RESPIRATORY FAILURE IN PREGNANCY

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Disclosures

- I have no financial disclosures
Objectives

At the end of this lecture, the participant should be able to:

- Discuss the physiologic changes of pregnancy that effect the respiratory system
- Identify the most common causes of respiratory distress in pregnancy
- Implement a treatment plan for acute respiratory failure during pregnancy
Respiratory insufficiency

- The most common indication for during pregnancy for admission to a critical care unit accounting for 25% of patients.
- Complicates 0.1% to 0.2% all pregnancies
Physiologic Changes

- Hyperventilation
  - Begins in the 1st trimester
  - Increases by 48% at term
    - Stimulated by progesterone
  - Due to an increase in minute ventilation which increases 20% to 40% above baseline
Physiologic Changes

- Oxygen consumption increased by 20%
- FEV$_1$ remains unchanged
- Tidal volume is increased
- Decreased in functional residual capacity by 18%
- Pulmonary vascular resistance decreases by 34%
- Colloid osmotic pressure decreases by 14%
Physiologic Changes

- **Respiratory Alkalosis**
  - Compensated renal acidosis, pH remains unchanged
  - Resting arterial CO2 tension about 30 mmHg or less
  - Resting arterial O2 tension about 105 mm Hg
  - Shift of oxygen dissociation curve to the right
Changes in ventilation during pregnancy

Time course of percent increases in minute ventilation, oxygen uptake, and basal metabolism during pregnancy. Redrawn from Prowse, CM, Gaensler, EA, Anesthesiology 1965; 26:381.
Changes in pulmonary function tests during pregnancy

Serial measurements of lung volume compartments during pregnancy. Functional residual capacity decreases approximately 20 percent during the latter half of pregnancy, due to a decrease in both expiratory reserve volume and residual volume.

Redrawn from Prowse, CM, Gaensler, EA, Anesthesiology 1965; 26:381.
Respiratory Distress

- Differential Diagnosis
  - Pulmonary
    - Asthma exacerbation
    - Pulmonary infections
    - Pulmonary edema
    - Systemic Inflammatory Response (Adult Respiratory Distress Syndrome)
    - Pulmonary Embolism
    - Air Embolism
  - Non-pulmonary
    - Anxiety
    - Drugs
    - Myocardial infarction
    - Thoracic aortic dissection
    - Acute chest syndrome
    - Amniotic fluid embolism
Respiratory Failure

- Inadequate gas exchange due to
  - Pulmonary conditions
  - Extra-pulmonary conditions

- Type 1 failure
  - Hypoxemia

- Type 2 failure
  - Hypercapnia
The Mechanics of Breathing

- **Inhalation**
  - Oxygen flows into the lungs through the diaphragm.

- **Exhalation**
  - Carbon dioxide flows out of the lungs as the space inside the chest decreases.
  - The diaphragm moves upward.
Physiology of gas exchange

Gas exchange between alveoli and capillaries

- Oxygen diffuses into red blood cells
- Carbon dioxide diffuses into alveolus
Respiratory Shunt

- Pulmonary Capillary
- Collapsed Alveolus
- Consolidated or Fluid-Filled Alveolus
- Non-oxygenated Blood

2 Types of Shunts
<table>
<thead>
<tr>
<th>P/F Ratio</th>
<th>Equivalent to a PaO2 on room air</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥ 400</td>
<td>≥ 80</td>
<td>Normal</td>
</tr>
<tr>
<td>&lt; 400</td>
<td>&lt; 70</td>
<td>Hypoxemia</td>
</tr>
<tr>
<td>&lt; 300</td>
<td>&lt; 60</td>
<td>Acute respiratory failure</td>
</tr>
<tr>
<td>&lt; 250</td>
<td>&lt; 50</td>
<td>Severe acute respiratory failure</td>
</tr>
<tr>
<td>&lt; 200</td>
<td>&lt; 40</td>
<td>Critical acute respiratory failure</td>
</tr>
</tbody>
</table>
Oxygen Pathway

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

- Drowning, low FiO₂, inappropriate ventilator settings
- Inflammation, Pneumonia, ARDS
- Heart failure, pulmonary embolism, Anemia, aorto-caval
- Shock states, hypotension
- Placenta infarcts, abruption,
- Vessel occlusion (kinks)
- Fetal anemia, heart failure, cardiac abnormalities, hyperthyroidism
I can't hold my breath much longer!
Respiratory Failure

- **Evaluation**
  - Examine the patient
  - Assess oxygen saturation
    - Less than 95% in pregnancy is concerning
  - Assess ventilation
    - Remember Type 2 failure
  - Assess respiratory rate
    - >30
Clinical Key Questions ????

- Does the patient appear to be becoming unstable?
- What are your available resources?
- Can the patient maintain adequate oxygenation using your current therapy?
- What is the status of the fetus?
- Does the patient have a full stomach?
Maternal stabilization
- Consider early intubation and airway protection

Fetal intervention—yes or no

Investigation and treatment of the underlying causes
Intermediate Therapies

Short term support for complications that may reverse rapidly

- Mask oxygen
- Non-re-breather mask
- CPAP mask
- Laryngeal cuff
Indications for Mechanical Ventilation

- Hypoxia
- Hypercapnia
- Increased work of breathing
- Severe metabolic acidosis
- Need for sedation
- Reduce myocardial or systemic oxygen demand
- Altered mental status
Objectives of Mechanical Ventilation

**Improve pulmonary gas exchange**
- *Reverse* hypoxemia/hypercapnia and *Relieve* acute respiratory acidosis

**Relieve respiratory Distress**
- Decrease oxygen cost of breathing and reverse respiratory muscle fatigue

**Alter pressure-volume relations**
- Prevent and reverse atelectasis
- Improve Compliance
- Prevent further injury

**Permit lung and airway healing**

**Avoid complications**
Things to consider with Intubation

- Placement of ET tube
  - Laryngeal edema and need for a smaller size tube
  - Video laryngoscope
  - Failure 8x more likely in pregnancy
Let's Make A Breath

- PEEP
- Tidal Volume
- Pressure
- Respiratory Rate
- FIO2
Mode of Ventilation

- Pressure control ventilation
  - Bi-level
  - Synchronized intermittent mandatory ventilatory support
  - Airway pressure release ventilation

- Volume control
  - Assist Control
  - Synchronized intermittent mandatory ventilatory support

- High frequency oscillatory ventilation
Ventilator Setting

- **Tidal Volume**

**Alveolar Protection**

- Vt is the amount of gas delivered with each breath
- Consider starting at ~6-8 ml/kg
  - Predicted body weight
  - 45.5 + 2.3(height in inches) - 60
Inspiratory Flow Rate

Patient Comfort

- Remember we breathe in a decelerating flow pattern
  - Initial setting-60L/min
  - Titrate to patient comfort
- Failure to pay attention to this parameter may increase sedation needs
Respiratory Rate

Titrating Ventilation

- PaCO₂ is your goal
- Initial rate-15 to 18 breaths/min
  - May increase to high as 30 to 40 breaths/min
- Consider use of end tidal CO₂
- PEEP and FiO2
  - Titrating Oxygenation
- Start with FiO2 of 100%
- Start with PEEP of 5 mmHg
- Decrease FiO2 to 30-40% as soon as possible
- Titrade PEEP using scale from ARDSnet ARMA trial
### ARDSnet Protocol

#### Lower PEEP/higher FiO2

<table>
<thead>
<tr>
<th>FiO2</th>
<th>0.3</th>
<th>0.4</th>
<th>0.4</th>
<th>0.5</th>
<th>0.5</th>
<th>0.6</th>
<th>0.7</th>
<th>0.7</th>
</tr>
</thead>
<tbody>
<tr>
<td>PEEP</td>
<td>5</td>
<td>5</td>
<td>8</td>
<td>8</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>12</td>
</tr>
</tbody>
</table>

#### Higher PEEP/lower FiO2

<table>
<thead>
<tr>
<th>FiO2</th>
<th>0.7</th>
<th>0.8</th>
<th>0.9</th>
<th>0.9</th>
<th>0.9</th>
<th>1.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>PEEP</td>
<td>14</td>
<td>14</td>
<td>14</td>
<td>16</td>
<td>18</td>
<td>18-24</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>FiO2</th>
<th>0.3</th>
<th>0.3</th>
<th>0.3</th>
<th>0.3</th>
<th>0.3</th>
<th>0.4</th>
<th>0.4</th>
<th>0.5</th>
</tr>
</thead>
<tbody>
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<td>PEEP</td>
<td>5</td>
<td>8</td>
<td>10</td>
<td>12</td>
<td>14</td>
<td>14</td>
<td>16</td>
<td>16</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>FiO2</th>
<th>0.5</th>
<th>0.5-0.8</th>
<th>0.8</th>
<th>0.9</th>
<th>1.0</th>
<th>1.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>PEEP</td>
<td>18</td>
<td>20</td>
<td>22</td>
<td>22</td>
<td>22</td>
<td>24</td>
</tr>
</tbody>
</table>
Peak Pressures

Alveolar Safety

- Goal is to keep 30-35 cm H2O

- Remember structural issues unique to pregnancy
  - Heavier chest wall due to breast enlargement
    - Patient positioning
## Strategies for Mechanical Ventilation in Pregnancy

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tidal Volume</td>
<td>5-8 ml/kg PBW</td>
</tr>
<tr>
<td>Inspiratory Rate</td>
<td>60 L/min</td>
</tr>
<tr>
<td>Respiratory Rate</td>
<td>15-18 breaths/min</td>
</tr>
<tr>
<td>Oxygen Saturation Goal</td>
<td>≥95%</td>
</tr>
<tr>
<td>Carbon dioxide Goal</td>
<td>Avoid hypercapnia, mild hypercapnia &lt;50 may be ok</td>
</tr>
<tr>
<td>PEEP</td>
<td>5 mm Hg</td>
</tr>
<tr>
<td>Peak pressure limit</td>
<td>30-35 cmH20</td>
</tr>
</tbody>
</table>
When should I deliver the fetus?

- Consider delivery after 34 weeks gestation if prolonged illness is expected.
- No data to suggest delivery improves maternal outcomes:
  - 10 patients
  - Delivery reduced oxygen requirements by 28%
  - No change in lung compliance

Adjunctive Therapies

- **Corticosteroids**
  - Remember that betamethasone is a large steroid dose
  - May be useful in ARDS due to direct pulmonary injury
  - Use after 14 days may increase mortality
Sedation

- Not contraindicated in pregnancy
- May cause changes in fetal heart rate
  - Decrease variability
  - Decreased baseline
- Decreases maternal oxygen consumption
<table>
<thead>
<tr>
<th>Agents</th>
<th>Dose</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morphine sulfate</td>
<td>1-10 mg/h</td>
<td>Avoid in renal failure. Increased histamine release with potential hypotension.</td>
</tr>
<tr>
<td>Fentanyl</td>
<td>25-100 μg/h</td>
<td>Minimal histamine release. High-dose boluses may lead to chest rigidity. Consider in setting of hypotension or renal failure.</td>
</tr>
<tr>
<td>Hydromorphone</td>
<td>0.2-2 mg/h</td>
<td>No active metabolites. Consider in setting of hypotension or renal failure.</td>
</tr>
<tr>
<td>Remifentanil</td>
<td>0.5 μg/kg bolus followed by infusion at 0.5-2 μg/kg/min</td>
<td>Half-life of 3 min. Metabolized by plasma esterases.</td>
</tr>
<tr>
<td>Lorazepam</td>
<td>1-10 mg/h</td>
<td>High doses may be associated with propylenglycol accumulation. No active metabolites.</td>
</tr>
<tr>
<td>Midazolam</td>
<td>1-10 mg/h</td>
<td>Active metabolites, avoid in renal disease.</td>
</tr>
<tr>
<td>Propofol</td>
<td>5-50 μg/kg/min</td>
<td><strong>Causes vasodilation and decreased cardiac output.</strong> High doses lead to propofol infusion syndrome.</td>
</tr>
<tr>
<td>Dexmedetomidine</td>
<td>0.2-1.5 μg/kg/h</td>
<td>No respiratory depression. Avoid in setting of hypotension of bradycardia. Less incidence of delirium.</td>
</tr>
<tr>
<td>Vecuronium</td>
<td>Bolus of 0.1 mg/kg followed by infusion at 1-2 μg/kg/min</td>
<td>Avoid in renal or liver failure.</td>
</tr>
<tr>
<td>Cisatracurium</td>
<td>0.2 mg/kg followed by infusion at 2-4 μg/kg/min</td>
<td>Metabolized by Hofmann reaction. Intrinsic anti-inflammatory properties.</td>
</tr>
</tbody>
</table>
Paralytics

- Patient should be sedated prior to use
  - Vecuronium
  - Cisatracurium
- While they cross the placenta in small amounts, little effect on fetus
Other anti-inflammatory agents

- Activated protein C has been shown to reduce morbidity in patients with sepsis

Nitric Oxide

- May be useful in patients with pulmonary hypertension

Surfactant

- Initial trials disappointing, new clinical trials underway
Principles of ECMO

- Basic principle
  - De-saturated blood is drained via venous CO2 is removed, O2 added through an “extracorporeal” device (an oxygenator), and the blood is then returned to systemic circulation via another vein (VV) or artery (AV)
ECMO outcome

- 18 patients
  - 4 were pregnant
- Median maternal age-32.6 years
- Median gestational age-32 weeks
- Maternal survival
  - 16 out of 18-(88.9%)
- Fetal survival-(77%); 100% if viable
- 4 patients delivered on ECMO
Viral pneumonia in pregnancy

- Increased mortality rates when compared to the general population
  - 2009-H1N1
    - 32% admission rate
    - 6 maternal deaths
  - COVID-19
    - Small case study – Wuhan
    - 9 patients; 9 live births
    - 0 maternal deaths
Conclusions

- Respiratory failure complicates 1 in 500 pregnancies
- Understanding respiratory physiology in pregnancy is important to recognizing failure
- Identifying the underlying cause may dictate treatment plan
Selected References