Objectives

• Definition of post-operative pulmonary complications (PPC)

• Risk factors for increased PPC:
  – Patient-Related
  – Surgery-Related

• Strategies to reduce PPC:
  – Pre-op
  – Peri-op
  – Post-op
Postoperative Pulmonary Complications

- "A pulmonary abnormality that produces identifiable disease or dysfunction that is clinically significant and adversely affects the clinical course"

- PPC include:
  - Atelectasis
  - Infection, including bronchitis and pneumonia
  - Prolonged mechanical ventilation and respiratory failure
  - Exacerbation of underlying chronic lung disease
  - Bronchospasm

The frequency of PPC varies from 2-70%

- This wide range is due to:
  - Patient selection
  - Procedure-related risk factors
  - Different definitions

- Nearly 25% of deaths occurring within 6 days postoperatively are related to PPC
Perioperative Pulmonary Physiology

• Thoracic and Upper abdominal surgeries:
  – Diaphragmatic dysfunction → Pain and splinting:
    • VC ↓ 50-60% → 1 week
    • FRC ↓ 30%
  – TV ↓, Loss of sighing breaths, Increased RR
  – Depress respiratory drive:
    • Residual effect of anesthesia and Post-op opioids

• Lower Abdominal Surgery:
  – Same effects (but not as dramatic)

• Extremities Surgery:
  – No effect on lung volumes

Atelectasis and V/Q mismatch

Annals of Internal Medicine

Risk Assessment for and Strategies To Reduce Perioperative Pulmonary Complications for Patients Undergoing Noncardiothoracic Surgery: A Guideline from the American College of Physicians

Ann Intern Med. 2006; 144:575-580
### Table 1. Patient-Related Risk Factors for Postoperative Pulmonary Complications

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>Studies, n</th>
<th>Pooled Estimate Odds Ratio (95% CI)</th>
<th>P, †</th>
<th>Trim-and-FI Estimate Odds Ratio (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50-59 y</td>
<td>2</td>
<td>1.50 (1.35–1.71)</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>60-69 y</td>
<td>7</td>
<td>2.28 (1.86–2.80)</td>
<td>50.4</td>
<td>3.06 (1.65–5.64)</td>
</tr>
<tr>
<td>70–79 y</td>
<td>4</td>
<td>3.90 (2.70–5.60)</td>
<td>81.6</td>
<td>3.04 (2.31–4.39)</td>
</tr>
<tr>
<td>80+ y</td>
<td>1</td>
<td>5.63 (3.49–8.30)</td>
<td>–</td>
<td></td>
</tr>
<tr>
<td>ASA class</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>8</td>
<td>3.83 (2.84–7.10)</td>
<td>0.0</td>
<td>4.57 (1.84–7.50)</td>
</tr>
<tr>
<td>II</td>
<td>15</td>
<td>2.12 (1.71–4.48)</td>
<td>65.2</td>
<td>2.95 (1.73–4.70)</td>
</tr>
<tr>
<td>III</td>
<td>20</td>
<td>2.33 (1.50–3.63)</td>
<td>–</td>
<td>2.39 (1.12–4.80)</td>
</tr>
<tr>
<td>Anesthesia</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>General anesthesia</td>
<td>2</td>
<td>1.65 (1.36–2.01)</td>
<td>82.6</td>
<td>–</td>
</tr>
<tr>
<td>Total</td>
<td>2</td>
<td>2.31 (1.09–2.75)</td>
<td>67.9</td>
<td>–</td>
</tr>
<tr>
<td>COPD</td>
<td>8</td>
<td>2.36 (1.90–2.93)</td>
<td>82.0</td>
<td>3.71 (1.44–9.32)</td>
</tr>
<tr>
<td>Weight loss</td>
<td>2</td>
<td>1.67 (1.12–2.47)</td>
<td>91.7</td>
<td>–</td>
</tr>
<tr>
<td>Abdominal surgical condition</td>
<td>5</td>
<td>1.46 (1.10–1.92)</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Cigarette use</td>
<td>5</td>
<td>1.40 (1.17–1.63)</td>
<td>67.5</td>
<td>1.26 (1.01–1.56)</td>
</tr>
<tr>
<td>Impaired respiration</td>
<td>2</td>
<td>1.39 (1.08–1.80)</td>
<td>63.0</td>
<td>–</td>
</tr>
<tr>
<td>Corticosteroid use</td>
<td>1</td>
<td>1.33 (1.12–1.56)</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Alcohol use</td>
<td>2</td>
<td>1.24 (0.91–1.73)</td>
<td>0.0</td>
<td>–</td>
</tr>
</tbody>
</table>

* ASA = American Society of Anesthesiologists; CHF = congestive heart failure; COPD = chronic obstructive pulmonary disease.
† Estimates derived from meta-analysis of adjusted odds ratios from multivariable studies.
* When compared with patients with lower ASA class values.
### Tobacco Use

- Current cigarette smokers have an increased risk for PPC even in the absence of chronic lung disease
- Smokers with a greater than 20 pack/year smoking history have a higher incidence of PPC than those with less

### Upper Respiratory Tract Infection

- Delay surgery if possible (***)
- Prophylactic antibiotics are not helpful

<table>
<thead>
<tr>
<th>Patient-Related Risk Factors</th>
<th>Non Cardio-Thoracic Surgeries</th>
<th>OR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (60-69)</td>
<td></td>
<td>2.09 (1.65-2.64)</td>
</tr>
<tr>
<td>(70-79)</td>
<td></td>
<td>3.04 (2.11-4.39)</td>
</tr>
<tr>
<td>CLD (COPD)</td>
<td></td>
<td>1.79 (1.44-2.22)</td>
</tr>
<tr>
<td>Tobacco</td>
<td></td>
<td>1.26 (1.01-1.56)</td>
</tr>
<tr>
<td>CHF</td>
<td></td>
<td>2.93 (1.02-8.03)</td>
</tr>
<tr>
<td>Functional dependence</td>
<td></td>
<td>2.51 (1.99-3.51)</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>1.65 (1.36-2.01)</td>
</tr>
<tr>
<td>Partial</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ASA (≥ II)</td>
<td></td>
<td>4.87 (3.34-7.10)</td>
</tr>
<tr>
<td>Obesity (BMI&gt;25)</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>Asthma</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>OSA</td>
<td></td>
<td>Trend → Yes</td>
</tr>
<tr>
<td>Impaired sensorium, abn. Chest exam, ETOH, Weight loss</td>
<td>Modest increase</td>
<td></td>
</tr>
<tr>
<td>Exercise capacity, DM, HIV</td>
<td></td>
<td>-</td>
</tr>
</tbody>
</table>

*Ann Intern Med. 2006; 144:575-580*
Obesity and mild or moderate asthma are not significant risk factors for post-operative pulmonary complications after noncardiothoracic surgery.

### Table 3. Summary Strength of the Evidence for the Association of Patient, Procedure, and Laboratory Factors with Postoperative Pulmonary Complications*

<table>
<thead>
<tr>
<th>Factor</th>
<th>Strength of Recommendation†</th>
<th>Odds Ratio‡</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Laboratory tests</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Albumin level &lt; 35 g/L (3.5 g/dL)</td>
<td>A</td>
<td>2.53</td>
</tr>
<tr>
<td>Chest radiography</td>
<td>B</td>
<td>4.81</td>
</tr>
<tr>
<td>BUN level &gt; 7.5 mmol/L (&gt;21 mg/dL)</td>
<td>B</td>
<td>NA</td>
</tr>
<tr>
<td>Spirometry</td>
<td>I</td>
<td></td>
</tr>
</tbody>
</table>

*Ann Intern Med, 2006*
Pulmonary Function Testing

• Spirometry
  – Value before extrathoracic surgery remains unproven
  – There is no prohibitive spirometric threshold below which the risks of surgery are unacceptable
  – Should be reserved for patients who:
    • May not be at baseline and require more aggressive optimization
    • Unexplained dyspnea or other symptoms

Radiographic Testing

• CXR
  – 23.1% of pre-op CXR were abnormal
  – Only 3% had findings clinically important enough to influence management
  – 10% of pre-op CXR were abnormal
  – Only 1.3% showed unexpected abnormalities and only 0.1% influenced management

• May be of benefit if:
  – Known cardiopulmonary disease
  – Age>50
  – Upper abdominal, thoracic, or abdominal aortic aneurysm surgery

Smetana GW, 2002
Archer C, 1993
Procedure Related Risk Factors

- **Surgical Site & Technique**
  - Most important factor in predicting the overall risk
  - Incidence of complications is inversely related to the distance of the surgical incision from the diaphragm
  - Laparoscopic procedures better than open procedures

- **Duration of Surgery**
  - 3 to 4 hours (OR: 2.14)

- **Anesthetic Technique**
  - General anesthesia (OR: 1.83)

- **Type of NM blockade**
  - Pancuronium (long acting)

- **Emergency Surgery**
  - OR: 2.21

---

**Surgical Site**

Table 2. Procedure-Related Risk Factors for Postoperative Pulmonary Complications

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>Studies, n</th>
<th>Pooled Estimate Odds Ratio (95% CI)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surgical site</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aortic</td>
<td>2</td>
<td>6.90 (2.74–17.36)</td>
</tr>
<tr>
<td>Thoracic</td>
<td>3</td>
<td>4.24 (2.89–6.23)</td>
</tr>
<tr>
<td>Any abdominal</td>
<td>6</td>
<td>3.09 (2.54–3.77)</td>
</tr>
<tr>
<td>Upper abdominal</td>
<td>4</td>
<td>2.96 (2.40–3.63)</td>
</tr>
<tr>
<td>Neurosurgery</td>
<td>2</td>
<td>2.53 (1.84–3.47)</td>
</tr>
<tr>
<td>Head and neck</td>
<td>2</td>
<td>2.21 (1.82–2.68)</td>
</tr>
<tr>
<td>Vascular</td>
<td>2</td>
<td>2.10 (0.81–5.42)</td>
</tr>
<tr>
<td>Emergency surgery</td>
<td>6</td>
<td>2.52 (1.69–3.75)</td>
</tr>
<tr>
<td>Prolonged surgery</td>
<td>5</td>
<td>2.26 (1.47–3.47)</td>
</tr>
<tr>
<td>General anesthesia</td>
<td>6</td>
<td>2.35 (1.77–3.12)</td>
</tr>
<tr>
<td>Transfusion (&gt;4 units)</td>
<td>2</td>
<td>1.47 (1.26–1.71)</td>
</tr>
</tbody>
</table>

* Estimates derived from meta-analysis of adjusted odds ratios from multivariable studies.
† For *P* definition and values, see the Appendix, available at www.annals.org.

Ann Intern Med, 2006
Preoperative Risk Assessment

• History & Physical Exam
  – Target known risk factors
  – Cough, dyspnea, exercise intolerance
  – Sleep apnea

Assessment of Postoperative Pulmonary Risk

• Risk prediction tools have utility in stratifying risk
• Questionable utility in individual patients
• May identify candidates for preoperative risk reduction interventions or additional testing
• Several tools
  – Gupta calculator for postoperative respiratory failure and pneumonia
  – Download online for free
### Table: American Society of Anesthesiologists Classification*

<table>
<thead>
<tr>
<th>ASA Class</th>
<th>Class Definition</th>
<th>Rates of PPCs by Class, %</th>
<th>Mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>A normally healthy patient</td>
<td>1.2</td>
<td>&lt;0.03%</td>
</tr>
<tr>
<td>II</td>
<td>A patient with mild systemic disease</td>
<td>5.4</td>
<td>0.2%</td>
</tr>
<tr>
<td>III</td>
<td>A patient with systemic disease that is not incapacitating</td>
<td>11.4</td>
<td>1.2%</td>
</tr>
<tr>
<td>IV</td>
<td>A patient with an incapacitating systemic disease that is a constant threat to life</td>
<td>10.9</td>
<td>8%</td>
</tr>
<tr>
<td>V</td>
<td>A moribund patient who is not expected to survive for 24 hours with or without operation</td>
<td>NA</td>
<td>34%</td>
</tr>
</tbody>
</table>

*Information is from reference 9. ASA = American Society of Anesthesiologists; NA = not applicable; PPC = postoperative pulmonary complication.

---

### Arozullah respiratory failure index

<table>
<thead>
<tr>
<th>Preoperative predictor</th>
<th>Point value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of surgery</td>
<td></td>
</tr>
<tr>
<td>Abdominal aortic aneurysm</td>
<td>27</td>
</tr>
<tr>
<td>Thoracic</td>
<td>21</td>
</tr>
<tr>
<td>Neurosurgery, upper abdominal, peripheral vascular</td>
<td>14</td>
</tr>
<tr>
<td>Neck</td>
<td>11</td>
</tr>
<tr>
<td>Emergency surgery</td>
<td>11</td>
</tr>
<tr>
<td>Albumin &lt;3.0 g/dL</td>
<td>9</td>
</tr>
<tr>
<td>BUN &gt;30 mg/dL</td>
<td>9</td>
</tr>
<tr>
<td>Partially or fully dependent functional status</td>
<td>7</td>
</tr>
<tr>
<td>History of chronic obstructive pulmonary disease</td>
<td>6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Age</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;70 years</td>
<td>6</td>
</tr>
<tr>
<td>50 to 59 years</td>
<td>4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Class</th>
<th>Point total</th>
<th>Percent respiratory failure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>≤10</td>
<td>0.5</td>
</tr>
<tr>
<td>2</td>
<td>11 to 19</td>
<td>1.0</td>
</tr>
<tr>
<td>3</td>
<td>20 to 27</td>
<td>4.2</td>
</tr>
<tr>
<td>4</td>
<td>28 to 40</td>
<td>10.1</td>
</tr>
<tr>
<td>5</td>
<td>&gt;40</td>
<td>26.6</td>
</tr>
</tbody>
</table>


---

---
Obstructive Sleep Apnea
Postoperative Complications in Patients With Obstructive Sleep Apnea Syndrome Undergoing Hip or Knee Replacement: A Case-Control Study

RAKESH M. GUPTA, MD; JAYAJEE PARVIZ, MD; ARLEN D. HANSEN, MD; AND PETER C. GAY, MD

Any Complications
Serious Complications
Unplanned ICU
LOS(d)

Group 1A - undx OSA
Group 1B - dxed OSA, No CPAP
Group 1B - dxed OSA, Home CPAP
Control

* P < .05

Slide Courtesy of Kingman Strohl

STOP-Bang questionnaire

Yes
No

Snore?
Do you Snore Loudly (loud enough to be heard through closed doors or your bed partner allows you for snoring at night)?

Tired?
Do you often feel Tired, Fatigued, or Sleepy during the daytimes (such as falling asleep during driving)?

Observed?
Has anyone Observed you Stop Breathing or Cheeking/Gaping during your sleep?

Prescribed?
Do you have or are being treated for High Blood Pressure?

Body Mass Index more than 35 kg/m^2?

Age older than 50 year old?

Neck size larger (measured around Adams apple)
For male, is your shirt collar 17 inches or larger?
For female, is your shirt collar 16 inches or larger?

Gender = Male?

Scoring criteria*:

For general population
Low risk of OSA: Yes to 0 to 2 questions
Intermediate risk of OSA: Yes to 3 to 4 questions
High risk of OSA: Yes to 5 to 6 questions

* Per validated scoring criteria in above patients, please refer to Improve topic on surgical risk and the preoperative evaluation and management of adults with obstructive sleep apnea.

References:
Obstructive Sleep Apnea

• If preoperative evaluation suggests OSA:
  – Manage the patient perioperatively based on clinical criteria alone
  – Obtain sleep studies, and treat in advance of surgery
  – Delay surgery if elective?

• Inpatient versus Outpatient Surgery
  – Patient age, sleep apnea status
  – Coexisting diseases, nature of surgery, type of anesthesia
  – Need for postoperative opioids, adequacy of post-discharge observation,
  – Capabilities of the outpatient facility

Obstructive Sleep Apnea

• Postoperative Management
  – Nonsupine positions when possible
  – PCA pumps: avoid continuous background infusions
  – NSAIDS and other modalities (e.g., ice, transcutaneous electrical nerve stimulation) should be considered if appropriate

  – When feasible (unless contraindicated) CPAP or noninvasive positive pressure ventilation (with or without supplemental oxygen) should be continuously administered to patients who were using these modalities preoperatively
  – Have patients bring their own equipment to the hospital.
Obstructive Sleep Apnea

• Postoperative Management
  – *Supplemental oxygen* should be administered continuously to all patients who are at increased perioperative risk from OSA until they are able to maintain their baseline oxygen saturation while breathing room air
  – *However*, supplemental oxygen may increase the duration of apneic episodes and may hinder detection of atelectasis, transient apnea, and hypoventilation by pulse oximetry
  – Hospitalized patients who are at increased risk of respiratory compromise from OSA should have *continuous pulse oximetry* monitoring after discharge from the recovery room
  – *Continuous monitoring* should be maintained as long as patients remain at increased risk

Obstructive Sleep Apnea

• Criteria for Discharge to Unmonitored Settings
  – Patients at increased perioperative risk from OSA should not be discharged from the recovery area to an unmonitored setting (i.e., home or unmonitored hospital bed) until they are no longer at risk of postoperative respiratory depression.
    – *This may require a longer stay* as compared with non-OSA patients undergoing similar procedures
    – To establish that patients are able to maintain adequate oxygen saturation levels while breathing room air, respiratory function may be determined by observing patients in an unstimulated environment, preferably while asleep
Strategies to Reduce the Risk of PPC

- Pre-operative
- Intra-operative
- Post-operative
Preoperative

• **Beneficial strategies:**
  - Smoking cessation for ≥ 8 weeks
  - Inhaled ipratropium or tiotropium for all patients with clinically significant COPD
  - Inhaled beta-agonists for patients with COPD or asthma who wheeze or have dyspnea
  - Preoperative corticosteroids for patients with COPD or asthma who are not optimized to best baseline and whose airway obstruction has not been maximally reduced
  - Delay elective surgery if respiratory infection present
  - Antibiotics for patients with infected sputum
  - Patient education regarding lung expansion maneuvers

Preoperative

• **Preoperative Smoking Cessation**
  - Only one RCT of a preoperative smoking cessation intervention: 6 to 8 weeks before → 10 days after hip or knee surgery
  - Results:
    • Overall complication rates was lower in the intervention group
      – Less wound complications and urinary infections
      – Trend toward shorter hospital stay and cardiac complications
    • *Postoperative ventilatory support* was the only measured pulmonary outcome and occurred in 1 patient in each group

Møller AM et al 2002
Preoperative

- **Preoperative Smoking Cessation**
  - A cohort study showed paradoxically higher PPC rates for smokers who stopped or reduced smoking within 2 months before non-cardiothoracic surgery
  - A prospective study of 200 patients undergoing CABG:
    - Tobacco cessation ≤ 2 months vs. ≥ 2 months: PPC rate: 57.1 versus 14.5 %
    - Tobacco cessation ≥ 6 months vs. never smoked: PPC rate: 11.1 and 11.9 %

Intraoperative Care

- **Pulmonary Artery Catheter**
  - One RCT of patients ASA class III and VI:
    - No difference in mortality or post-op pneumonia
    - No beneficial effect of PAC strategy to reduce PPC
- **Anesthesia**
  - Data is insufficient
- **NM blockade**
  - Avoid long acting like pancuronium
- **Techniques**
  - Lap vs. open
Post-operative

• Lung Expansion Modalities
  – Incentive spirometry
  – Chest physical therapy, including deep breathing exercises
  – Cough
  – Postural drainage
  – Percussion and vibration
  – Suctioning and ambulation
  – Intermittent positive-pressure breathing and continuous positive-airway pressure

Post-operative

• For patients undergoing abdominal surgery, any type of lung expansion intervention is better than no prophylaxis at all
• No one modality is clearly superior
• Combined methods do not give additional benefit
• Incentive Spirometry is the least labor-intensive
Post-operative

• Selective use NGT decompression:
  – Significantly lower rate of pneumonia and atelectasis (as compared to routine use)
  – No difference in aspiration rates

• Pain Management:
  – May help minimize PPC
  – Epidural > other routes in preventing PPC

Post-operative

• Nutritional Support
  – Malnutrition and hypoalbuminemia increase the risk of PPC
  – No proven advantage to TPN over no supplementation or total enteral nutrition in reducing PPC
“I'll pause for a moment so you can let this information sink in.”

New Yorker Magazine
Recommendation 1

• All patients undergoing non-cardiothoracic surgery should be evaluated for the presence of the following significant risk factors for PPC
  – COPD
  – Age > 60 years
  – ASA ≥ II
  – Functional dependence
  – Congestive heart failure

Ann Intern Med. 2006; 144:575-580

Recommendation 2

• Patients undergoing the following procedures are at higher risk for PPC
  – Prolonged surgery (>3 hours)
  – Abdominal surgery, thoracic surgery, neurosurgery, head and neck surgery, vascular surgery, aortic aneurysm repair
  – Emergency surgery
  – General anesthesia

Ann Intern Med. 2006; 144:575-580
Recommendation 3

• A low serum albumin level (<35 g/L) is a powerful marker of increased risk for PPC
• Serum Albumin is recommended for:
  – All patients who are clinically suspected of having hypoalbuminemia
  – Patients with 1 or more risk factors for perioperative pulmonary complications

Ann Intern Med. 2006; 144:575-580

Recommendation 4

• All patients who after preoperative evaluation are found to be at higher risk for PPC should receive
  – Deep breathing exercises or incentive spirometry
  – Selective use of a nasogastric tube
    • Postoperative nausea or vomiting
    • Inability to tolerate oral intake
    • Symptomatic abdominal distention

Ann Intern Med. 2006; 144:575-580
Recommendation 5

• Preoperative spirometry and CXR should not be used routinely for predicting risk for PPC

Ann Intern Med. 2006; 144:575-580

Recommendation 6

• The following procedures should not be used solely for reducing PPC:
  – Right-heart catheterization
  – Total parenteral nutrition or total enteral nutrition (for patients who are malnourished or have low serum albumin levels)

Ann Intern Med. 2006; 144:575-580