HFOV:
High Frequency Oscillatory Ventilation

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What shall we talk about today?

• Principles
• Physiology
• Papers
• Practicalities
• *Panacea*?
Preterm baby with RDS/SDLD

- Small, stiff, underdeveloped lungs with a tendency to collapse at end-expiration

- Hypoxia
- Hypercapnia
- Increasing pulmonary vascular resistance
What we want to do is…

- Open up the alveoli
- Keep them open
- Get oxygen in
- Get carbon dioxide out
- Work with the baby
- Damage the alveoli as little as possible
- Wean the baby off the ventilator
Conventional Ventilation

- **Rise time**
- **Exp. time**
- **PIP**
- **MAP**
- **PEEP**
- **Insp. time**
- **Time (secs)**
HFO - Principles

• Higher MAP
• Very fast rate
• Small tidal volumes
• More uniform lung recruitment
• Complex gas transport
• Animal work promising
Literature review…
Evidence – early data

• HiFi (1989) n=673
  • HFOV did not improve respiratory outcomes
  • ?HFOV increased severe IVH & cystic PVL

• PROVO (1996) n=125, m1.5kg, m31w
  • HFO – less O₂ and days ventilated
  • No difference in survival to discharge
UKOS – NEJM 2002

• 25 centres, 23-28+6w, randomised <1hr
• CV – TCPL, r60, i time 0.40
• HFO – freq 10, MAP 6-8, wobble varied
• CXR used for MAP (≤9 ribs)

• Weaning, surfactant protocols

• 29w, 91% ANS, same C-S
• No difference in demographics
Infants < 29 wk of gestation

870 Infants randomized (59% of births at < 29 wk of gestation)

Reasons for not undergoing randomization:
- Insufficient time (37%)
- Parent declined (30%)
- Parent too ill (7%)
- No oscillator available (6%)
- Parent spoke no English (3%)
- Other (17%)

66 Infants ineligible
- 27 Died
- 23 Did not need ventilation
- 13 Were > 28 wk of gestational age at delivery
- 3 Were ineligible for other reasons

804 Infants eligible for trial

7 Infants withdrawn after entry
- 5 Deemed ineligible
- 2 Withdrawn at parent’s request

797 Infants included in analysis
- 264 With gestational age of 23–25 wk
- 513 With gestational age of 26–28 wk

400 Infants received high-frequency oscillatory ventilation
- 397 Infants received conventional ventilation

400
HFOV

397
SIMV
• Only significant differences:
  – 23-25
    • HFO less pulmonary haemorrhage (16 v 28%)
  – 26-28
    • HFO more NEC (12 v 7%)

UKOS, NEJM, 2002
Longer term outcomes

- **AmJRCC 2004**
  - Pulmonary function @ 1yr CGA
  - HFOV offers no advantage over CV in terms of pulmonary function at follow-up

- **Eur J Peds 2004**
  - UKOS CXR reviews
  - No difference at 28d or 36CGA

- **ADC F&N, 2006**
  - Respiratory problems common
  - HFOV or CV had no impact on respiratory or neurodevelopmental morbidity at 2 years.

- “HFOV and CV appear equally effective for the early treatment of respiratory distress syndrome”
Neonatal Ventilation Study Group: NEJM 2002

- 26 tertiary NICUs, 601-1200g (n=500)
- ETT, x1 surfactant, ≥25% O2, MAP 6
- Exclusion: severe hypotension, known anomaly
- Randomised (& stratified)
- SIMV or Sensormedics HFO

**Settings:**
- SIMV: I time 0.25-0.4, V_T 4-7ml/kg, r≤60, PEEP 4-6,
- HFO: MAP 2 above SIMV, freq 10, 8 - 9.5 post ribs

- Sats: 88-96, modest hypercapnia, pH ≥7.20
- Aggressive weaning of ventilation
Table 1. Characteristics of Infants at Study Entry.*

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>High-Frequency Oscillatory Ventilation (N=244)</th>
<th>Synchronized Intermittent Mandatory Ventilation (N=254)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean birth weight — g</td>
<td>859±161</td>
<td>848±160</td>
<td>0.45</td>
</tr>
<tr>
<td>Birth weight — no. (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>601–700 g</td>
<td>46 (19)</td>
<td>55 (22)</td>
<td>0.50</td>
</tr>
<tr>
<td>701–800 g</td>
<td>57 (23)</td>
<td>62 (24)</td>
<td>0.83</td>
</tr>
<tr>
<td>801–1000 g</td>
<td>87 (36)</td>
<td>84 (33)</td>
<td>0.57</td>
</tr>
<tr>
<td>1001–1200 g</td>
<td>54 (22)</td>
<td>53 (21)</td>
<td>0.75</td>
</tr>
<tr>
<td>Gestational age at birth — wk</td>
<td>26.0±1.6</td>
<td>26.1±1.6</td>
<td>0.49</td>
</tr>
<tr>
<td>Prenatal betamethasone therapy — no. (%)†</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Complete</td>
<td>104 (43)</td>
<td>108 (43)</td>
<td>1.0</td>
</tr>
<tr>
<td>Incomplete</td>
<td>75 (31)</td>
<td>72 (28)</td>
<td>0.62</td>
</tr>
<tr>
<td>Partial</td>
<td>17 (7)</td>
<td>25 (10)</td>
<td>0.26</td>
</tr>
<tr>
<td>None</td>
<td>48 (20)</td>
<td>49 (19)</td>
<td>1.0</td>
</tr>
<tr>
<td>Maternal chorioamnionitis — no. (%)</td>
<td>28 (11)</td>
<td>27 (11)</td>
<td>0.78</td>
</tr>
<tr>
<td>Mother positive for group B</td>
<td>16 (7)</td>
<td>24 (9)</td>
<td>0.25</td>
</tr>
<tr>
<td>Delivery by cesarean section — no. (%)</td>
<td>144 (59)</td>
<td>150 (59)</td>
<td>1.0</td>
</tr>
<tr>
<td>Male sex — no. (%)</td>
<td>127 (52)</td>
<td>141 (55)</td>
<td>0.47</td>
</tr>
<tr>
<td>Singleton — no. (%)</td>
<td>176 (72)</td>
<td>195 (76)</td>
<td>0.26</td>
</tr>
<tr>
<td>Born in institution — no. (%)</td>
<td>222 (91)</td>
<td>231 (91)</td>
<td>1.0</td>
</tr>
<tr>
<td>Median Apgar score</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>One-minute</td>
<td>5</td>
<td>5</td>
<td>0.81</td>
</tr>
<tr>
<td>Five-minute</td>
<td>7</td>
<td>7</td>
<td>0.83</td>
</tr>
<tr>
<td>Age at randomization — hr</td>
<td>2.7±0.9</td>
<td>2.7±0.9</td>
<td>1.0</td>
</tr>
<tr>
<td>Mean airway pressure — cm of water</td>
<td>8.2±1.6</td>
<td>8.3±1.8</td>
<td>0.51</td>
</tr>
<tr>
<td>FiO₂</td>
<td>0.57±0.25</td>
<td>0.60±0.27</td>
<td>0.20</td>
</tr>
</tbody>
</table>

No significant differences
• HFOV=245, SIMV=255
• **HFOV**: quicker extubation
• HFOV more alive at 36w (no O2)
  – 56% v 47% \( p=0.046 \)
• No difference in IVH, cPVL, ROP, NEC, PDA, sepsis, pneumothorax
• **HFO**: more PIE (0.052), less pulH (0.015)
### Respiratory Outcomes

<table>
<thead>
<tr>
<th>Outcome</th>
<th>High-Frequency Oscillatory Ventilation (N=244)</th>
<th>Synchronized Intermittent Mandatory Ventilation (N=254)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>At 36 weeks — no. with outcome/total no. (%)*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alive and weaned from all support</td>
<td>131/234 (56)</td>
<td>117/250 (47)</td>
<td>0.046</td>
</tr>
<tr>
<td>Birth weight</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>601–700 g</td>
<td>12/44 (27)</td>
<td>17/54 (31)</td>
<td>0.67</td>
</tr>
<tr>
<td>701–800 g</td>
<td>27/55 (49)</td>
<td>21/60 (35)</td>
<td>0.14</td>
</tr>
<tr>
<td>801–1000 g</td>
<td>52/83 (63)</td>
<td>45/84 (54)</td>
<td>0.27</td>
</tr>
<tr>
<td>1001–1200 g</td>
<td>40/52 (77)</td>
<td>34/52 (65)</td>
<td>0.28</td>
</tr>
<tr>
<td>Death</td>
<td>38/234 (14)</td>
<td>40/250 (16)</td>
<td>0.61</td>
</tr>
<tr>
<td>Ventilation</td>
<td>4/234 (2)</td>
<td>12/250 (5)</td>
<td>0.08</td>
</tr>
<tr>
<td>Nasal continuous positive airway pressure</td>
<td>2/234 (1)</td>
<td>3/250 (1)</td>
<td>1.0</td>
</tr>
<tr>
<td>Supplemental oxygen</td>
<td>64/234 (27)</td>
<td>78/250 (31)</td>
<td>0.37</td>
</tr>
<tr>
<td>First extubation†</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median age — days</td>
<td>6</td>
<td>7</td>
<td>0.14</td>
</tr>
<tr>
<td>Reintubation — no. of infants‡</td>
<td>99</td>
<td>115</td>
<td>0.21</td>
</tr>
<tr>
<td>Reason for reintubation — no. of infants</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apnea or bradycardia</td>
<td>57</td>
<td>76</td>
<td>0.08</td>
</tr>
<tr>
<td>Respiratory acidosis</td>
<td>30</td>
<td>21</td>
<td>0.18</td>
</tr>
<tr>
<td>Oxygenation</td>
<td>7</td>
<td>10</td>
<td>0.62</td>
</tr>
<tr>
<td>Other</td>
<td>5</td>
<td>8</td>
<td>0.58</td>
</tr>
<tr>
<td>Successful extubation‡</td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>No. of infants</td>
<td>200</td>
<td>204</td>
<td></td>
</tr>
<tr>
<td>Median age — days</td>
<td>13</td>
<td>21</td>
<td></td>
</tr>
</tbody>
</table>
• Why has HFOV not shown to be better?
  – SIMV is standard – everyone knows it
  – HFO margin for error is less
  – Extubation from SIMV is standard
  – Concern about BP, cUSS on HFOV
  – Difference between HFO machines
  – CLD pathogenesis is multi-factorial
Elective high-frequency oscillatory versus conventional ventilation in preterm infants: a systematic review and meta-analysis of individual patients’ data

Filip Cools, Lisa M Askie, Martin Offringa, Jeanette M Asselin, Sandra A Calvert, Sherry E Courtney, Carlo Dani, David J Durand, Dale R Gerstmann, David J Henderson-Smart, Neil Marlow, Janet L Peacock, J Jane Pillow, Roger F Soll, Ulrich H Thome, Patrick Truffert, Michael D Schreiber, Patrick Van Reempts, Valentina Vendettuoli, Giovanni Vento, on behalf of the PreVILIG collaboration

Summary

Background Population and study design heterogeneity has confounded previous meta-analyses, leading to uncertainty about effectiveness and safety of elective high-frequency oscillatory ventilation (HFOV) in preterm infants. We assessed effectiveness of elective HFOV versus conventional ventilation in this group.

Methods We did a systematic review and meta-analysis of individual patients’ data from 3229 participants in ten randomised controlled trials, with the primary outcomes of death or bronchopulmonary dysplasia at 36 weeks' postmenstrual age, death or severe adverse neurological event, or any of these outcomes.

Findings For infants ventilated with HFOV, the relative risk of death or bronchopulmonary dysplasia at 36 weeks' postmenstrual age was 0.95 (95% CI 0.88–1.03), of death or severe adverse neurological event 1.00 (0.88–1.13), or any of these outcomes 0.98 (0.91–1.05). No subgroup of infants (eg, gestational age, birthweight for gestation, initial lung disease severity, or exposure to antenatal corticosteroids) benefited more or less from HFOV. Ventilator type or ventilation strategy did not change the overall treatment effect.

Interpretation HFOV seems equally effective to conventional ventilation in preterm infants. Our results do not support selection of preterm infants for HFOV on the basis of gestational age, birthweight for gestation, initial lung disease severity, or exposure to antenatal corticosteroids.
HFOV Setup

**Before HFO**
- ?sedation
- ?CXR
- ?volume
- inotropes
- MAP 2cmH2O above conventional
- Freq 10
- $\Delta P$ 20
- FiO2 as sats

**After HFO**
- Consider more MAP
- Alter $\Delta P$ with wobble
- Blood gas
- CXR
- Watch BP
Further care

• If CO2 high
  – Increase $\Delta P$
  – Reduce frequency

• If O2 low
  – Increase FiO2
  – Increase MAP

• In-line suction
• MAP – less can be more
• Regular CXR
Conclusions

• Clear theory and animal data for success with HFOV vs CV

• No consistent significant differences in outcomes in human neonatal trial data

• Anecdotal evidence very strong that some babies are much better on HFOV (& vv)
Respiratory

Contains the following guidelines and supporting information: Apnoea and bradycardia, Chronic lung disease, CPAP (Continuous Positive Airway Pressure), HFOV (High Frequency Oscillatory Ventilation), Intubation, Nitric oxide, Oxygen NEW FOR 2009, Oxygen on discharge, Persistent Pulmonary Hypertension of the Newborn (PPHN), Pulmonary haemorrhage, Surfactant replacement therapy, Synchronous Positive Pressure Ventilation (SIPPV) NEW FOR 2009, Transcutaneous C02 and O2 NEW FOR 2009, and Ventilation.

Apnoea and Bradycardia and Supporting Evidence

Chronic Lung Disease and Supporting Evidence

CPAP (Continuous Positive Airway Pressure) and Supporting Evidence

HFOV (High Frequency Oscillatory Ventilation) and Supporting Evidence

Intubation and Supporting Evidence

Nitric Oxide and Supporting Evidence

Oxygen NEW FOR 2009 and Supporting Evidence

Oxygen on Discharge and Supporting Evidence

Persistent Pulmonary Hypertension of the Newborn (PPHN) and Supporting Evidence