**Perioperative Management of the Patient with Severe Lung Disease**

*From the 18th Annual Rhode Island Anesthesia Conference, presented by the Warren Alpert Medical School of Brown University and Departments of Anesthesia at the Rhode Island Hospital and Miriam Hospital*

**Peter D. Slinger, MD, Professor of Anesthesiology, University of Toronto Faculty of Medicine, Toronto, ON**

**Chronic Obstructive Pulmonary Disease (COPD)**

**Case example 1:** 60-yr-old woman scheduled for laparotomy for bowel obstruction with history of severe emphysema (forced expiratory volume in 1 sec [FEV1] 27% of predicted); medications include inhalers and steroids for exacerbations of symptoms

Bullae: should be ruled out with preoperative chest radiograph in patient with this presentation; if present, patient at risk for rupture and tension pneumothorax during general anesthesia (GA); preparation — determine location of nearest chest drain set and person responsible for performing procedure; locate double-lumen tube or bronchial blocker (in case of bronchopleural fistula), and ensure adequate support staff present (requires forethought if surgery during evening or weekend)

Pathophysiology: bullae wrongly described as positive-pressure sacs compressing surrounding lung tissue; *spider’s web model of lung* — breaking strand of web creates bulla; loss of structural support tissue occurs, with elastic recoil, but no change in pressure; pressure inside bulla equals mean alveolar pressure averaged over respiratory cycle; *mean alveolar pressure* — 2 cm H2O, and average bulla pressure less than that in surrounding lung tissue; all bullae communicate, but some very slowly (avoid nitrous oxide); *positive-pressure ventilation* — mean alveolar pressure becomes positive and size of bulla (unavoidably) increases; use pressure-control ventilation with small tidal volumes

Arterial blood gas (ABG): necessary for prediction of level of CO2 retention; preoperative PCO2 level important if postoperative ventilation anticipated; respiratory drive based on brainstem pH (7.4); case patient retains CO2 and bicarbonate and still maintains CO2 respiratory drive; hypoxic drive also present (altered from normal), and “switches on” when PO2 <60 (or 50) mm Hg (in healthy individual, threshold at 80 mm Hg); effects of postoperative supplemental O2 — patients with COPD have heterogeneous lungs (mixture of healthy and sick regions); unhealthy regions poorly ventilated (alveolar O2 low, which results in hypoxic pulmonary vasoconstriction); blood that would normally flow into unhealthy region forced into regions with better ventilation (ie, ventilation-perfusion matching); increased PO2 abolishes hypoxic pulmonary vasoconstriction and creates intrapulmonary “blood steal,” which causes excess ventilation in relation to perfusion and increased dead space

Hypercapnia: *case report* — 16-yr-old boy presented with airway packed with aspirated grain after fall into silo; PCO2 measured at 500 mm Hg; patient fully recovered without sequelae after clearing of airway and placement on ventilator support; *implications* — CO2 stored in body and not detrimental (unlike O2); CO2 ≥100 mm Hg has anesthetic effects; airway loss from hypercapnic sedation cause of death in COPD patients receiving high levels of supplemental O2; in CO2-retaining patients, supplemental O2 should be titrated and level of consciousness monitored

Administration of GA to case patient: patient underwent rapid-sequence induction with propofol, fentanyl, and rocuronium; intubation uncomplicated (bilateral ventilation achieved; end-tidal CO2 30 mm Hg); after 1 min of ventilation, heart rate increased from 80 to 96 bpm and blood pressure (BP) dropped from 120/60 to 50/30 mm Hg; absence of tracheal deviation and bilaterally equal entry of air rule out ruptured bulla

Dynamic hyperinflation: normal individuals increase expiratory flow ≥3-fold with effort, but patients with severe emphysema unable to increase flow; air flows into lungs easily, with resulting “breath stacking” and auto-positive end-expiratory pressure (PEEP), decreased venous return, severe hypotension, and potential cardiac arrest; *Lazarus syndrome* — recovery after cardiac arrest in patient with severe COPD that occurs only after discontinuation of resuscitation efforts; *treatment of dynamic hyperinflation* — involves administration of vasopressors and halting ventilation (to allow air to release from lungs);

**Educational Objectives**

The goal of this program is to improve anesthetic management of patients with severe lung disease. After hearing and assimilating this program, the clinician will be able to:

1. Explain the pathophysiology of bullae and the risks they present.
2. Use arterial blood gases to direct the anesthetic management of patients with chronic obstructive pulmonary disease.
3. Avoid or effectively treat dynamic hyperinflation.
4. Recognize differences in behavior of right-heart vs left-heart pulmonary hypertension during anesthesia.
5. Monitor right ventricular function in patients with pulmonary hypertension.

**Faculty Disclosure**

In adherence to ACCME Standards of Commercial Support, Audio-Digest requires all faculty and members of the planning committee to disclose relevant financial relationships within the past 12 months that might create any personal conflicts of interest. Any identified conflicts were resolved to ensure that this educational activity promotes quality in health care and not a proprietary business or commercial interest. For this program, Dr. Slinger and the planning committee reported nothing to disclose.
management — difficult; consists of slow respiratory rates, long expiratory times, bronchodilators (slightly beneficial), and PEEP (counterintuitive); adding PEEP to ≤50% of intrinsic PEEP decreases hyperinflation by preventing collapse of distal airways (through creation of pneumatic stent), which allows some patients (particularly those with emphysema) to breathe out more easily; ventilators in intensive care unit (ICU) measure intrinsic PEEP and show changes in total PEEP as PEEP added (measurement not available with anesthesia ventilator); instead, monitor end-expiratory flow rate (no observed increase in expiratory flow rate with addition of PEEP indicates benefit)

Thoracic epidural: respiratory complications generate greatest hospital costs for noncardiac surgery (associated increase in costs [due to increased length of stay] 3-fold higher than that with other complications); incidence of mortality due to postoperative pulmonary complications highest after abdominal surgery; conclusion — good prospective and retrospective evidence shows that use of thoracic epidural may offer case patient significant improvement in outcome

Pulmonary Hypertension

Case example 2: 54-yr-old woman scheduled for open wedge resection of recurrent left upper lobe mass; thoracoscopic resection of left upper lobe lesion performed 1 yr previously; GA uneventful during previous surgery, but patient developed deep venous thrombosis postoperatively; has history of colectomy for cancer 3 yr previously (pulmonary mass likely metastasis from colon); medical history includes COPD, hypertension, diabetes (treated with oral medication), obstructive sleep apnea, and morbid obesity, with body mass index (BMI) of 53; preoperative studies reveal FEV<sub>1</sub> drop with each attempt to discontinue vasopressors; patient comfortable after emergence but epi-

Anesthetic management: well-functioning thoracic epidural placed preoperatively (good sensory block from T4-T10); systolic BP decreased from 160 to 100 mm Hg after epidural placed; anesthesia induced with fentanyl, propofol, and rocuronium, and patient intubated; systolic BP dropped to 70 mm Hg; multiple doses of ephedrine and phenylephrine administered over 3 hr; eventually, dopamine and norepinephrine (Levophed) infusions started for persistent hypotension; patient comfortable after emergence but epidural unusable due to persistent hypotension (BP dropped with each attempt to discontinue vasopressors); patient managed with patient-controlled analgesia and developed pneumonia with prolonged ventilation in ICU (unsatisfactory outcome); surgery performed 1 yr previously — similar anesthetic (without epidural) administered, with much better outcome; pulmonary hypertension with RVSP 55 mm Hg reported in preoperative notes; echocardiography report showed pulmonary hypertension, while current report showed normal RVSP; repeat echocardiography performed 1 wk after surgery showed RSVP of 58 mm Hg; pulmonary hypertension not transient disease, but missed in study

Transthoracic echocardiography: not adequate for diagnosis of pulmonary hypertension (“can rule it in, but not rule it out”); pressure gradient between RV and right atrium measured by continuous-wave Doppler; calculations performed to find value for RVSP (equating pulmonary artery [PA] systolic pressure); error occurs if Doppler beam misplaced; under-read more common than over-read (in this case, resulted in false-negative study)

Consequences of pulmonary hypertension: places patients at high risk for respiratory complications; associated with 20% rate of delayed extubation (vs 3% in patients without pulmonary hypertension), and 10% mortality

Types of pulmonary hypertension: anesthetists and anesthesiologists encounter 2 types of pulmonary hypertension: left-sided (heart disease [eg, poor LV function, mitral valve disease]), and right-sided (related to lung disease); anesthesia providers more likely to encounter pulmonary hypertension resulting from lung disease; unlike LV, RV shows poor tolerance for sudden increases in afterload (results in drastic decrease in output)

Anesthesia recommendations: any GA (eg, propofol) acceptable; hypotension — very dangerous in patients with pulmonary hypertension; RV requires perfusion during full cardiac cycle and depends on mean arterial pressure (MAP); hypertrophic RV exquisitely sensitive and quickly develops ischemia in presence of hypotension; ideal MAP 4 times mean PA pressure; animal study suggests greater risk for hypotension with sevoflurane than with desflurane, and intermediate risk with isoflurane (more study needed); ketamine — drug of choice for patients with pulmonary hypertension; has “bad reputation” based on historical sedation studies; recent studies confirm benefits of ketamine (maintains MAP); modulators — eg, dopamine, dobutamine; useful for left-sided disease; α-agonists — eg, ephedrine, phenylephrine, nor-epinephrine, vasopressin; preferred for right-sided disease; nitric oxide — unpredictable but beneficial; access limited in operating room; prostacyclin (Flolan) nitric oxide alternative available in any hospital and delivered by nebulizer with any ventilator

Monitoring of RV: transesophageal echocardiography (TEE) — better than no monitoring, but inadequate as “minute-to-minute monitor” (better system available in ≤5 yr); PA catheter — recommended monitoring method; increase in PA pressure unfavorable, but decrease may be good or bad sign (may indicate failure of ventricle); therefore, PA pressure alone not adequate (requires concomitant measurement of cardiac output)

Thoracic epidural: many case reports in literature of good outcomes associated with lumbar epidurals for labor and delivery in patients with primary pulmonary hypertension; however, few case reports exist of use of thoracic epidural in such patients; patients with pulmonary hypertension dependent on cardiac sympathetic outflow (T2-T4), and require vasopressors or inotropic support if blocked

Summary (pulmonary hypertension): avoid hypotension; ketamine and etomidate acceptable; norepinephrine and vasopressin beneficial; nitric oxide or prostacyclin beneficial; TEE acceptable (cardiac output better); epidurals may be acceptable; avoid hypoxemia and hypercarbia
Sildenafil (Viagra): oral nitric oxide used for weaning patients on nitric oxide from ventilator; used prophylactically by mountain climbers for prevention of high-altitude pulmonary edema.

Take-home points: COPD—remember pathophysiology of bullae and CO2 retainers (CO2 retainers always show increase in CO2 with supplemental O2); avoid dynamic hyperinflation with induction of anesthesia and positive-pressure ventilation; pulmonary hypertension—remember differences in behavior between right-heart and left-heart pulmonary hypertension during anesthesia.

Acknowledgements

Dr. Slinger was recorded at the 18th Annual Rhode Island Anesthesia Conference, held March 23, 2013, in Providence, RI, and sponsored by the Warren Alpert Medical School of Brown University and Rhode Island and Miriam Hospitals. For information on upcoming meetings sponsored by the Warren Alpert Medical School of Brown University and Rhode Island and Miriam Hospitals, please visit http://brown.edu/academics/medical/education/other-programs/continuing-medical-education/. www.miriamhospital.org/continuing-medical-education, or check our website, Audio-Digest.org, under “Upcoming Meetings.” The Audio-Digest Foundation thanks Dr. Slinger and the sponsors for their cooperation in the production of this program.

Suggested Reading


Accreditation: The Audio-Digest Foundation is accredited by the Accreditation Council for Continuing Medical Education to provide continuing medical education for physicians.

Designation: The Audio-Digest Foundation designates this enduring material for a maximum of 2 AMA PRA Category 1 Credits™. Physicians should claim only the credit commensurate with the extent of their participation in the activity.

The American Academy of Physician Assistants (AAPA) accepts certificates of participation for educational activities designated for AMA PRA Category 1 Credit™ from organizations accredited by ACCME or a recognized state medical society. Physician assistants may receive a maximum of 2 AAPA Category 1 CME credits for each Audio-Digest activity completed successfully.

Audio-Digest Foundation is accredited as a provider of continuing nursing education by the American Nurses Credentialing Center’s (ANCC’s) Commission on Accreditation. Audio-Digest designates each activity for 2.0 CE contact hours.

Audio-Digest Foundation is approved as a provider of nurse practitioner continuing education by the American Academy of Nurse Practitioners (AANP Approved Provider number 030904). Audio-Digest designates each activity for 2.0 CE contact hours, including 0.5 pharmacology CE contact hours.

The California State Board of Registered Nursing (CA BRN) accepts courses provided for AMA category 1 credit as meeting the continuing education requirements for license renewal.

Expiration: The CME activity qualifies for Category 1 credit for 3 years from the date of publication.

Cultural and linguistic resources: In compliance with California Assembly Bill 1195, Audio-Digest Foundation offers selected cultural and linguistic resources on its website. Please visit this site: www.audiodigest.org/CLCresources.

Estimated time to complete the educational process:

<table>
<thead>
<tr>
<th>Activity</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Review Educational Objectives on page 1</td>
<td>5 min</td>
</tr>
<tr>
<td>Take pretest</td>
<td>10 min</td>
</tr>
<tr>
<td>Listen to audio program</td>
<td>60 min</td>
</tr>
<tr>
<td>Review written summary and suggested readings</td>
<td>35 min</td>
</tr>
<tr>
<td>Take posttest</td>
<td>10 min</td>
</tr>
</tbody>
</table>
PERIOPERATIVE MANAGEMENT OF THE PATIENT WITH SEVERE LUNG DISEASE

To test online, go to www.audiodigest.org and sign in to online services.
To submit a test form by mail or fax, complete Pretest section before listening and Posttest section after listening.

1. Pressure inside a bulla:
   (A) Is higher than in the surrounding lung tissue
   (B) Causes compression of adjacent lung tissue
   (C) Is negative compared to surrounding lung tissue
   (D) Is equal to average mean alveolar pressure

2. Patients with chronic obstructive pulmonary disease (COPD) who retain CO₂:
   (A) Are easy to predict based on physical examination
   (B) Should not have PCO₂ values >10% above baseline
   (C) Require arterial blood gases for diagnosis
   (D) Lose their CO₂ respiratory drive

3. Which of the following statements about hypercapnia is correct?
   (A) Can be caused by high levels of supplemental oxygen
   (B) High levels of CO₂ are toxic to the body
   (C) Results from decreased dead space
   (D) Deaths from hypercapnia are caused by progressive slowing of respirations

4. The key ventilatory technique for treatment of dynamic hyperinflation is:
   (A) Rapid shallow breaths
   (B) Deep sustained breaths
   (C) High-flow oxygen
   (D) Halting of ventilation

5. In order to minimize dynamic hyperinflation, positive end-expiratory pressure (PEEP) should:
   (A) Be set at twice the intrinsic PEEP
   (B) Match intrinsic PEEP
   (C) Be set at ≤50% intrinsic PEEP
   (D) Never be used

6. In right-sided pulmonary hypertension, the right ventricle is exquisitely sensitive to:
   (A) Hypotension
   (B) Hypertension
   (C) Bradycardia
   (D) Tachycardia

7. Inodilators are preferred over α-agonists for right-sided pulmonary hypertension.
   (A) True
   (B) False

8. Choose the best monitor for intraoperative management of patients with pulmonary hypertension.
   (A) Pulmonary artery (PA) pressure
   (B) PA pressure plus cardiac output
   (C) Transesophageal echocardiography
   (D) Transthoracic echocardiography

9. Which of the following statements about the use of epidurals in patients with pulmonary hypertension is correct?
   (A) Extensive case reports available for thoracic epidurals
   (B) Lumbar epidurals have proved risky in obstetric patients with primary pulmonary hypertension
   (C) Most beneficial when blocked from T2 to T4
   (D) Inotropic support or vasopressors may be necessary for patients with thoracic epidurals

10. Sildenafil (Viagra) can be used to aid in weaning nitric oxide-dependent patients from the ventilator.
    (A) True
    (B) False

Answers to Audio-Digest Anesthesiology Volume 55, Issue 31: 1-A, 2-C, 3-D, 4-B, 5-B, 6-D, 7-D, 8-A, 9-A, 10-B