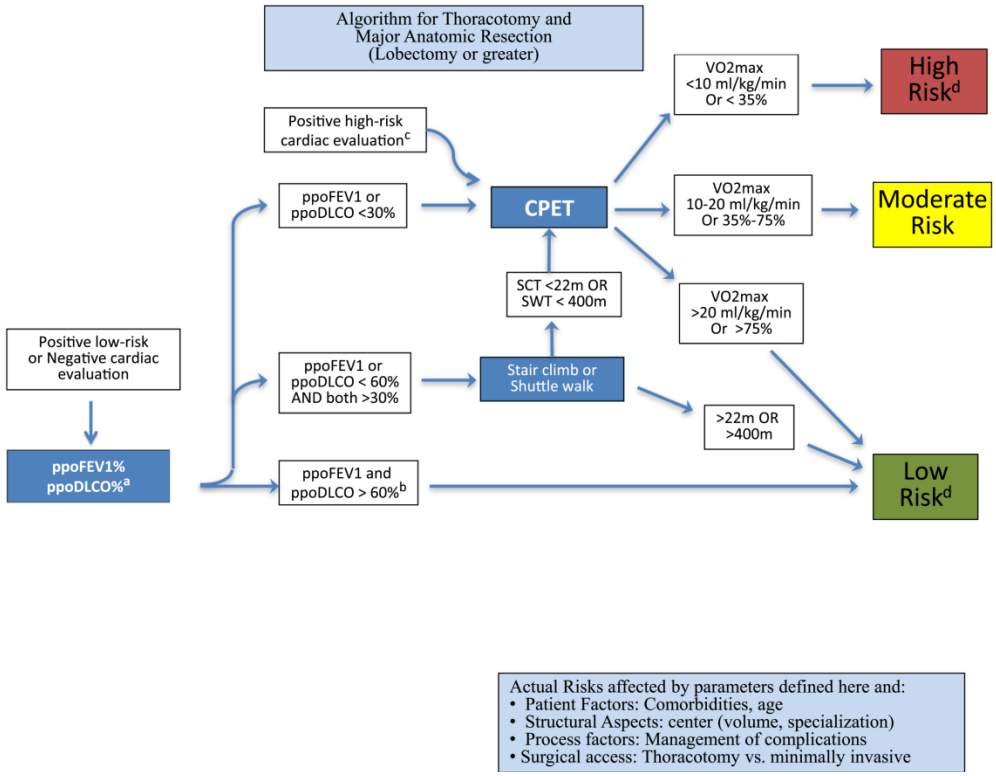
Incremental shuttle walk test: walking at progressively increasing speed for 12 minutes between cones placed 10 meters apart. Cutoff is being able to do 400 meters. If unable to do so, then a cardiopulmonary exercise test is recommended.

Question 8: What is the role of formal cardiopulmonary exercise testing (CPET)?

Formal CPET is often used when the patient's risk has not been clearly defined by the above studies, or as an alternative to the low technology exercise tests. Maximal VO_2 (VO_2max) is the measurement used to assess risk: VO_2max>20 mL/kg/min is considered acceptable for any type of resection, including pneumonectomy. VO_2max<10 mL/kg/min is considered to be high risk and unacceptable for lung resection. If the VO_2max is between 10 and 20 mL/kg/min, the predicted postoperative VO_2max should be calculated: if <10 ml/kg/min, resection correlates with a high risk of mortality and long-term disability for major anatomic resection and ideally should not be done; if >10 ml/kg/min, a shared decision-making process (with explanation of risk) should be used with the patient.

Question 9: When should surgery be performed in a smoker?

Smokers are at increased risk of postoperative pulmonary complications. The effect of current tobacco use on PPC risk was dependent on type of surgery (Schmid, M., Am J Surg 2015). If the surgery is elective, patients should minimally have a 4-week smoke-free period (and ideally an 8 week smoke-free period) before the surgery. Preoperative smoking cessation for year or greater is associated with reduced in-hospital morbidity and mortality (Turan, A., Eur J Anaesthesiology 2018). There is debate about whether the risk of postoperative complications is increased if the patient stops smoking less than 4-8 weeks before the surgery.



Algorithm from Brunelli A, et al. Chest, 2013.

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Pre/Post-Test Questions:

1. You are seeing a 55-year-old man with a history of asthma (controlled on inhaled steroids), OSA, obesity and diabetes for a pre-operative risk assessment before upcoming cholecystectomy for abdominal pain related to cholelithiasis. On exam he is well appearing, with normal vitals and a peripheral oxygen saturation of 97% on room air. Which of the following factor(s) in this patient would be associated with increased post-operative pulmonary complications?
    a. Asthma
    b. Age
    c. Site of surgery
    d. All of the above
    e. A & B
    f. B & C

2. According to published guidelines which of the following tests should be performed prior to surgery to help with risk stratification?
    a. PFTs
    b. 6MWT
    c. ABG
    d. All of the above
    e. None of the above

3. You are seeing a 72-year-old man with COPD and a 3.5 cm lung mass found to be adenocarcinoma. He has no evidence of distant spread and thus he is being considered for possible lobectomy. You order PFTs that show an FEV_1 (1.8 L) 65% predicted with a DLCO 62% predicted. Which of the following is true regarding this patient's candidacy for surgical resection?
    a. There is no clear consensus on absolute cutoffs for candidacy based on PFTs
    b. His FEV_1 would disqualify him from candidacy.
    c. His DLCO would disqualify him from candidacy
    d. Both the FEV_1 and DLCO would disqualify him from candidacy