Spectrum of postoperative complications in pulmonary hypertension and obesity hypoventilation syndrome

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Purpose of review
The purpose of this review is to identify chronic pulmonary conditions which may often not be recognized preoperatively especially before elective noncardiac surgery and which carry the highest risk of perioperative morbidity and mortality.

Recent findings
This review discusses some of the most recent studies that highlight the perioperative complications, and their prevention and management strategies.

Summary
Pulmonary hypertension is a well recognized risk factor for postoperative complications after cardiac surgery but the literature surrounding noncardiac surgery is sparse. Pulmonary hypertension was only recently classified as an independent risk factor for postoperative complications in the American Heart Association/American College of Cardiology Foundation Practice Guideline for noncardiac surgery. Spinal anesthesia should be avoided in most surgeries on patients with pulmonary hypertension because of its rapid sympatholytic effects. The presence of significant right ventricle dysfunction and marked hypoxemia should prompt re-evaluation of the need for elective surgery. Obesity hypoventilation syndrome is even harder to recognize preoperatively as arterial blood gases are generally not obtained prior to elective noncardiac surgery. Amongst patients with obstructive sleep apnea this group of patients carries much higher risk of postoperative respiratory and congestive heart failure.

Keywords
anesthesia, noncardiac surgery, obesity hypoventilation syndrome, perioperative complications, pulmonary hypertension

INTRODUCTION
Many patients with chronic pulmonary conditions are at high risk of postoperative complications. Chronic obstructive pulmonary disease for example, has been noted to be independently associated with postoperative mortality and morbidity including acute renal failure; cardiac arrest and myocardial infarction. Systemic postoperative complications related to chronic lung disease are not well characterized in literature and same holds true to a large extent about the preoperative screening and optimization of chronic pulmonary disease. Diseases like pulmonary hypertension and obesity hypoventilation syndrome (OHS) present a significant comorbid burden and are not always well recognized in terms of their severity and risk stratification particularly among patients going for elective noncardiac surgery (NCS).

PERIOPERATIVE MORBIDITY IN PATIENTS WITH PULMONARY HYPERTENSION
Pulmonary hypertension is understood to be a major contributor to postoperative morbidity and mortality after heart and lung transplantation [1], liver transplantation [2–5], and pneumonectomy. Pulmonary circulation and right ventricle (RV) function tend to be one of the most important components in the evaluation of candidacy for...
Among patients with obstructive sleep apnea; those with moderate to severe sleep apnea should be avoided in most surgeries and acute RV failure account for 19% mortality and 50% complications after cardiac transplantation [6]. Preoperative, pulmonary vascular resistance (PVR) >4 wood units (normal range 0.3–1.6 wood units) is an independent risk factor for early death after heart transplantation [7,8]. Clamping of pulmonary artery during lung implantation (single or the first lung in sequential bilateral transplant) can lead to sudden increase in pulmonary hypertension precipitating RV failure and hence the need for emergency CPB. A few centers use CPB routinely for pulmonary hypertension compared with those without pulmonary hypertension undergoing NCS, Ramakrishna et al. [13] reported 7%, 30 day mortality and found that respiratory failure (60%) and RV failure (50%) were the most frequent contributing factors. Our group reported the first ever case–control study on patients with pulmonary hypertension undergoing NCS with an overall mortality of 2.6% (OR 13); higher postoperative congestive heart failure (CHF) (OR 11.9) and statistically significant hemodynamic instability, respiratory failure and prolonged intubation; ICU & hospital length of stay, among patients with pulmonary hypertension compared with those without it [14]. Among the relatively minor surgical procedures, lung biopsy with one lung ventilation (OLV) in patients with pulmonary hypertension has been reported to be a major difficulty by several case reports [15,12,16]. Kreider et al. [17] reported two deaths and significant postoperative morbidity (50%) among eight patients (diagnosed with pulmonary hypertension on preoperative assessment) after lung biopsy. Authors propose, hypoxic pulmonary vasoconstriction as the mechanism, resulting in an intolerable rise in PVR as confirmed by response to inhaled NO and epoprostenol. Pulmonary hypertension was only recently classified as an independent risk factor for postoperative complications in the American Heart Association/American College of Cardiology Foundation Practice Guideline for NCS [18**].

**KEY POINTS**

- The presence of significant RV dysfunction and marked hypoxemia should prompt re-evaluation of the need for elective surgery.
- Spinal anesthesia should be avoided in most surgeries on patients with pulmonary hypertension because of it’s rapid sympatholytic effects.
- Among patients with obstructive sleep apnea; those with obesity hypoventilation may carry the highest risk of postoperative complications.

**Preoperative evaluation**

Preoperative evaluation for pulmonary hypertension is performed in patients undergoing cardiac surgery, but evidence has been lacking for patients undergoing NCS until recently. Signs of RV dysfunction/failure should be sought by means of thorough history and physical examination, electrocardiography and echocardiography. Cardiac catheterization should be performed where appropriate for accurate characterization of pulmonary artery pressures, cardiac output (CO), and the status of the coronary circulation. Presence of significant RV dysfunction (low CI; RAP >15 mmHg), metabolic acidosis and marked hypoxemia should prompt re-evaluation of the need for surgery. In most cardiac transplant centers, pulmonary artery systolic pressures greater than 50 mmHg and PVR >4 wood units despite optimal vasodilatation is a relative contraindication for transplantation [19]. Once diagnosed, it is a standard policy of most cardiac transplant programs to assess the potential reversibility of PVR (fall in mean PAP >25% or a fall in PVR of >33%) with the use of various pharmacologic agents and eligibility for cardiac transplantation. However, the Cardiac Transplant Research Database has not identified a cut-off value for PVR above which the risk of death after cardiac transplantation is unacceptable [20]. Inhaled nitric oxide (iNO) is the preferred agent for acute vasodilator testing but adenosine, epoprostenol and inhaled iloprost can also be used [21–23]. iNO is rapidly inactivated without any systemic side-effects but can precipitate pulmonary edema when used to reduce PVR in patients with LV dysfunction. If a patient has newly identified pulmonary hypertension and surgery cannot be delayed, a PDE5 inhibitor such as sildenafil 20–40 mg tid or iNO can be started preoperatively [24].

**Intraoperative management**

It is essential that the anesthesiologist avoid precipitating intraoperative pulmonary hypertension and...
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consequent RV failure and systemic hypotension, by avoidance of exacerbating factors such as hypothermia, hypoxia, hypercarbia, acidosis, and hypert/hypovolemia. Wherever applicable parenteral prostanoids, calcium channel antagonists, endothelin receptor antagonists, phosphodiesterase-5 inhibitors, inhaled prostacyclin analogues and oxygen, being used to treat pulmonary hypertension should be continued intraoperatively. Coumadin should be discontinued 5 days before surgery with no need for bridging but with appropriate DVT prophylaxis perioperatively. All intravenous lines and syringes must be meticulously de-aired; as even small amounts of air otherwise normally tolerated can worsen pulmonary hemodynamics [25]. Closer hemodynamic monitoring with a pulmonary artery arterial catheter may allow better maintenance of blood pressure and fluid management via assessment of pulmonary capillary wedge pressure (PCWP), CO, mixed venous oxygen saturation, and PVR, however, it may also be a risk factor for arrhythmias. Trans-esophageal echocardiography (TEE) probe can serve as an alternative to a pulmonary artery catheter, help with differentiating hypovolemia from RV failure when used in conjunction with CVP; assess RV size and function. It is important to keep in mind, that CVP is not an accurate indicator of LV preload in patients with pulmonary hypertension. At this point in time, there are no specific indications for TEE monitoring but it’s use may be particularly meaningful in patients with pulmonary hypertension undergoing major surgery with expected higher blood loss. In these types of surgery, general anesthesia (GA) with invasive monitoring is preferred over regional anesthesia.

General anesthetic agents and sedatives may produce a decrease in systemic vascular resistance which may lead to hypotension in patients with a fixed CO [26]. Spinal anesthesia should be avoided in most surgeries on patients with pulmonary hypertension because of its rapid sympatholytic effects. Etomidate is a preferred induction agent, due to it’s minimal myocardial depressant effect [27,28]. Careful combination with an opiate helps prevent or reverse sympathetic mediated increase in PVR. On the other hand, propofol and sodium pentothal decrease cardiac contractility and are best avoided. Nitrous oxide is known to increase PVR and contribute to RV failure [29,30]. Supplemental oxygen regardless of the type of anesthesia and 100% oxygen by face mask to fill the functional residual capacity (FRC) prior to induction are important. In patients with intrinsic lung disease or OSA; the risks of sympathetic stimulation from ‘awake intubation’ with fiberoptic bronchoscopy should be balanced against the benefit of avoiding a period of poor ventilation accompanied by potential hypoxia induced vasoconstriction. It is important to remember that lung volumes should be maintained at normal FRC at which PVR is the lowest; PEEP <15 mmHg and permissive hypocapnia when necessary PaCO₂ ≤30–35 mmHg [31,32].

Postoperative management

Intensive monitoring is required in the immediate postoperative period as, these patients are at risk of developing worsening pulmonary hypertension and RV ischemia as the effects of regional and inhalational anesthetics and opioids, used during surgery, wear off. Exubation should be delayed if massive/large volume resuscitation is required or any question of RV failure exists. Postoperative withdrawal of iNO or other pulmonary vasodilators can be associated with life-threatening rebound pulmonary hypertension and can be attenuated by administration of other pulmonary vasodilators like sildenafil [33]. Systemic hypotension is the most feared postoperative complication which usually occurs from RV failure from worsening of pulmonary hypertension [34]. In hypotensive patients (CVP ≤10 mmHg), intravenous (iv) fluid boluses should be considered if the mean arterial pressure increases with the patient lifting his/her legs. Episodes of hypotension can be treated with vasopressor agents such as nor-epinephrine or vasopressin. Dopamine and epinephrine can increase heart rate and myocardial oxygen consumption and are therefore less preferred [35]. In patients with frank RV dysfunction, once systemic BP is stabilized with above therapy, short-acting pulmonary vasodilators like iNO [36] or prostacyclin [37] or oral/iv sildenafil [38] can be used to reduce PVR. Management of hypotension in patients with pulmonary hypertension is better aimed at by vasopressor therapy than backing off pulmonary vasodilators being used. Sudden increases in pulmonary artery pressure should be treated with treatment of the precipitating cause (such as attenuation of noxious stimuli and treatment of hypoxia), pain management with epidural analgesia, peripheral nerve blocks and body warming blankets to minimize hypothermia can also mitigate hypoxic pulmonary vasoconstriction and elevations in PVR.

PERIOPERATIVE MORBIDITY IN PATIENTS WITH OBESITY HYPOVENTILATION SYNDROME

Compared to the eucapnic obese, patients with OHS have been reported to have higher odds of CHF; angina pectoris and cor pulmonale (OR 9); pulmonary hypertension: 30–88% and higher
mortality (23% versus 8%) [39,40]. OHS is characterized by a triad of chronic daytime hypercapnia (PaCO$_2$ ≥45 mmHg), sleep disordered breathing and obesity with a BMI >30 kg/m$^2$ [41]. ABG measurements are important for confirming chronic daytime hypercapnia, but difficult to obtain in routine outpatient preoperative settings. Moreover, the diagnosis of OHS can only be established after excluding other possible causes of hypercapnia like severe chronic obstructive pulmonary disease (COPD), severe kyphoscoliosis or interstitial lung disease and neuromuscular disorders, thereby making it difficult to establish a diagnostic cohort. Obesity surgery mortality risk score (OS-MRS); developed in patients undergoing bariatric surgery; assigns 1 point to each of five preoperative variables namely: male gender; BMI >50; pulmonary hypertension; OHS; prior thromboembolism, presence of inferior vena cava (IVC) filter. Mortality rates ranged from 0.2% (in low risk class: 0–1 morbidity) to 2.4% (among high risk class: 4–5 co-morbidities) [42].

Our group recently reported a significantly higher rate of postoperative, respiratory failure (OR: 10.9); CHF (OR: 5.4); ICU transfer (OR: 10.9); longer ICU (beta-coefficient, 0.86; SE: 0.32; $P = 0.009$) and hospital stay (beta-coefficient, 2.94; SE: 0.87; $P = 0.0008$) among patients with OHS when compared with those with OSA [43]. In obese patients (BMI ≥30 kg/m$^2$) with OSA, the presence of hypercapnia regardless of whether it was a consequence of obesity hypoventilation or associated COPD seemed to contribute the most to poor postoperative outcomes.

**INTRAOPERATIVE CONSIDERATIONS**

**Airway management**

The use of supraglottic airway devices can act as a conduit for intubation if difficult laryngoscopy is encountered or if unexpected difficulty mask ventilation occurs after induction of GA.

**Preoxygenation**

OHS patients are at risk of rapid oxygen desaturation after induction of GA due to a higher incidence of obstructed airway, a reduction in FRC as well as a high oxygen consumption [44].

Preoxygenation with 100% oxygen with a tight fitting mask in chest elevated position can prolong the time to desaturation [45].

**Choice of anesthesia technique**

Central neuraxial anesthesia techniques (spinal and epidural anesthesia) utilizing local anesthetics have the benefit of avoiding airway instrumentation and limiting the use of anesthetic agents that can contribute to an already blunted respiratory drive in patients with OHS [46]. Use of central neuraxial catheters is also recommended for lengthy surgical procedures, especially in cases performed in positions other than the supine position. This is to avoid the scenario of a resolving block in a patient positioned in the lateral or prone position, where GA cannot be readily induced. Associated left ventricular systolic and diastolic dysfunction as well as concomitant pulmonary hypertension in patients with OHS requires careful titration of induction agents to avoid unnecessary hemodynamic fluctuations.

**Patient positioning**

The head elevated laryngoscopy position (HELP)/ramp-up uses a 25 degree backup elevation to elevate the upper part of the body above the chest. Beside improving the laryngoscopic view, this position compensates for the exaggerated flexion of the neck due to the cervical pad of fat and adds advantage to respiratory mechanics [47]. Repositioning patients into this position after failed intubation can be quite tedious. While prone positioning should potentially improve lung compliance, oxygenation and ventilation, it may have a deleterious effect if incorrect positioning does not allow free diaphragmatic excursion. Resulting increased intra-abdominal and intra-thoracic pressure can worsen inferior vena caval (IVC) and aortic compression resulting in a worsening cycle of reduced venous return, reduced CO, hypoperfusion, hypoxemia and hypercarbia that can only be reversed by a change in patient position. At the conclusion of surgery, positioning the patient into the reverse trendelenburg position improves respiratory compliance, reduces alveo-arterial oxygen tension difference and improves oxygenation through an improvement in FRC. However, care must be taken to avoid unrecognized migration of the endotracheal tube (ET) into the right main stem especially with change of patient position into a trendelenburg or lithotomy position, especially because breath sounds may not be easily auscultated in this patient population. ET position can be confirmed by fiberoptic bronchoscopy. Extreme changes to patient position, such as the use of maximal flexion of the ‘kidney rest’ on the operating table, can result in rhabdomyolysis, especially with prolonged surgeries.

**Postanesthesia extubation and PAP therapy**

Following extubation criteria meticulously with an emphasis on complete reversal of muscle relaxant effect is essential in ensuring that low tidal volumes...
do not accentuate the pre-existing hypercarbia, resulting in a vicious cycle of increasing respiratory acidosis, blunted central respiratory drive and CO₂ narcosis that can ultimately result in hypoxemia when supplemental oxygen is given. It is important to note that acute respiratory acidosis augments neuromuscular blocking agent activity and interferes with its reversal. Even mild reductions in TOF ratio (<0.9) may accentuate the hypercarbia in patients with OHS.

Exubation is preferred in the semi-sitting or sitting position; thereby compensating for the reduced FRC as well as the operating table can be rapidly repositioned for reintubation if needed.

Any signs of airway obstruction should prompt the use of CPAP or noninvasive/bi-level ventilation. Use of PAP reduced postextubation respiratory failure in obese ICU patients [48].

Monitoring and opioid-induced ventilatory impairment

Opioid-induced ventilatory impairment (OIVI) is a frequent cause of postoperative hypventilation. Use of multimodal analgesic regimens to decrease the reliance on narcotics for postoperative pain; early detection of postoperative OIVI through implementation of centralized monitoring units: including centralized pulse oximetry and/or end-tidal or subcutaneous capnography monitors [49]. The Anesthesia Patient Safety Foundation (APSF) recommends continuous electronic monitoring be utilized for inpatients receiving postoperative opioids. Utilization of sedation scoring systems in postoperative patients using opioids may prove to be better than monitoring respiratory rate, which alone may not be a reliable sign of OIVI [50].

Postoperative supplemental oxygen

Recent data advise extreme caution in administration of high concentration of supplemental oxygen to this group of patients as significant decrease in minute ventilation and consequent worsening of hypercapnia have been reported [51]. In patients receiving supplemental oxygen, especially those who are receiving intravenous patient-controlled analgesia, monitors of ventilation (e.g., capnography) may be necessary to detect hypoventilation [52].

CONCLUSION

Patients with known or undiagnosed pulmonary hypertension and or OHS are at high risk for postoperative complications and proper perioperative evaluation and management are of utmost importance to optimize postoperative outcomes.

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Conflicts of interest

There are no conflicts of interest.

REFERENCES AND RECOMMENDED READING

Papers of particular interest, published within the annual period of review, have been highlighted as:

- of special interest
- of outstanding interest


This most updated version of the ACC/AHA guidelines introduces pulmonary hypertension for the first time as a preoperative risk factor based on limited evidence in literature till date.

This is the first ever case control study that compares postoperative outcomes in patients with OHS to those of patients with OSA alone.