Respiratory failure: the Pregnant patient

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Toronto
Disclosures

- No conflicts of interest

- By the nature of the topic and the lack of literature in pregnancy, some interventions described may be “off label”
Objectives

- Respiratory physiology in pregnancy
- Causes of respiratory failure in pregnancy
- ICU management during pregnancy
How common is acute respiratory failure in the pregnant or postpartum patient?

<table>
<thead>
<tr>
<th>Characteristic (N = 41)a</th>
<th>Developingb (n = 16)</th>
<th>Developedb (n = 25)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Study duration (years), mean ± SD</td>
<td>5.4 ± 2.9</td>
<td>7.4 ± 3.6</td>
<td>0.06</td>
</tr>
<tr>
<td>Participants</td>
<td>73 (30–1,902)</td>
<td>65 (18–754)</td>
<td>0.81</td>
</tr>
<tr>
<td>Deliveries during study period</td>
<td>28,209 (5,764–822,591)</td>
<td>24,347 (2,724–82,623)</td>
<td>0.92</td>
</tr>
<tr>
<td>Incidence of ICU admission during study period</td>
<td>2.7 (1.3–13.5)</td>
<td>3.0 (0.7–8.8)</td>
<td>0.52</td>
</tr>
<tr>
<td>Maternal deaths (%)</td>
<td>14.0 (0.0–40.0)</td>
<td>3.4 (0.0–18.4)c</td>
<td>0.002</td>
</tr>
<tr>
<td>Overall proportion of ICU admissions (%)</td>
<td>2.4 (0.5–16.0)</td>
<td>1.5 (0.4–12.0)</td>
<td>0.38</td>
</tr>
<tr>
<td>Received mechanical ventilation (%)</td>
<td>41.0 (3.0–100.0)</td>
<td>41.5 (13.0–76.0)</td>
<td>0.60</td>
</tr>
<tr>
<td>Hypertensive disease of pregnancy (%)</td>
<td>39.8 (10.0–74.0)</td>
<td>32.5 (13.0–88.0)</td>
<td>0.93</td>
</tr>
<tr>
<td>Hypertensive disease of pregnancy (per 1,000 deliveries)</td>
<td>1.1 (0.2–6.7)</td>
<td>0.9 (0.2–4.7)</td>
<td>0.75</td>
</tr>
<tr>
<td>Obstetric haemorrhage (%)</td>
<td>25.0 (8.5–53.0)</td>
<td>21.5 (5.0–46.5)</td>
<td>0.85</td>
</tr>
<tr>
<td>Obstetric haemorrhage (per 1,000 deliveries)</td>
<td>0.8 (0.4–1.8)</td>
<td>0.6 (0.1–2.3)</td>
<td>0.27</td>
</tr>
<tr>
<td>Sepsis/infection (%)</td>
<td>5.0 (0.0–17.0)</td>
<td>4.8 (0.0–24.0)</td>
<td>0.85</td>
</tr>
<tr>
<td>Sepsis/infection (per 1,000 deliveries)</td>
<td>0.2 (0.0–2.3)</td>
<td>0.1 (0.0–0.9)</td>
<td>0.62</td>
</tr>
<tr>
<td>Other direct obstetric complications (%)</td>
<td>4.5 (0.0–30.0)</td>
<td>5.8 (0.0–55.0)</td>
<td>0.31</td>
</tr>
<tr>
<td>Other direct obstetric complications (per 1,000 deliveries)</td>
<td>0.1 (0.0–1.6)</td>
<td>0.2 (0.0–3.4)</td>
<td>0.95</td>
</tr>
<tr>
<td>Non-obstetric diagnoses (%)</td>
<td>21.5 (6.5–43.0)</td>
<td>25.8 (0.0–47.0)</td>
<td>0.92</td>
</tr>
<tr>
<td>Non-obstetric diagnoses (per 1,000 deliveries)</td>
<td>0.9 (0.2–2.2)</td>
<td>0.7 (0.0–3.0)</td>
<td>0.99</td>
</tr>
<tr>
<td>Anaesthetic complications (%)</td>
<td>0.3 (0.0–26.0)</td>
<td>0.0 (0.0–22.0)</td>
<td>0.83</td>
</tr>
<tr>
<td>Anaesthetic complications (per 1,000 deliveries)</td>
<td>0.0 (0.0–0.5)</td>
<td>0.0 (0.0–0.6)</td>
<td>0.71</td>
</tr>
</tbody>
</table>

Pollock et al, Int Care Med  2010, 36:1465
How common is acute respiratory failure in the pregnant or postpartum patient?

- 0.2 - 0.4% of deliveries require ICU
  - respiratory failure accounts for 40 - 50%
  - ie. about 1-2 per 1000 deliveries

- Account for about 1% of ICU admissions
- Vast majority admitted postpartum
Respiratory physiology in pregnancy
Anatomic effects

- airway edema, friability
- widened AP and transverse diam.
- elevated diaphragm
- widened subcostal angle
- enlarging uterus

Functional effects
Anatomic effects

- airway edema
- friability
- widened AP and transverse diam.
- elevated diaphragm
- widened subcostal angle
- enlarging uterus

Functional effects

- increased respiratory drive
- minimal change in TLC
- increased Vt
- reduced FRC
- normal diaphragmatic function
- increased $O_2$ consumption and $CO_2$ production
Anatomic effects

- airway edema, friability
- widened AP and transverse diam.
- elevated diaphragm
- widened subcostal angle
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Functional effects

- increased respiratory drive
- minimal change in TLC
- increased Vt
- reduced FRC
- normal diaphragmatic function
- increased O\textsubscript{2} consumption and CO\textsubscript{2} production
Blood gases in late pregnancy

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>7.43</td>
</tr>
<tr>
<td>PaCO₂</td>
<td>30 mmHg</td>
</tr>
<tr>
<td>PaO₂</td>
<td>105 mmHg</td>
</tr>
<tr>
<td>HCO₃⁻</td>
<td>20 mEq/L</td>
</tr>
</tbody>
</table>

- hyperventilation
- normal a-A gradient
- renal compensation

Decreased oxygen reserve
- reduced FRC
- increase O₂ consumption
% change from baseline
Fetal Oxygenation

Determinants
- placental function
- uterine oxygen delivery
Fetal Oxygenation

Determinants

- placental function
- uterine oxygen delivery
  - Maternal oxygen content
  - Uterine blood flow
Fetal Oxygenation

Determinants

- Placental function
- Uterine oxygen delivery
  - Maternal oxygen content
  - Uterine blood flow
    - Normally maximally dilated
    - Decreased by catecholamines, alkalosis, hypotension, contractions
Fetal Oxygenation
Causes of respiratory failure in pregnancy

- Pregnancy specific:
- Aggravated by pregnancy
- Other
Causes of respiratory failure in pregnancy

- **Pregnancy specific:**
  - Preeclampsia and pulmonary edema
  - Amniotic fluid embolism
  - Tocolytic induced pulmonary edema

- **Aggravated by pregnancy**
  - Gastric acid aspiration
  - Venous thromboembolism
  - Sepsis and ARDS
  - Cardiac failure

- **Other**
  - Pneumonia
  - Asthma
  - Neuromuscular disease
ARDS in pregnancy

- pre-eclampsia
- obstetric sepsis
- amniotic fluid embolism
- aspiration
- TRALI
- placental abruption

Catanzarite, Obstet Gynecol Survey 1997, 52:381
ARDS in pregnancy

- Important cause of maternal death
- Pregnant women appear more susceptible:
  - Reduced serum albumin
  - Increased blood volume
  - Upregulation of components of the inflammatory response in the lung

Catanzarite, Obstet Gynecol Survey 1997, 52:381
H1N1 in Pregnancy

- Increased risk of severe disease
  - 7 - 9% of ICU patients (1% of population)

- Major risks to fetus
  - Fever
  - Hypoxemia

- Management
  - Oseltamivir
  - Optimize oxygenation
Restrictive lung disease

- **Parenchymal disease**
  - eg. IPF, sarcoid, connective tissue disease

- **Chest wall abnormalities**
  - eg. kyphoscoliosis, osteogenesis imperfecta

- **Neuromuscular disease**
  - eg. myopathy, spinal muscular atrophy
Restrictive Lung Disease in Pregnancy

- Retrospective chart review:
  - Pregnant women with restrictive lung disease (FVC < 70% predicted)

- 12 patients with 15 pregnancies
  - Kyphoscoliosis (6) total 8 including NMD
  - Parenchymal lung disease (4)
  - Neuromuscular disease (with kyphoscoliosis) (2)

*Lapinsky et al, Chest (in press)*
<table>
<thead>
<tr>
<th>Measure</th>
<th>Pred.</th>
<th>Actual</th>
<th>%Pred.</th>
</tr>
</thead>
<tbody>
<tr>
<td>TLC (Pleth) (L)</td>
<td>3.76</td>
<td>2.01</td>
<td>53</td>
</tr>
<tr>
<td>IC (L)</td>
<td>1.74</td>
<td>0.59</td>
<td>34</td>
</tr>
<tr>
<td>SVC (L)</td>
<td>2.71</td>
<td>0.89</td>
<td>33</td>
</tr>
<tr>
<td>RV (Pleth) (L)</td>
<td>1.04</td>
<td>1.12</td>
<td>107</td>
</tr>
<tr>
<td>RV/TLC (Pleth) (%)</td>
<td>28</td>
<td>56</td>
<td>201</td>
</tr>
<tr>
<td>FVC (L)</td>
<td>2.71</td>
<td>0.87</td>
<td>32</td>
</tr>
<tr>
<td>FEV1 (L)</td>
<td>2.16</td>
<td>0.86</td>
<td>40</td>
</tr>
<tr>
<td>FEV1/FVC (%)</td>
<td>80</td>
<td>99</td>
<td>125</td>
</tr>
<tr>
<td>FEF 50% (L/sec)</td>
<td>2.71</td>
<td>2.69</td>
<td>99</td>
</tr>
<tr>
<td>FEF 75% (L/sec)</td>
<td>1.36</td>
<td>1.46</td>
<td>108</td>
</tr>
<tr>
<td>Raw (cmH2O/L/s)</td>
<td>2.98</td>
<td>1.06</td>
<td>36</td>
</tr>
<tr>
<td>MIP (cmH2O)</td>
<td>-90</td>
<td>-85</td>
<td>95</td>
</tr>
<tr>
<td>MEP (cmH2O)</td>
<td>153</td>
<td>110</td>
<td>72</td>
</tr>
</tbody>
</table>
Restrictive Lung Disease in Pregnancy

Results:

- Small changes in lung functions:
  - Increase, same, decrease (<15%)
  - Not related to underlying disease

- Supplemental oxygen
  - Required in 3 pregnancies (20%)
  - NIV required by 1 patient
  - Post-delivery ventilation required by 1 patient
Delivery - mode

- C-section: 10/15
- Vaginal: 5/15
- Neuraxial
- General
Delivery - mode

- C-section (10/15)
- Vaginal (5/15)
- Neuraxial
- General
- Spontaneous labour

- FVC 64% predicted
- FCV 26% predicted
- Preeclampsia

Conditions:
- Parenchymal
- Kyphoscoliosis
- Neuromuscular
Outcome

- **Maternal:**
  - 2 ICU admissions
  - All patients survived

- **Neonatal**
  - 5 required NICU care
  - All survived to hospital discharge
Respiratory failure in pregnancy

Management
ICU Management of OB Patients

Obstetrician/Maternal-Fetal Medicine
0.2 to 0.5% of patients require ICU

Intensivist
1 – 2% of patients are OB
0.1% are pregnant

Obstetric Medicine
Other consultants:
Hematology
Rheumatology
Cardiology
Dietitian
Respiratory failure in pregnancy

- ICU must be prepared
Respiratory failure in pregnancy

- **ICU must be prepared:**
  - **Drugs:** oxytocin, Hemabate, ergotamine
  - **Equipment:** Vaginal delivery, Caesarean delivery, Neonatal resuscitation
  - **Decisions:** fetal resuscitation status
  - **Contact details:** OB, anesthesia, neonatology
Non-invasive Ventilation

- **Advantages**
  - avoids the upper airway
  - avoids sedation

- **Concerns**
  - nasal congestion
  - reduced lower esophageal sphincter tone
  - aspiration
Non-invasive Ventilation - Role

- Acute respiratory failure
  - Pulmonary edema (preeclampsia, cardiogenic)
  - Other (eg. asthma, pneumonia)

- Chronic respiratory failure
  - Neuromuscular disease
  - Kyphoscoliosis
  - Bronchiectasis

Endotracheal intubation in pregnancy

Failed intubation 8x more common than non-pregnant patient

Affected by
anatomical changes
aspiration risk
weight gain
reduced oxygen reserve
preeclampsia

Munnur et al, Crit Care Med, 2005, 33:S259
Mechanical Ventilation in Pregnancy

Intubation

- **Indications**
  - Remember normal PaCO$_2$ levels

- **Tube size**
  - eg. 6.5 to 7.5

- **Airway friability**
  - Avoid nasal route

- **Aspiration**
  - delayed gastric emptying, increased abdominal pressure

- **Oxygen desaturation**
  - reduced O$_2$ reserves
**Conventional Ventilation**

- **Oxygenation**
  - optimize: $\text{PaO}_2 > 90 \text{ mmHg}$

- **Ventilation**
  - normal $\text{PaCO}_2$ 30 mmHg
  - permissive hypercapnia?
  - avoid alkalosis

- **Pressure**
  - respiratory system compliance
  - adequate PEEP
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**Conventional Ventilation**

- **CO₂ goal in pregnancy**
  - Limited animal and human data
  - \( \text{CO}_2 \) gradient required for \( \text{CO}_2 \) excretion
  - Maternal \( \text{PaCO}_2 \) < 25 mmHg is associated with fetal hypoxia and acidosis, due to reduced uterine blood flow
  - Mild hypercapnia produces fetal acidemia secondary to maternal acidemia, but NOT fetal hypoxemia
  - Mild ↑\( \text{CO}_2 \) associated with better APGARs than ↓\( \text{CO}_2 \)
  - Maternal \( \text{PaCO}_2 \) of 52 mmHg well tolerated (case report)

*References*

Peng et al, Br J Anaesth 1972, 44:1173
Buss Am J Physiol 1975; 228:1497
Clark Anesth Analg 1971; 50:713
Hollmen, Acta Anaesth Scan 1972, 221
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- **Ventilation**
  - normal $\text{PaCO}_2$ 30 mmHg
  - permissive hypercapnia?
  - avoid alkalosis

- **Pressure**
  - respiratory system compliance is reduced
  - adequate PEEP
Mechanical Ventilation in Pregnancy

Less Conventional Ventilation

- Prone positioning
  - no data on maternal or fetal effects

- Nitric oxide
  - little data, case reports in Pulm HTN

- HFO
  - Recent experience during H1N1

- ECMO
  - Australian case-series during H1N1
Mechanical Ventilation in Pregnancy

Sedation & NM blockade

- No completely “safe” drugs
- Opiates: most OK
- Benzodiazepines: cross placenta, potential problems. We use midazolam
- Propofol: short term OK? Propofol syndrome in mother and fetus?
- Neuromuscular blockers: cross placenta
- Delivery: warn neonatologist!
Risks of an ICU stay to the fetus

- Review of 93 pregnant women admitted to ICU (Mayo Clinic 1995-2005)
- Fetal loss
  - 1st trimester: 65% spontaneous abortion
  - 2nd trimester: 43% fetal loss
  - 3rd trimester: 5% fetal loss
- Risk factors for fetal loss:
  - Maternal shock
  - Maternal transfusion
  - Lower gestational age

Cartin-Ceba et al, Crit Care Med 2008; 38:2746
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  - Maternal transfusion
  - Lower gestational age
## Table 2. Maternal clinical management and outcome, n (%)

<table>
<thead>
<tr>
<th>Need for vasopressors</th>
<th>Yes</th>
<th>4 (67)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No</td>
<td>2 (33)</td>
</tr>
<tr>
<td>Use of hemodialysis</td>
<td>Yes</td>
<td>2 (33)</td>
</tr>
<tr>
<td></td>
<td>Tamiflu</td>
<td>6 (100)</td>
</tr>
<tr>
<td>Maternal outcomes</td>
<td>Death</td>
<td>2 (33)</td>
</tr>
<tr>
<td></td>
<td>Survival</td>
<td>4 (67)</td>
</tr>
<tr>
<td></td>
<td>Iatrogenic medical complications</td>
<td>2 (33)</td>
</tr>
</tbody>
</table>

## Table 3. Obstetrical and neonatal management and outcome

<table>
<thead>
<tr>
<th>Obstetric status and outcome</th>
<th>n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gestational age at end of pregnancy (n = 6), weeks</td>
<td></td>
</tr>
<tr>
<td>≤14</td>
<td>1 (16.7)</td>
</tr>
<tr>
<td>15–28</td>
<td>1 (16.7)</td>
</tr>
<tr>
<td>≥29</td>
<td>4 (66.6)</td>
</tr>
<tr>
<td>Antenatal complications (n = 6)</td>
<td></td>
</tr>
<tr>
<td>Gestational hypertension</td>
<td>1 (16.5)</td>
</tr>
<tr>
<td>PPROM</td>
<td>1 (16.5)</td>
</tr>
<tr>
<td>Preterm labour</td>
<td>1 (16.5)</td>
</tr>
<tr>
<td>Pregnancy outcome (n = 6)</td>
<td></td>
</tr>
<tr>
<td>Stillbirth</td>
<td>1 (16.7)</td>
</tr>
<tr>
<td>Live birth</td>
<td>4* (66.6)</td>
</tr>
<tr>
<td>SA</td>
<td>1 (16.7)</td>
</tr>
<tr>
<td>Mode of delivery (n = 5)</td>
<td></td>
</tr>
<tr>
<td>SVD</td>
<td>2 (40)</td>
</tr>
<tr>
<td>CS</td>
<td>3 (60)</td>
</tr>
<tr>
<td>NICU admissions</td>
<td>3 (60)</td>
</tr>
<tr>
<td>Length of NICU admission, days,</td>
<td></td>
</tr>
<tr>
<td>Survivors (2)</td>
<td>mean 23.5</td>
</tr>
<tr>
<td>Non-survivors (1)</td>
<td>2</td>
</tr>
<tr>
<td>Neonatal outcomes (n = 4)</td>
<td></td>
</tr>
<tr>
<td>Death</td>
<td>1 (25)</td>
</tr>
<tr>
<td>Survival</td>
<td>3 (75)</td>
</tr>
<tr>
<td>Without sequelae of HIE</td>
<td>2 (50)</td>
</tr>
<tr>
<td>With sequelae of HIE</td>
<td>1 (25)</td>
</tr>
<tr>
<td>Evidence of HIE on investigation</td>
<td>2†</td>
</tr>
</tbody>
</table>
Radiological Procedures

Fetal risk

- oncogenicity
  - increased incidence of childhood leukemia (RR 1.5 - 2.0)
  - associated with 1 - 5 rads
  - 1 childhood cancer death per 1,700 1 rad exposures

- teratogenicity
  - fetal exposure 10 to 50 rads
  - 10 - 20 in first 6 weeks gestation

- neurological development
  - 5-30 rad at 8-15 weeks

Fetal exposure (rad)
- chest XR 0.001
- V/Q 0.060
- CT angio 0.100
- CT pelvis/abdo 5.0

National Radiological Protection Board, 1998
Ratnapalan et al, CMAJ 2008; 179:1293
Radiological Procedures

- **Consider risk-benefit**
  - Don’t avoid necessary studies, eg. CT angio
  - Don’t do unnecessary, eg. daily CXR, lateral
  - Remember contrast for CT angio may carry risk

- **Screen abdomen**
  - Reduce exposure by 50%
  - Still internal scatter, use Barium swallow?

- **Discuss with mother and father**
  - Perceived risk very high (parents and family doc)
  - Can be a major source of concern

National Radiological Protection Board, 1998
Ratnapalan et al, CMAJ 2008; 179:1293
Delivery of the fetus

- Given the physiological changes, it may be considered that delivery of the pregnant women with respiratory failure is beneficial to the mother.
Delivery of the fetus

- Given the physiological changes, it may be considered that delivery of the pregnant women with respiratory failure is beneficial to the mother.

- **NOT always the case:**
  - Some oxygenation improvement
  - Little change in compliance or PEEP requirement

Delivery of the fetus

- Given the physiological changes, it may be considered that delivery of the pregnant women with respiratory failure is beneficial to the mother.
  - Not always the case:
    - Some oxygenation improvement
    - Little change in compliance or PEEP requirement

- Delivery:
  - If fetus is viable and at risk due to maternal hypoxia
  - Not purely to improved maternal condition
