Review Article

Pre-operative pulmonary evaluation in the patient with suspected respiratory disease

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ABSTRACT

Post-operative pulmonary complications (POPC) occur frequently, especially in patients with pre-existing pulmonary disease and have a significant effect on post-surgical morbidity and mortality. By understanding the patient's existing pulmonary diseases that have a significant effect on post-operative morbidities a combination of information has to be gathered from a thorough history and physical exam as well as selected laboratory and diagnostic tests. Evidence based scores can then be employed to predict the risk of significant POPC. Numbers and testing alone, however, such as diagnosis of chronic obstructive pulmonary disease based on spirometry, may not provide as clear a picture as of the true risk of POPC that is determined by a combination of estimations of the patient's functional status, (b) measured by the patient's estimates of activity and (c) confirmed by the patient's ability to perform simple tasks such as the 6-minute walk test. This information can then be used to rationalize perioperative interventions and improve the safety of the perioperative experience.

Key words: Anaesthesia, complications, pre-operative testing, postoperative pulmonary complications

INTRODUCTION

The preoperative evaluation of a patient's pulmonary status and estimation of functional reserve is essential as postoperative pulmonary complications (POPC) are numerous (2-7.9%)[1,2] and costly, in monetary[3] and physiologic terms.[4] Development of POPC is due to a combination of factors, including surgical pathology and existing co morbidities, as well as surgical and anaesthetic management in the perioperative period.[1-4] There are multiple evaluation scoring systems[5-9] that provide evidence based risk stratification for the prediction of POPC. However, it is often difficult to balance these well thought out and validated scoring systems with clinical practice and real world experience. This can lead to miscalculation of the risk of POPC when the mathematical formulas alone are used as predictors. Furthermore, the published literature is replete with a confusing mixture of POPC that may or may not be clinically important. With this in mind, the available data such as risk factors, physical examination findings, and diagnostic testing can be examined with an eye to their clinical utility for diagnosing and predicting clinically important POPC.

ESTIMATING THE RISK OF POST-OPERATIVE COMPLICATIONS

History and physical examination

A thorough history and physical exam remains an essential tool in estimating the severity of pulmonary compromise and the extent of pre-operative pulmonary reserve.[10-13] General appearance, muscle wasting, neck circumference, digit clubbing, cyanosis, respiratory rate and pattern, shape of the thorax, respiratory effort during conversation and with movement, etc., are all

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important clues to the patient's pulmonary status. In addition to signs and symptoms of obvious lung and lung related conditions, non-pulmonary disorders such as heart failure (HF) that increase POPC can be suspected/diagnosed by history and physical exam. Questions about daytime sleepiness, snoring, estimation/measurement of neck circumference, episodes of observed apnea and the use of standardised questionnaires (STOP-BANG, Berlin), will raise the index of suspicion for obstructive sleep apnoea (OSA), an important risk factor for the development of POPC.[2]

Patient determination of symptoms

Important elements of the patient's history and physical exam should include:

The symptoms, such as cough (AM vs. PM, production and changes in amount, color and character of secretions, etc.), shortness of breath (SOB), at rest and in response to activity, dyspnoea, and recent infections, are useful for estimating the degree of baseline pulmonary compromise. Furthermore, noting the patient's pace (speed), when walking, can provide important clues to patient function, as patients with chronic obstructive pulmonary disease (COPD) may limit their pace to combat increasing SOB and dyspnoea.[11] Patient complaints of increasing (fluid retention) or decreasing weight (malnutrition/protein deficiency/10% weight loss in the preceding 6 months) should be noted. Cardiac angina (and equivalents) as well as easy fatigability should be noted. Incidental findings, such as increasing SOB with bending forward from the waist, when standing still should lead to the suspicion of increased pulmonary pressures and the patient be evaluated appropriately. The combination of self-reported symptoms, extensive tobacco use history (greater than 20 pack/years), maximal laryngeal height of 4 cm or less, and <45 years old correlate with a diagnosis of COPD.[10]

Exposure to pulmonary toxic medication

Exposure to pulmonary toxic medications (bleomycin, amiodarone, etc.) or to environmental/occupational contamination (coal dust, second hand smoke, asbestos, etc.) is an important part of the patient's preoperative history.

Tobacco use

The amount of tobacco used can assist in judging the patient's lung status. A trigger of 20 pack/years can be used to predict the beginning of small airway compromise and airflow restrictions seen on spirometry or with other diagnostic testing even in asymptomatic patients. A significant smoking history should lead the practitioner to assume that COPD (and associated pulmonary and cardiac disorders) may be an issue with the patient, even with spirometry in the 'normal' range. The use of other inhaled tobacco products (e-cigarettes, pipes, cigars, marijuana, etc.) should also be obtained as their effects may be similar to cigarettes. Noting exposure to second hand smoke in the home or the workplace will be important.

Exercise capacity

A self-estimate of patient's exercise capacity before they note SOB is predictive of cardio pulmonary status.[10,11,14] Ability to climb 2 flights of stairs or walk approximately 0.4 miles or 350-400 m at a reasonable pace (3.5 miles/h) without SOB surpasses the threshold of 4 METS that is considered essential for elective surgery. Failure to achieve these milestones connotes a patient at increased risk for both cardiac and pulmonary complications, with higher rates of complications correlating with lower levels of activities performed.[14,15] Recent decline in activity due to pulmonary (COPD, acute bronchitis) and non-pulmonary causes (hypothyroidism, worsening peripheral vascular disease) may mask deteriorating cardio-pulmonary function. Finally, informal 'exercise testing' during the physical exam can be as simple as walking with the patient during the interview to judge their ability to exercise even to this slight degree without SOB. Dyspnoea, a measure of the work of breathing and effort, is important to ascertain.

Airway examination

A thorough airway exam cannot be over emphasized in the perioperative setting; especially in populations where head and neck pathology is common. In addition, laryngeal height[12] the distance from the top of the thyroid cartilage to the suprasternal notch, can assist in preoperative risk stratification. Laryngeal descent, the difference between minimal (measured at the end of inspiration) and maximal laryngeal height (measured at the end of expiration) and maximal laryngeal height (of 4 cm or less) may assist in 'ruling in' the diagnosis of COPD.[16]

Cardiovascular examination

Patient complaints of SOB and dyspnoea, increasing fatigue, change in weight and complaints of early satiety, lower extremity oedema, pulmonary rales,

jugular venous distention, measurement of blood pressure, and SpO_2 assist in confirming a diagnosis of HF and in establishing the functional status (New York Heart Association Classification) of the patient. After a clinical diagnosis is made additional testing such as chest radiograph (CXR), echocardiography, and laboratory testing provide important diagnostic and prognostic information.[15-19]

Lung examination

Diminished breath sounds in certain portions or over the entire lung fields correlates with the presence of significant COPD.[10] Adventitial lung sounds, wheezing, rales, and rhonchi assist in planning peri-operative interventions. A positive cough test, where the patient coughs involuntarily after deep inspiration,[10] has been associated with increased POPC.

Diagnostic and laboratory testing

Chest radiograph

A pre-operative CXR for patients with known cardiopulmonary disease undergoing high risk surgery has been recommended,[12] however, a baseline CXR is not usually a useful tool in assessing the risk of POPC.[3] The results of a screening CXR will not often alter anaesthesia planning, unless surgical planning changes. CXR rarely demonstrates a disorder that is not suspected/noted from the patient's history and physical exam. Therefore, there is little justification for a screening CXR unless indicated from the patient's medical findings and clinical course. Follow-up CXR can assist with judging the effect of a pre-operative intervention and in timing as well as planning for the surgery.

Lung computerized tomographic and magnetic resonance image scans

These may be useful in screening high risk preoperative populations for COPD[17] and lung cancer. In addition, computerized tomographic (CT) and magnetic resonance image (MRI) scanning will assist in defining the extent and severity of known disease processes and assist in clarifying abnormalities noted on CXR. However, as with CXR, the information from these studies will rarely alter anesthesia planning, if surgical planning is not altered. Finally, examination of MRI and CT scans may provide information that will assist anesthesia providers in their planning (sizing the trachea on chest MRI to plan for a double lumen endotracheal tube, estimation of total lung capacity (TLC)).

Spirometry

The measurement of lung volumes and flows will assist in confirming clinical diagnoses, defining pulmonary disease and in estimating the risk of POPC. Of the measured values the most important to anaesthesia providers are the forced expiratory volume at 1 s (FEV_1), the forced vital capacity (FVC) and their ratio (FEV_1/FVC).[5,18] An FEV_1/FVC ratio (<80%) with reduced FVC and reductions in other lung volumes suggests restrictive disease. Obstructive lung disease can also be diagnosed and quantified using spirometry. The Global Initiative for Chronic Lung Disease (GOLD) has published guidelines agreed upon definitions for diagnosing COPD and judging its severity.[19]

An FEV_1/FVC ratio of <0.70, as measured after an adequate dose of a short acting bronchodilator treatment, is consistent with a diagnosis of COPD. The stages of COPD have been classified as 'mild', FEV_1 > 80%, moderate, FEV_1 < 80->50%, severe, <50->30, and very severe, FEV_1 <30%. This is important in the perioperative period as the diagnosis of COPD is an independent and significant risk factor in the development of POPC.[4,5] However, there does not appear to be a direct correlation with spirometry results and POPC such that spirometry alone cannot be used to determine the feasibility of elective surgery.[20] Rather the totality of the patient's symptoms, functional status and spirometry will assist in estimating the postoperative pulmonary function. In addition, lung pathology may be present despite normal spirometry. Chest CT combined with 6-minute walk test (6MWT)[21] and symptomatic history-defines a population of current and former smokers with pulmonary functional impairment despite normal spirometry.[17] Use of 'lower limits of normal' (LLN)[20] for spirometry versus the GOLD definition of COPD may reduce over diagnosis in older populations while providing more accurate diagnosis in younger population (<45 years old). In high risk (thoracic and upper abdominal>lower abdominal) surgeries, spirometry assists in estimating POPC for abdominal surgery and lung reduction. Other flows and volumes that may be helpful when planning an anaesthetic intervention for patients with pulmonary disease, include total lung capacity (TLC) and vital capacity (VC). TLC, the volume of air in the lungs after maximal inspiration and VC, the maximum volume exhaled after maximal inspiration either during forced exhalation (FVC) or slow expiration (slow vital capacity) can be used to define restrictive lung disease (volumes <5% of normal). Testing for the diffusing capacity for carbon

monoxide (DLCO) can be used to differentiate intrinsic restrictive lung disease (low volumes, low DLCO) from extrinsic restrictive (neuromuscular disorders, chest wall and pleural disease-low volumes normal DLCO) disease. Obstructive spirometry values and reduced DLCO suggest emphysema.

Flow volume loops, the measure of volumes (plotted on the x-axis) and flow (y-axis) inhaled and exhaled during maximal effort over time can be helpful in anaesthesia planning. They allow evaluation of airway obstruction as well as differentiating between fixed and variable (intra- and extra thoracic) obstruction to air flow. These can be helpful in the workup of patients with unexplained dyspnoea, stridor, suspected tracheal stenosis and vocal cord pathology.[18]

Spirometry is best reserved for patients at high risk for COPD as judged by information gathered during the history and physical examination. In addition, disease progression over time as well as the effects of therapeutic interventions can be judged by serial spirometry. All patients with symptomatic complaints and spirometry defined COPD should have a trial of bronchodilator therapy (beta agonist+/−inhaled steroids, anticholinergics) (weeks to months) even if no change is noted on initial spirometry with bronchodilators.[5]

Laboratory investigations

Blood testing

Elevated blood urea nitrogen (BUN) (>30 mg/dl) is an independent risk factor for POPC.[15] Low serum haemoglobin increases the risk of POPC[7] and will influence anaesthetic planning and fluid/blood replacement in the peri operative period. Use of serum brain natriuretic peptide levels can provide useful diagnostic and prognostic information,[22-25] and may influence the choice of anaesthetic technique. Low serum albumin (<3.5 mg/dl) is also a significant predictor of POPC.[4]

Arterial blood gas analysis

Arterial blood gas (ABG) can also be used to confirm the values noted with SpO_2 as well as to determine if elevated CO_2 is present and changes are acute or chronic. However, elevated pre-operative $PaCO_2$ is not useful in predicting problems with post-operative pulmonary function. Measure of baseline oxygen saturation and PaO_2 along with hemoglobin levels will allow calculation of oxygen delivery and help with planning perioperative (supplemental) O_2 and blood replacement.

Serum cotinine levels

A byproduct of nicotine metabolism, serum cotinine levels may be helpful in determining a patient's exposure to cigarette smoking, either as a smoker or due to second hand exposure.[26,27] Normal serum cotinine levels may vary by race and ethnic origin, however.[27]

Carboxyhaemoglobin

As with cotinine, measurement of carboxyhaemoglobin which results from the avidity with which carbon monoxide and hemoglobin bind (200 - 250X O_2), may assist in determining active smokers from nonsmokers. However, environmental causes (exposure to high concentrations of carbon monoxide), medical disorders (hemolytic processes) and iatrogenic causes (phenytoin, phenobarbital, and progesterone) need to be eliminated. Finally, carboxyhaemoglobin has a relatively short half-life, 300 minutes breathing room air, therefore patients who smoke intermittent or recently quit may not show elevated carboxyhaemoglobin levels.

Exercise testing

Cardiopulmonary exercise testing (CPET) measures the maximum oxygen consumption (VO_2) and carbon dioxide production (VCO_2) while the subject uses a stationary bike (or treadmill) to exercise to maximum heart rate and respiratory rate or to until symptoms (SOB, dyspnoea, muscle fatigue). CPET measures cardiac and pulmonary function as well as muscle power and can be used to identify high (versus low) risk patients. Patients with a maximum VO2 < 10 ml/kg/m (or 35% predicted) are at an increased risk of postoperative complication and death. Maximum VO2 of between 10 and 15 ml/kg/m define increased but intermediate risk group, while maximum VO2 of >20 ml/kg/m defines a group "suitable for any type of lung surgery".[28] Field walking tests, such as 6MWT, the incremental shuttle walk test and the endurance shuttle walk test provide important information concerning the functional capacity of patients with pulmonary disease.[5,18,29-31] Of these, the 6MWT provides valuable information concerning 'functional exercise capacity', and can be helpful in judging the 'physical capacity' of patients with pulmonary disease.[21] Standards for the performance of the 6MWT have been defined by the American Thoracic[30] and European Respiratory Societies[21] although the result and calculations of work performed will vary with patient and geographic factors.[21] There is also a patient 'learning effect' (an average increase in distance walked by about 23 m

between a first and second 6MWT). This makes the second test a better measure of function than the first. A healthy subject can walk 400-700 m during the 6MWT. An increase of 35-50 m in distance walked during a 6MWT correlates with clinically significant improvements in pulmonary function. Alternatively with very severe COPD, changes in distance walked and declines in SpO_2 during the 6MWT may allow for clearer estimations of disease progression and effects of intervention than spirometry.[18] Observations on changes in heart rate and SpO_2 give important information about the patient's response to stress such as that experienced in the perioperative period.

SpO_2

Measurement of SpO_2 is a simple and non-invasive way of estimating the patient's oxygen balance (supply and demand). SpO_2 does not replace direct measurements of the patient's blood oxygen content but is a useful proxy for more expensive and invasive testing (e.g. ABG). Given the sigmoid shape of the oxygen disassociation curve, $SpO_2 > 95\%$ is 'adequate/normal' for a patient at rest while breathing room air. Patients with SpO_2 between 91% and 95% will be at increased risk for POPC with the risk increasing as the SpO_2 values fall below 90%.[7] Significant changes with exercise (5%) even when the baseline is acceptable may be indicative of patients at increased risk for POPC. Patients with resting $SpO_2 < 90\%$, requiring supplemental oxygen for sleep/performing activities of daily living, etc., or with significant decrease in SpO_2 on assuming the required surgical position (spine/prone) would seem to call into question the wisdom of elective surgery.

Diagnosis

Patients with the following medical diagnoses have been noted to be at increased risk for peri-operative pulmonary complications:

Chronic obstructive pulmonary disease

This is already discussed in one of the above sections.

American society of anesthesiologist physical status score

The subjective nature of the American Society of Anesthesiologist score (ASA PS) and the lack of inclusion of functional status in its calculation has been noted[8,9] but ASA PS>2 remains a risk factor for the development of POPC.[4,5,7]

Age

Beginning at age 50, increasing chronologic age is associated with increasing risk of POPC regardless of such factors as overall health, associated co morbidities or ASA PS.[5-7]

Poor medical condition

Inability to perform the activities of daily living without assistance or live independently correlate with increased POPC.[4] Alcohol use, unexpected weight loss (10% over the preceding 6 months), and impaired sensorium increase the risk of POPC.[4]

Heart failure

The diagnosis of HF will increase the risk of POPC. Combining diagnostic and laboratory measures of cardiac compromise and estimating functional status may yield a clearer picture of the risk of POPC associated with HF rather than 'blind' use of selected data (ex: Left ventricular ejection fraction).

Obstructive sleep apnoea

A diagnosis of OSA, whether made using a formal sleep study or suspected OSA from the use of standard criteria, increases the risk of perioperative complications including hypoxia, pneumonia, difficult intubation, unplanned inpatient and intensive care admissions, myocardial infarction and increased length of hospital stay.[32-36] The prevalence of OSA varies with the surgical population studied with about a quarter to almost a half of all surgical patients having a diagnosis or at high risk of OSA.[32,33] In special surgical populations such as bariatric (>70%), orthopaedic or neurosurgery (33- 64%) patients the prevalence of OSA may be even higher with >80% of patients undiagnosed before the pre surgical period.[32] Medications used for general anaesthesia (induction and maintenance), sedation and analgesia will all increase the pathology underlying OSA.[32,33] This appears to be due to decreased upper airway dilatory activity (propofol and inhalation agents),[36] decreases in the arousal response to airway obstruction and respiratory depression (benzodiazepines, opioids).[31] There is also sleep disruption associated with the immediate postoperative period with an absence of REM sleep for 1-2 nights after surgery. The rebound in rapid eye movement (REM) sleep may worsen OSA with increased sympathetic tone and decreased ventilation.[32] The use of continuous positive airway pressure (CPAP) therapy before surgery is the mainstay of therapy for OSA. Pre-operative use of CPAP was reported (in a small retrospective study) to reduce the rate of complications and shorten length of stay by 1 day[33] and non-compliance increasing the incidence of complications. The pre-operative

diagnosis of OSA, and assuming effective treatment and patient compliance did not lower POPC, but postoperative cardiac complications were reduced.[34]

Metabolic abnormalities

The presence of low serum albumin, elevated BUN, and low haemoglobin increases the risk of POPC. However, there is no clear evidence to prove that pre-operative correction of these factors will reduce POPC.

Smoking

Active smoking increases the risk of POPC after major surgery, but perhaps not after minor surgery.[15,37] Smoking contributes to a chronic inflammatory disorder that develops over time (weeks to years) and requires a prolonged period of abstinence (>2 months) for favorable changes to be noted. Smoking cessation immediately before surgery (hours to days) may increase the incidence of perioperative patient complaints (increased cough, sputum production, etc.). Regardless, the peri-operative period is a point at which intervention for smoking cessation may be more successful and smoking cessation should be actively counselled.

Pulmonary hypertension

Pulmonary hypertension of even mild or moderate degree increases postoperative morbidity and mortality.[5]

Surgical risk factors

The planned surgery will be among the most important risk factors to consider when evaluating the risk of POPC.[5,11] Thoracic surgery, aortic aneurysm repair, abdominal (upper> lower) surgery, neurologic surgery, vascular and head and neck surgeries should be considered high risk for the development of POPC. In addition prolonged surgery (>2 h) and emergency procedures are both independent risk factors for POPC.

Anesthetic factors

Use of general anesthesia and long acting muscle relaxant is associated with increased POPC in high risk populations.[5]

RISK SCORING

Multiple risk indices have been proposed to assist with predicting specific POPC and more general pulmonary complications. For example, the 2 separate Gupta calculators can be used to predict postoperative pneumonia or respiratory failure (failure to wean from mechanical ventilation or reintubation within 48 h) using data from large databases.[5] The Arozullah index[38] is derived from a study of more than 150 000 patients and can be used to predict the likelihood of postoperative pneumonia based on surgical intervention and multiple patient factors. The ARISCAT Risk Index,[4,5,7,39] allows the use of 7 risk factors and defines low, intermediate and high risk groups, with POPC increasing form 1.6% in the low risk group, 13.3% in the intermediate and 42.2% in the high risk group.[4,5,7,28] ARISCAT allows an easy calculation of the risk of POPC. However, even though the ARISCAT Risk Index was subsequently validated[4,5,28] in a more diverse surgical population, it has been noted that "performance differs between geographic areas".[28] Although neither designed for nor validated in a perioperative population, the American Medical Associations assessment of pulmonary dysfunction and disability may give a more complete picture of the extent of the preoperative pulmonary status and functional extent.[18]

Selective pre-operative testing can also be used to predict post-operative pulmonary function. Pre-operative FEV_1 and DLCO of >80% define a lower risk group for permanent postoperative pulmonary disability.[39] Then considering the fraction of lung tissue planned for surgical removal, a predicted postoperative FEV1 of 45-50% has been associated with "acceptable mortality".[39] Below these values the risk/benefit assessment of the proposed surgery needs to be examined and more information obtained. A lung perfusion scan can assist in determining the percentage of perfused lung that will be removed and this effect on predicted post-operative FEV_1.[39] Furthermore, the maximum ventilator volume (MVV), the maximum amount of air the patient can inhale and exhale over 12 s (extrapolated to 1 min) test both muscle power and lung function. The MVV can be thought of as 'the will to live' (author's note) with a MVV of <50% used to predict the increased risk of POPC. However, preoperative spirometry alone should not preclude a patient from planned surgery. Rather, a shared decision by physician and patient of the predicted risk/benefit ratio of the planned intervention should be the ultimate guide to surgical intervention.[39] Consensus of opinion is that lower pre-operative spirometry values do not absolutely preclude surgery.[39] However, surgeries that would leave the patient with a predicted post-operative FEV_1 of <0.8 L must be undertaken with patient participation and an honest assessment of risk/benefit ratio.

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Conflicts of interest

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Announcement

CALENDAR OF EVENTS OF ISA - 2015

Certain important dates are given here for the members. All the applications should be sent by registered post (with Acknowledgement Due)

Date	Name of the Award/Post	Application has to be sent to
30th June 2015	Bhopal Award for Academic Excellence	Hony. Secretary, ISA
15th August 2015	Prof. A. P. Singhal Life Time Achievement Award	Hony. Secretary, ISA
31st October 2015	Dr. (Mrs.) Rukmini Pandit Award - Publication format along with Conference Presentation Certificate	Hony. Secretary, ISA
31st October 2015	Y. G. Bhoj Raj Award - Best Review Article in IJA	Hony. Secretary, ISA
31st October 2015	Dr. Kop's Award	Chairman Scientific committee of ISACON with a copy to Hony Secretary ISA
27th November 2015	Dr. TN Jha Memorial & Dr. KP Chansoriya Travel grant	Hony. Secretary, ISA
27th November 2015	Late Dr. Venkata Rao Memorial Oration	Hony. Secretary, ISA
27th November 2015	Ish Narani Best Poster Award	Chairman Scientific Committee ISACON
28th November 2015	ISA GOLDCON QUIZ Competition	Chairman Scientific Committee ISACON
28th November 2015	Awards for 1. Best City Branch 2. Best State Branch 3. Best Metro Branch 4. Public Awarness Individual 5. Public Awarness City 6. Public Awarness State 7. Ether Day State 8. Ether Day City 9. Membership Drive % (State) 10. Membership Drive No.s (State) 11. Individual Drive	Hony. Secretary, ISA

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