Mechanical ventilation in Pregnancy

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Toronto
How common is acute respiratory failure in the pregnant or postpartum patient?

Table 4 Characteristics of included studies according to country level of development

<table>
<thead>
<tr>
<th>Characteristic (N = 41)</th>
<th>Developing (n = 16)</th>
<th>Developed (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 (2,224–82,623)</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)*</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>
**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
Blood gases in late pregnancy

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</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
• Questions:
  - Tidal volume and plateau pressure goals?
  - PaCO$_2$ and PaO$_2$ goals?
  - Sedative drug therapy?
  - Effect of delivery on maternal lung function?
Literature review

- 43 ventilated women (1990’s)
  - delivery in 86%, 14% mortality
  - No data on ventilatory management
    Am J Obstet Gynecol 2003; 188:549-552

- 10 ventilated pregnant women (1990’s)
  - All of whom delivered while on ventilation
  - Modest benefit: 28% reduction in FiO₂

- Other case reports, small case series
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*
Blood Gas Targets in Pregnancy

O₂

CO₂
Blood Gas Targets in Pregnancy

**Oxygen**

As with any organ, oxygen delivery is determined by:

- Oxygen saturation
- Hemoglobin
- Cardiac output

Placental function
Oxygen Targets in Pregnancy

Modelling based on animal data:
Maternal Sat 96% to 85% will result in fetal:
70% to 55%

Maternal hypoxemia (10% O₂): no adverse effect on fetal monitoring

Winnipeg H1N1 experience: 6 pregnant women, initial sats 50 - 88%: 4/6 marked ischemic encephalopathy

Meschia, Clin Chest Med 2011;32:15
Blood Gas Targets in Pregnancy

Carbon dioxide

UBF → CO₂

CO₂ 30 mmHg → HCO₃⁻
CO₂ Targets in Pregnancy

- over ventilation reduces uterine blood flow
  - effects of positive pressure on C.O.
  - effects of resp alkalosis on UBF

- Hypercapnia (adding CO₂): no effect on UBF

- Comparison low CO₂ v. high CO₂ at delivery:
  higher CO₂ associated with better APGAR

- Risk of fetal acidosis

Levinson et al. Anesthesiology. 1974;40:340-7
Retrospective review

- Retrospective chart review
- 4 ICUs, 2004 - 2013
- Maternal, ventilation and outcome data
- Effects of delivery on maternal respiratory parameters
### Results

<table>
<thead>
<tr>
<th>29 patients:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>29.0 (±7.7)</td>
</tr>
<tr>
<td>Gestation at admission (wk)</td>
<td>25.4 (±6.0)</td>
</tr>
<tr>
<td>Actual weight (kg)</td>
<td>71.7 (±20.2)</td>
</tr>
<tr>
<td>Predicted body weight (kg)</td>
<td>54.6 (±5.9)</td>
</tr>
</tbody>
</table>

**Indications for ICU admission**

<table>
<thead>
<tr>
<th>Obsetric:</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Preeclampsia</td>
<td>2 (6.7%)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Non-obstetric:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Pneumonia</td>
<td>5 (17%)</td>
</tr>
<tr>
<td>Viral pneumonitis</td>
<td>5 (17%)</td>
</tr>
<tr>
<td>Other sepsis</td>
<td>7 (24%)</td>
</tr>
<tr>
<td>Neurological</td>
<td>4 (14%)</td>
</tr>
<tr>
<td>Cardiac failure</td>
<td>5 (17%)</td>
</tr>
<tr>
<td>Sickle cell crisis</td>
<td>1 (3%)</td>
</tr>
</tbody>
</table>
## Results

### Ventilation

- **Ventilation duration (days)**: 6.0 (± 8.2)
- **Highest PEEP (cmH₂O)**: 10.9 (± 4.4)
- **Highest Plateau pressure (cmH₂O)**: 27.3 (± 6.5)

### Tidal volume

<table>
<thead>
<tr>
<th></th>
<th>Day 1</th>
<th>Day 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>actual (ml)</strong></td>
<td>446 (± 90)</td>
<td>452 (± 102)</td>
</tr>
<tr>
<td><strong>by PBW (ml/kg)</strong></td>
<td>7.9 (± 1.5)</td>
<td>8.1 (± 1.7)</td>
</tr>
</tbody>
</table>

### Compliance (ml/cmH₂O)

- **Day 1**: 21.4 (± 9.2)
- **Day 2**: 22.8 (± 8.6)
Distribution of worst blood gases in first 48 hr

Oxygen saturation (%)

Carbon dioxide (mmHg)

90% 30 mmHg
Estimated Respiratory system compliance

![Graph showing compliance vs gestation for pulmonary disease and normal lungs.](Image)
Effect of delivery:

For those that delivered, O.I. and compliance:

Oxygenation index: \( \frac{\text{FiO}_2 \times \text{MAP}}{\text{PaO}_2} \)

Estimated Respiratory system compliance: \( \frac{V_t}{\text{plateau pressure}} \)
Effects of Delivery (n=10)
## Results - maternal benefit from delivery

<table>
<thead>
<tr>
<th>Indication for delivery</th>
<th>Gestation (weeks)</th>
<th>Respiratory disease</th>
<th>Predelivery PaO₂/FiO₂</th>
<th>Delivery</th>
<th>Neonatal weight (g)</th>
<th>OI % decrease</th>
<th>Compliance % increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>maternal</td>
<td>37.0</td>
<td>Pulmonary edema</td>
<td>246</td>
<td>CS</td>
<td>3190</td>
<td>15.9</td>
<td>53.0</td>
</tr>
<tr>
<td>maternal</td>
<td>30.0</td>
<td>Pneumonia</td>
<td>60</td>
<td>CS</td>
<td>1554</td>
<td>47.1</td>
<td>-</td>
</tr>
<tr>
<td>maternal</td>
<td>27.0</td>
<td>ARDS</td>
<td>502</td>
<td>CS</td>
<td>900</td>
<td>72.1</td>
<td>135.2</td>
</tr>
<tr>
<td>maternal</td>
<td>29.0</td>
<td>ARDS</td>
<td>68</td>
<td>CS</td>
<td>1722</td>
<td>64.4</td>
<td>26.4</td>
</tr>
<tr>
<td>maternal</td>
<td>27.4</td>
<td>Pulm edema/ARDS</td>
<td>326</td>
<td>CS</td>
<td>800</td>
<td>14.8</td>
<td>78.3</td>
</tr>
<tr>
<td>OB</td>
<td>29.2</td>
<td>ARDS</td>
<td>130</td>
<td>CS</td>
<td>1550</td>
<td>64.8</td>
<td>76.0</td>
</tr>
<tr>
<td>OB</td>
<td>34.2</td>
<td>Pulmonary edema</td>
<td>292</td>
<td>CS</td>
<td>2465</td>
<td>26.3</td>
<td>17.5</td>
</tr>
<tr>
<td>OB</td>
<td>26.4</td>
<td>Preeclampsia, HELLP</td>
<td>135</td>
<td>CS</td>
<td>1020</td>
<td>31</td>
<td>179.2</td>
</tr>
<tr>
<td>OB</td>
<td>32.0</td>
<td>Sickle cell crisis</td>
<td>338</td>
<td>CS</td>
<td>2000</td>
<td>15.8</td>
<td>-16.7</td>
</tr>
<tr>
<td>spontaneous</td>
<td>26.0</td>
<td>Pneumonia/ARDS</td>
<td>291</td>
<td>SVD</td>
<td>760</td>
<td>6.9</td>
<td>24.8</td>
</tr>
</tbody>
</table>
Conclusions

- Conventional approach to ventilation
- CO₂ not usually targeted at 30 cmH₂O
- Delivery has a small and variable benefit
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

ANZICS. BMJ. 2010 Mar 18;340:c1279
Sedation & NM blockade

- No completely “safe” drugs
- Opiates: most OK
- Benzodiazepines: cross placenta, potential problems. We use midazolam, if needed
- Propofol: short term OK? Propofol syndrome in mother and fetus?
  

- Neuromuscular blockers: cross placenta
- Delivery: warn the neonatologist!
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
  – Some change in compliance

Lapinsky et al, 2014
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:
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  – Some change in compliance

• Delivery:
  – If fetus is viable and at risk due to maternal hypoxia
  – NOT purely to improved maternal condition

Lapinsky et al, 2014
Delivery of the fetus

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

- NOT always the case:
  - Some oxygenation improvement
  - Some change in compliance

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

Lapinsky et al, 2014
Conclusions

- Clinicians use standard approach to ventilation
- Usual drugs used, but try to minimize
- Mild hypercapnia and hyoxemia may be tolerated
- Delivery has a modest, unpredictable effect on maternal respiratory parameters