THORACIC ANESTHESIA: AN UPDATE AND REVIEW

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THORACIC ANESTHESIA

OBJECTIVES

- ANATOMY REVIEW
- PHYSIOLOGY
- CHEST DYNAMICS
- SPONTANEOUS
- LATERAL
- CHEST CRISIS
- OPTIONS FOR LUNG ISOLATION

Diagram of Thoracic Area
The Larynx

- epiglottis
- hyoid bone
- thyroid cartilage
- cricoid cartilage
- trachea

TRACHEA & BRONCHI

- Trachea
- Trachea brachiocephalic trunk, right
- Trachea brachiocephalic trunk, left
- Trachea right mainstem bronchus
- Trachea left mainstem bronchus
- Trachea right upper lobe bronchus
- Trachea left upper lobe bronchus
- Trachea right upper lobe bronchus
- Trachea left upper lobe bronchus
- Trachea right lower lobe bronchus
- Trachea left lower lobe bronchus
LUNG RIGHT SIDE

Tracheobronchial Tree

THE BRONCHUS TO BRONCHIOLE BREAKDOWN
**BRONCHIAL DIAGRAM**

**DYNAMICS OF PULMONARY BLOOD FLOW**

- Blood flow is greatest in dependent parts of lung
- Hypoxic Pulmonary Vasoconstriction (HPV) redistributes blood away from poorly ventilated alveoli

**SPONTANEOUS VENTILATION**

Perfusion greatest at bases
DYNAMIC BLOOD FLOW IN THE LATERAL DECUBITUS POSITION

Gravity pulls blood flow to bases

Dynamics of Spontaneous Breathing
- Diaphragm descends causing a negative intrathoracic pressure
- Gas flows from higher pressure to lower pressure
- Greatest gas flow in spontaneous ventilation is to bases

SPONTANEOUS VENTILATION
Ventilation greatest at bases
Dynamics of Spontaneous Breathing

- Apex alveoli already distended from greater NEGATIVE pleural pressure thus they have less compliance to expand and receive volume increases
- Apex ribs short and expand minimally
- Base alveoli have greatest gas flow due to greater change in thoracic pressures during insp.- exp. Phases d/t insp. diaphragmatic downward movement d/t pail handle effect
- Abdominal contents pushing up and gravity pulling lungs down lessens the negative pleural pressure in bases (REMEMBER MQ/ABDOMINAL Pressures)

*Greater negative pressure in apex during end expiration- small change during inspiration

PAIL HANDLE EFFECT

- Internal intercostals, pull downward, aid expiration
- External intercostal, elevate ribs, aid inspiration
- Pneumonic: In-Ex, Ex-In
INTERCOSTALS

Note; internal and external intercostal muscles

LUNGS WANT TO RECOIL, THORACIC CAGE WANTS TO EXPAND

Thus, the pleural cavity has a vacuum (a negative pressure)
SPONTANEOUS VENTILATION

- Ventilation (V) to Perfusion (Q) well matched in spontaneous ventilating patients
- Decreasing intra-pleural pressure during inspiration draws inspired gas into bases of lung where there is the most blood flow
- Pleural pressure end exp. ~5 cm H2O
- Pleural pressure during insp. ~7.5 H2O
- Pleural pressure change 2.5 cm H2O

Thoracic Pressure Differences

- Driving pressure: Pressure difference between two points in a tube or vessel (force)
- Trans airway pressure: Barometric pressure difference between the mouth pressure and alveolar pressure
- Trans pulmonary pressure: The pressure difference between alveolar pressure and pleural pressure
- Trans thoracic pressure: The difference between alveolar pressure and the body surface pressure
- Pleural pressure: The primarily negative pressure in the pleura

Changes in lung volume, alveolar pressure, pleural pressure, and trans pulmonary pressure during normal breathing
Ventilation/Perfusion V/Q

- Ventilation is closely matched to perfusion
- Normal V/Q matching is 0.8
- Causes of mismatching include:
  - Physiologic shunt
  - Hypoventilation
  - Dead space
  - Pneumonic process

Pressure Dynamics within lung units:
- Alveolar (A)
- arterial (a)
- venous (v)

Zones of West

- Zone 1: $P_A > P_o > P_a$
- Zone 2: $P_o > P_a > P_v$
- Zone 3: $P_v > P_o > P_a$
- Blood flow
Zones of West

1. $P_A > P_a > P_v$
2. $P_a > P_A > P_v$
3. $P_a > P_v > P_A$

Zone 1

Alveolar pressure exceeds arterial exceeds venous

Zone 2

Arterial pressure exceeds Alveolar exceeds venous
Zone 3

Arterial pressure exceeds venous pressure
Alveolar

ZONES OF WEST ALVEOLI

Volume representation of end expiration to end inspiration

Mechanical ventilation

Greatest blood flow to bases
Greatest gas flow to apexes
Mechanical ventilation

Greatest gas flow to apices of lung

MECHANICAL VENTILATION

- Ventilation (V) to Perfusion (Q) poorly matched in mechanically ventilated patients
- Positive pressure ventilation pushes gas into apexes of lung. Path of least resistance. Blood perfuses primarily the dependent parts of lung again due in part to the pull of gravity

Hypoxic Pulmonary Vasoconstriction (HPV)

- HPV effectively redirects blood flow away from hypoxic or poorly ventilated lung units
- Pulmonary vascular endothelium release potent vasoconstrictor peptides called endothelins
- Volatile anesthetics above 1 MAC and nitrous oxide block HPV
MECHANICAL VENTILATION

- Gas flow to apex and blood flow to bases = V/Q mismatching
- Poorly ventilated alveoli are prone to atelectasis and collapse
- Intravascular volume, increased pressures, Pleural Effusions, Mucous plugging all causes.

ATELECTASIS

- Atelectasis is essentially collapse of pulmonary tissue that prevents O₂ & CO₂ exchange.
- Primary causes: obstruction of airway and lack of surfactant
- Absorption atelectasis is caused by occlusion of an airway with resultant absorption of trapped gas and collapse of alveoli. higher [O₂] worsens due to removal of N as an inert stabilizer
- Hypoventilation during positive pressure ventilation is often primary cause of absorption atelectasis

FACTORS THAT AFFECT ONE LUNG (OLV) AND THORACIC ANESTHESIA

- General anesthetics above 1 MAC block HPV
- Mechanical ventilation alters gas flow dynamics
- Paralysis increases resistance to gas flow
- Absorption atelectasis frequently seen to varying degrees
Worsening V/Q mismatch

<table>
<thead>
<tr>
<th>Spontaneous ventilation</th>
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<th>Positive pressure ventilation</th>
<th>Positive pressure ventilation</th>
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<tbody>
<tr>
<td>Anesthetized</td>
<td>Anesthetized</td>
<td>Paralyzed</td>
<td>Paralyzed</td>
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<tr>
<td>V/Q 0.8</td>
<td>V/Q 0.7</td>
<td>V/Q 0.5</td>
<td>V/Q 0.4</td>
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The V/Q mismatch is a combination of so many physiologic variables!

Open Chest Ventilation Dynamics

- Paradoxical ventilation
- Closed (simple) pneumothorax
- Communicating pneumothorax
- Tension pneumothorax
- Hemothorax

Closed (Simple) Pneumothorax

- No atmospheric communication
- Treatment based on size and severity—catheter aspiration, thoracostomy, observation
COMMUNICATING PNEUMOTHORAX
- Affected lung collapses on inspiration and slightly expands on expiration.
- Treatment: O2, thoracostomy tube, intubation, mech. vent.

TENSION PNEUMOTHORAX
- Air progressively accumulates under pressure within pleural cavity. Compressing other lung, great vessels.
- Treatment: Immediate needle decompression.

HEMOTHORAX
- Accumulation of blood in pleural space.
- Treatment: Airway management, support hemodynamics, evacuation.
Lung Isolation Tubes/ Techniques

- Single-Lumen Endobronchial Tubes
- Endobronchial Blockers
- Double-Lumen Endobronchial Tubes

Indications for Lung Isolation

- Control of Foreign material
- Lung Abscess, Bronchiectasis, Hemoptysis
- Airway Control
- Bronchopleural-cutaneous (B-p) fistula
- Surgical exposure
  - Lung resection
  - Esophageal surgery or Vascular (aortic) surgery
  - Video Assisted Thoracic Surgery (VATS)
- Special procedures
  - Lung lavage, Differential ventilation

Single-Lumen Endobronchial Tubes

- Utilized for several decades
- Replaced by double-lumen tubes today
- Two versions
  - MacIntosh-Leatherdale left tube
  - Gordon-Green right tube
- Disadvantages
  - Inability to clear material from operative lung
  - Potential for limited ventilation - nonintubated surgical lung
Endobronchial Blockers
Types of Bronchial blockers
- McGill catheter
- Fogerty catheter
- Foley catheter
- Univent tube
- COOK BRONCHIAL BLOCKER

UNIVENT TUBE

POSITIONING UNIVENT TUBE
COOK BRONCHIAL BLOCKER

UNIVENT TUBE + CPAP

DOUBLE LUMEN TUBES

Note difference in left and right tubes accounting for anatomical difference.
PLACEMENT DLT

Start at 3 o’clock thru cords advance as you turn to 12 o’clock position

FOB Visual Confirmation

1. Inflate the tracheal cuff.
2. Verify bilaterally equal breath sounds. If breath sounds are present on only one side, both lumens are in the same bronchus. Deflate the cuff and withdraw the tube 1 to 2 cm at a time until breath sounds are equal bilaterally.
3. Inflate the endobronchial cuff.
4. Clamp the endobronchial lumen and open its lumen cap proximal to the clamp.
5. Verify breath sounds in the correct lung and the absence of breath sounds in the opposite lung.
6. Verify that breath sounds are equal at the apex of the lung and at the lateral lung. If the apex is diminished, withdraw the tube until upper lung sounds return.
7. Verify the absence of air leakage through the opposite lumen cap.
8. Unclamp the endobronchial lumen and verify bilateral breath sounds.
9. Clamp the tracheal lumen and open its cap.
10. Verify breath sounds on the side opposite the lung with the endobronchial lumen, and the absence of breath sounds on the other.
11. When absolute lung separation is needed, as in bronchopulmonary lavage, connecting a clamped lumen to an underwater drainage system will show air bubbles if there is a leak.
ONE LUNG VENTILATION

- Ventilation/Perfusion is altered by:
  - General anesthesia
  - Lateral positioning
  - Open chest and one lung ventilation
  - Surgical manipulation
- Numerous factors affect oxygenation and ventilation

One Lung Ventilation

Oxygenation

- Amount of shunt is main component of oxygenation
- Hypoxic Pulmonary Vasoconstriction may limit shunting unless HPV is blunted
- Pulmonary pathology may limit shunting
- Lateral position decreases blood flow to Non Dependent lung by gravity
- Monitor with consistent pulse oximeter and frequent ABG’s

ONE LUNG VENTILATION

VENTILATION

- Maintain ETCO₂ as with 2-lung ventilation
- Maintain PIP below 35 cm H₂O
- Maintain minute ventilation w/o causing Auto-PEEP
- Always hand-ventilate prior to switching to or from 2-lung and 1-lung ventilation
ONE LUNG VENTILATION

- Use large TV (10-12 ml/kg)
- Ventilation rate adjusted to avoid hyperventilation
- Compliance is reduced and resistance is increased
  - (one lumen instead of two)
- PIPs will be higher
- Some auto PEEP may be generated, depend on size of DLT
- If pulse oximetry is <94% or PO₂ <100, recheck DLT or BB

O2 MANAGEMENT DURING ONE LUNG VENTILATION

- Decrease shunt & minimize VL atelectasis
- D/C or avoid N₂O prn to maintain PaO₂
- Check tube position and suction as needed
- PEEP to vented lung (may shunt blood to NVL)
- Apneic oxygenation to NVL q 10-20 minutes
- CPAP to non-ventilated lung (5-8 cmH₂O)
- Reinflate NVL w/ 100% FiO₂ prn, 2-lung vent
- Have surgeon clamp NVL PA or go to Bypass

EMERGENCE

- Prior to closing chest - Inflate lungs to 30 cm H₂O to reinflate atelectatic areas and to check for leaks
- Surgeon inserts chest tube to drain pleural cavity and aid lung reexpansion
- Patient is extubated in OR, or exchange DL-ETT for SL-ETT (HV-LP) if patient is to remain intubated
- Chest tubes to water seal and 20 cm H₂O suction, except in pneumonectomy => water seal only
- Patient transferred in head elevated position to ICU on monitors and nonrebreathing mask O₂
**LUNG ISOLATION COMPLICATIONS**

- **Trauma**
  - Dental and soft tissue injury
  - Large tube diameter causes laryngeal injury
  - Tracheobronchial wall ischemia/stenosis
- **Malposition**
  - Advancement of tube too far or too proximal
- **Hypoxemia**
- **Aspiration**

**KEY CONCEPTS**

- Spontaneous ventilation is sub-atmospheric pressure process. Gas is “sucked” in.
- Mechanical Ventilation is positive pressure, above atmospheric pressure. Gas is “pushed” in.
- Blood flow is primarily gravity dependent.
- Negative pleural pressures coupled with the pale handle effect pulls more gas to the dependant areas of lungs with spontaneous ventilation.
- Opening thorax alters negative intra-thoracic pressures altering lung dynamics ⇒ know details.
- Single lung ventilation gives 100% gas to one lung. Blood flow is split between both lungs ⇒ V/Q mismatch!

**Questions**