Breath of Life for Mom and Fetus: Mechanical Ventilation in the Pregnant Patient

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Respiratory Care Conference
18th of September, 2018
Disclosures

* No financial disclosures
Objectives

* Understand pulmonary anatomic and physiologic adaptations in pregnancy.
* Describe etiologies for respiratory failure and ARDS in pregnancy.
* Describe gas exchange for the fetus.
* Describe mechanical ventilation techniques in pregnancy.
* Management of Acute Respiratory Distress Syndrome in Pregnancy.
A 28 year old women is 28 weeks pregnant and is admitted for acute pyelonephritis. She is diagnosed with Sepsis. She is hypoxic with tachypnea and “tri-poding” with purse-lip breathing. She is contracting every 2-3 minutes and the fetal heart rate category is 2 from recurrent late decelerations.
Spirometry in Pregnancy

- Increased
  - Tidal Volume
  - Respiratory Rate
  - Minute Ventilation

- Decreased
  - Residual Volume
  - Expiratory Reserve Volume
  - Total Lung Capacity
Respiratory alkalosis is NORMAL

- pH 7.42-7.46
- PaCO2 28-32 (≤32) mmHg
- PaO2 >100 mmHg
- Bicarbonate 18-21 (≤22)

*7.43/32/105/21/0*

- Goal PaO2 for fetal perfusion is ≥70 mmHg or SaO2 ≥95
- Goal pH 7.25-7.45 (may need to avoid permissive hypercapnia)
Hemoglobin-Oxygen Dissociation is Unchanged
Etiology of Respiratory Failure

- “Direct Injury”
  - Aspiration, pneumonia, pulmonary contusion (trauma), inhalational injury, fat emboli, drowning, IV contrast

- “Indirect Injury”
  - Sepsis, TRALI, trauma, DIC, head trauma, pancreatitis, reperfusion injury, anaphylactoid reaction of pregnancy (AFE)

- Pregnancy Specific
  - Preeclampsia, tocolytics, acute fatty liver, amniotic fluid embolism
Workup

* History & Physical
* Labs to consider
  * Arterial blood gas
  * Complete blood count
  * Chemistries
  * Brain natriuretic peptide/troponins
  * Blood, sputum, and/or other cultures
  * Drug screen
* Electrocardiogram
* Imaging
  * Roentograph, echocardiogram, computed tomography
Acute Respiratory Distress Syndrome (ARDS)

- Etiology as above
- Incidence is increasing
  - 36.5 per 100,000 live births (2006)
  - 59.6 per 100,000 live births (2012)
- Mortality rate about 9%
* Same Berlin Criteria
  * Timing: within 7 days of known insult
  * Imaging: roentograph or computed tomography of patchy bilateral infiltrates or opacities (excluding effusion, lobar collapse, or nodules)
  * Pulmonary origin: not cardiogenic nor fluid overload
  * Hypoxemia: PaO₂/FiO₂<300 with PEEP ≥5
    * Mild P/F = 200-299
    * Moderate P/F = 100-199
    * Severe P/F <99
Pulmonary Insult → Pulmonary Inflammation

- Neutrophil Recruitment
- Epithelial and Endothelial Injury
  - Hyalinization
  - Cellular Edema
    - Protein Leakage: “loss of oncotic pressure”
    - Fluid and debris in alveoli
    - Reduction of surfactant

- Pulmonary artery vasoconstriction
  - Right Ventricle Wall Stress
    - Acute MI
    - CHF

- Reduced O2 Diffusion and Hypoxia
  - Reduced Lung Compliance
Early-stage ARDS

Damaged alveolar epithelium and capillary endothelium

Protein Fluid
Blood Flow Distribution

Normal 60% → ARDS 40%

Normal 100% → ARDS + PEEP 75%

Normal + PEEP 100% → ARDS + PEEP 90%

Oxygen Saturations

LA 90% 95%
Our patient was diagnosed with acute respiratory failure with hypoxia and ARDS.

So what does inadequate oxygenation and ventilation do to the fetus? What is the pathway of O2 and CO2 to the baby?
Oxygen Pathway

Air or Ventilator → Maternal lung → Circulation: (Hemoglobin) (Dissolved) → Uterus → Placenta → Umbilical Artery (CO₂, O₂) → Umbilical Vein → Fetal Circulation (Hemoglobin) (Dissolved) → Fetal Tissues

Drowning, low FiO₂, Inappropriate ventilator settings

Inflammation, Pneumonia, ARDS

Heart failure, pulmonary embolism, Anemia, aorto-caval compression

Shock states, hypotension

Placenta infarcts, abruption,

Vessel occlusion (kinks)

Fetal anemia, heart failure, cardiac abnormalities, hyperthyroidism
True Knot

Picture courtesy of Scott A Harvey, MD
Fetal Hemoglobin

* Fetal hemoglobin
  * Normal PaO2 is 35-40 mmHg
  * PaO2 of 18-19 mmHg reflects hypoxemia and late decelerations
  * Δ Maternal PaO2 >>>> Δ Fetal PaO2 (rapid offloading)

Fig. 2 Oxygen dissociation curves for fetal and adult blood. The $P_{50}$ value is 3.6 kPa for fetal blood and 4.8 kPa for adult blood.
Fetal physiology

Maternal Dysoxia
- Maternal anaerobic metabolism
- Reduced maternal oxygen delivery
  - Maternal acidemia and lactic acidosis
    - Reduced maternal pH
    - Reduced blood flow to placenta
- Placenta
  - Placental vasoconstriction
  - Low fetal Oxygenation

Fetal Dysoxia
- Fetal acidemia

Fetal Asphyxia
Fetal physiology

Fetal Dysoxia
(Low PaO2 in umbilical Vein)

Fetal adrenergic response -> HTN ->
carotid/aortic sinus ->
CN IX brain stem ->
CN X

Fetal carotid/aortic bodies -> CN IX -> Brain Stem -> CN X

Persistent Hypoxia

Fetal anaerobic metabolism

Reduced maternal pH and/or Increased CO2

Fetal acidemia

Myocardial depression
Case Study

* How do we manage respiratory failure in pregnancy?
Treat the underlying cause!!!
- Judicious use of fluids (euvolemia)
- Stop tocolytics?
- Intubation and mechanical ventilation
- Adjunctive treatments
- Deliver?
- ECMO?
Indications for Mechanical Ventilation

- Hypoxia refractory to treatment (PaO2<70)
- Hypercarbia (PaCO2 >40)
- Increased work of breathing
- Severe metabolic acidosis
- Need for sedation/neuromuscular blockade
- To reduce systemic or myocardial oxygen consumption
- Increase intracranial pressure
- Altered mental status
- Anticipated massive resuscitation*
- Transport*
Mechanical Ventilation in Pregnancy

- Endotracheal tubes
- Modes of ventilation
- Goals of ventilation
- Adjuncts
- Positioning
- Fetal preparation
Mechanical Ventilation in Pregnancy

- **Endotracheal tubes**
  - Modes of ventilation
  - Goals of ventilation
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Endotracheal tubes

- Subglottic suctioning
- Placement same as non-pregnant
- Smaller size
- Consider video laryngoscope
- Anchor instead of taping (diaphoresis and swelling)
Mechanical Ventilation in Pregnancy

- Endotracheal tubes

- **Modes of ventilation**
  - Goals of ventilation
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  - Fetal preparation
Modes of Ventilation

* Pressure control ventilation
  * Spontaneous
  * Bi-Level
  * Synchronized intermittent mandatory ventilation
  * Airway pressure release ventilation
* Volume control
  * Assist control
  * Synchronized intermittent mandatory ventilation
* High frequency oscillatory ventilation
Low tidal volume ventilation (6 mL/kg)

Ideal body weight

- $45.5 + 2.3 \times \text{height in inches} - 60$
- $45.5 + 0.91 \times \text{height in centimeters} - 152.4$

Avoid permissive hypercapnia if it causes acidemia (acidosis means acidotic baby)

Ideal FiO2 ≤0.5

Ventilator alarms
Mechanical Ventilation in Pregnancy

- Endotracheal tubes
- Modes of ventilation

**Goals of ventilation**

- Adjuncts
- Positioning
- Fetal preparation
Goals of ventilation

- ABG goals
- High PEEP, low tidal volume ventilation
- Low peak inspiratory and peak plateau pressures
- Relatively higher respiration rate to achieve minute ventilation (however, avoid breath stacking)
- Shortest duration of mechanical ventilation
Mechanical Ventilation in Pregnancy

* Endotracheal tubes
* Modes of ventilation
* Goals of ventilation

* **Adjuncts**
* Positioning
* Fetal preparation
Adjuncts

* PPI or H2 blocker
* Decontamination of oral mucosa
* Humidification
* Chemoprophylaxis from DVT/PE
Adjunctive therapies

- Methylprednisolone and Hydrocortisone ok in pregnancy
- Sedation
- Paralytics
- Nitric oxide
Mechanical Ventilation in Pregnancy

- Endotracheal tubes
- Modes of ventilation
- Goals of ventilation
- Adjuncts
- **Positioning**
- Fetal preparation
Positioning

- Head of bed $>30$ degrees
- Avoid supine position
- Left and right tilt $>20$ degrees
- Proning is possible...
Mechanical Ventilation in Pregnancy

- Endotracheal tubes
- Modes of ventilation
- Goals of ventilation
- Adjuncts
- Positioning

* Fetal preparation
Cardiac monitoring
- Continuous pulse oximetry
- End-tidal capnography
- Vital signs
- Arterial blood gases
- Chest roentographs
- At least daily monitoring to liberate from mechanical ventilation
- **FETAL MONITORING if viable and desiring intervention for decelerations.**
Fetal preparation

- Fetal resuscitation equipment and warmer
- Delivery equipment
- Fetal monitoring
- Neonatology and obstetric involvement
- Institution appropriate for patient
Emergencies with intubation

* DOPE – Dislodgement, Obstruction, Pneumothorax, Equipment failure
* Hypoxia
  * Tension pneumothorax
  * Bronchial main-stem intubation
  * Inadequate settings
  * Esophageal intubation
* Hypotension
  * Intravascular depletion
  * Tension pneumothorax
* Fetal bradycardia
  * Usually from hypotension or acidemia
Other considerations

* Continued poor response:
  * Delivery?
  * Change ventilator settings?
  * ECMO?
- H1N1 epidemic
- Study of about 78% survival rate (median duration of 14 days)
- Earlier ECMO may aid in survival and prolonged gestation
Pregnancy induces a respiratory alkalosis.

Pregnant women should have slight alteration in management when in respiratory failure, but management is mostly conserved.

Goals for pregnancy include PaO2 ≥70mmHg, SaO2 ≥95%, and pH 7.25-7.45.

The fetus serves as a great therapeutic endpoint of managing respiratory failure, but fetal asphyxia has multiple etiologies.
Key References

* Fundament of Critical Care Support, sixth edition. Society of Critical Care Medicine