Apnoeic oxygenation in pregnancy: a modelling investigation

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Background

- Apnoea in the parturient results in a faster time to desaturation when compared to the non-pregnant state.
Apnoeic oxygenation

- Mass inflow of oxygen can occur during apnoea if there is an open airway and an oxygen source. (1)
Nasal oxygen during apnoea

Original contribution

Apneic oxygenation during prolonged laryngoscopy in obese patients: a randomized, controlled trial of nasal oxygen administration

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Amy Shanks MS (Research Coordinator),
Christopher R. Turner MD, MBA (Attending Anesthesiologist)
Question

• What is the effect of supplemental oxygen during apnoea, on time to critical desaturation, in a term parturient with an open airway?
Methods

- Nottingham Physiology Simulator – computational model of respiratory and cardiovascular system.
- Validated for investigation of pre-oxygenation and apnoea in adults and specifically in pregnancy.(2)
Computer Simulation

3 min tidal breathing with 100% O₂

Pre-oxygenation

Apnoea

Apnoea with different FiO₂ applied at open glottis

Rapid Sequence Induction
Model Parturients

- ‘Average’
- ‘Average’ in labour
- BMI 35 kg/m^2
- BMI 50 kg/m^2
- Sepsis
- Twins
- Anaemia
Data

- $\text{SaO}_2$
- $\text{PaO}_2$
- $\text{PaCO}_2$
- pH
Results
The effect of increasing FiO₂ at the open glottis during apnoea on SaO₂ (%) in the average parturient model (not in labour)

**Pre-oxygenation**

<table>
<thead>
<tr>
<th>FiO₂ during apnoea</th>
<th>0.21</th>
<th>0.28</th>
<th>0.35</th>
<th>0.4</th>
<th>0.6</th>
<th>0.8</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time to SaO₂ 90%</td>
<td>4min 28s</td>
<td>5min 2s</td>
<td>5min 41s</td>
<td>6min 13s</td>
<td>9min 36s</td>
<td>17min 30s</td>
<td>58min</td>
</tr>
</tbody>
</table>
SaO₂ and PaCO₂ over time during apnoea with FiO₂ 1.0 at open glottis in the average parturient model (not in labour)

Pre-oxygenation

pH 7.0 at 15min
The effect of increasing FiO$_2$ at the open glottis during apnoea on time to SaO$_2$ 90% in all parturient models
Conclusions

- Oxygen at the open glottis prolongs the time to desaturation in all parturient models.
- Greatest increases in apnoea time at FiO₂ 0.8 – 1.0.
- Desaturation rate below SaO₂ 90% only significantly slowed at FiO₂ 1.0.
- PaCO₂ rises significantly during apnoea.

- Potential benefit of continuous oxygen therapy during induction of anaesthesia.
Study limitations and future work

- Computer modelling vs real life.
- Reliant on open airway.
- What FiO$_2$ is delivered to the glottis from nasal devices during apnoea?


Acknowledgments

Dr Marc Chikhani and Dr Jonathan Hardman,
Academic Department of Anaesthesia and Critical Care,
Nottingham University.
Questions?
## Time to $\text{SaO}_2$ 90% during apnoea in all models

<table>
<thead>
<tr>
<th>$\text{FiO}_2$</th>
<th>Average</th>
<th>Average Labour</th>
<th>BMI 35</th>
<th>BMI 50</th>
<th>Twins</th>
<th>Sepsis</th>
<th>Anaemia</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.21</td>
<td>4min 28s</td>
<td><strong>3min 4s</strong></td>
<td>3min 30s</td>
<td>2min 10s</td>
<td>4min 11s</td>
<td>3min 22s</td>
<td>4min 30s</td>
</tr>
<tr>
<td>0.28</td>
<td>5min 2s</td>
<td>3min 27s</td>
<td>3min 58s</td>
<td>2min 28s</td>
<td>4min 41s</td>
<td>3min 46s</td>
<td>5min 4s</td>
</tr>
<tr>
<td>0.35</td>
<td>5min 41s</td>
<td>3min 54s</td>
<td>4min 31s</td>
<td>2min 52s</td>
<td>5min 19s</td>
<td>4min 16s</td>
<td>5min 43s</td>
</tr>
<tr>
<td>0.4</td>
<td>6min 13s</td>
<td>4min 17s</td>
<td>4min 57s</td>
<td>3min 11s</td>
<td>5min 32s</td>
<td>4min 41s</td>
<td>6min 17s</td>
</tr>
<tr>
<td>0.6</td>
<td>9min 36s</td>
<td>6min 34s</td>
<td>7min 42s</td>
<td>5min 12s</td>
<td>9min</td>
<td>7min 12s</td>
<td>9min 42s</td>
</tr>
<tr>
<td>0.8</td>
<td>17min 30s</td>
<td>12min</td>
<td>14min 18s</td>
<td>10min 6s</td>
<td>16min 24s</td>
<td>13min</td>
<td>17min 30s</td>
</tr>
<tr>
<td>1</td>
<td>58min</td>
<td><strong>40min 18s</strong></td>
<td>49min 24s</td>
<td>43min</td>
<td>54min 24s</td>
<td>43min 12s</td>
<td>57min 48s</td>
</tr>
</tbody>
</table>
**PaCO$_2$ over time during apnoea in all models**

![Graph showing PaCO$_2$ over time during apnoea in all models.](image)

- **Average in labour**
- **BMI 50**
- **pH 7.0 at 13min**

- **Average**
- **BMI 50**
- **BMI 35**
- **Twin pregnancy**
- **Anaemia**
- **Sepsis**
Rate of rise of PaCO₂ during apnoea in all models

<table>
<thead>
<tr>
<th>Model Parturient</th>
<th>Rate of rise of PaCO₂ (kPa/min)</th>
<th>Rate of fall of pH (pH/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>1.12</td>
<td>0.02</td>
</tr>
<tr>
<td>Average in labour</td>
<td>1.65</td>
<td>0.02</td>
</tr>
<tr>
<td>Sepsis</td>
<td>1.46</td>
<td>0.02</td>
</tr>
<tr>
<td>Anaemia</td>
<td>1.12</td>
<td>0.02</td>
</tr>
<tr>
<td>Twin pregnancy</td>
<td>1.21</td>
<td>0.02</td>
</tr>
<tr>
<td>BMI 35</td>
<td>1.28</td>
<td>0.02</td>
</tr>
<tr>
<td>BMI 50</td>
<td>1.56</td>
<td>0.02</td>
</tr>
</tbody>
</table>
**Table 1** Baseline physiological values for the virtual subjects used to model pre-oxygenation and apnoea in pregnancy. Values are referenced where published physiological data were available. The ‘average pregnant’ subject in this study was identical to that in our previous work [1, 2].

<table>
<thead>
<tr>
<th></th>
<th>Average pregnant</th>
<th>Labour</th>
<th>BMI 50</th>
<th>BMI 35</th>
<th>BMI 50 &amp; labour</th>
<th>BMI 35 &amp; labour</th>
<th>Sepsis</th>
<th>Hypo-volaemia</th>
<th>Anaemia</th>
<th>Pre-eclampsia</th>
<th>Twins</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FRC; ml</strong></td>
<td>1600</td>
<td>1600</td>
<td>1600</td>
<td>1600</td>
<td>1600</td>
<td>1600</td>
<td>1600</td>
<td>1600</td>
<td>1600</td>
<td>1600</td>
<td>1600</td>
</tr>
<tr>
<td><strong>Dead space; ml</strong></td>
<td>140</td>
<td>140</td>
<td>140</td>
<td>140</td>
<td>140</td>
<td>140</td>
<td>140</td>
<td>140</td>
<td>140</td>
<td>140</td>
<td>140</td>
</tr>
<tr>
<td><strong>Cardiac output; l.min⁻¹</strong></td>
<td>6.9</td>
<td>8.3</td>
<td>[8, 10]</td>
<td>9.4</td>
<td>[11, 16]</td>
<td>8.0</td>
<td>11.3</td>
<td>9.6</td>
<td>9.0 [19]</td>
<td>5.3</td>
<td>8.2</td>
</tr>
<tr>
<td><strong>Total blood volume; l</strong></td>
<td>6.5</td>
<td>6.5</td>
<td>8.7</td>
<td>[11, 17]</td>
<td>7.5 [11, 17]</td>
<td>8.7</td>
<td>7.5</td>
<td>6.5</td>
<td>5.0</td>
<td>6.5</td>
<td>6.5</td>
</tr>
<tr>
<td><strong>Haemoglobin; g.dl⁻¹</strong></td>
<td>11.3</td>
<td>11.3</td>
<td>11.9</td>
<td>[11]</td>
<td>11.3</td>
<td>11.9</td>
<td>11.3</td>
<td>11.3</td>
<td>11.3</td>
<td>8.0</td>
<td>4.1</td>
</tr>
<tr>
<td><strong>VO₂; ml.min⁻¹</strong></td>
<td>330</td>
<td>495</td>
<td>[8, 9]</td>
<td>450</td>
<td>[12]</td>
<td>380</td>
<td>675</td>
<td>570</td>
<td>430</td>
<td>330</td>
<td>330</td>
</tr>
<tr>
<td><strong>Respiratory quotient</strong></td>
<td>0.88</td>
<td>0.88</td>
<td>0.88</td>
<td>0.88</td>
<td>0.88</td>
<td>0.88</td>
<td>0.88</td>
<td>0.88</td>
<td>0.88</td>
<td>0.88</td>
<td>0.88</td>
</tr>
</tbody>
</table>

BMI 50/35, body mass index 50/35 kg.m⁻²; FRC, functional residual capacity; Q₅/Q₇, shunt fraction; VO₂, oxygen consumption.