Comparison of the Rate of Improvement in Gas Exchange between Two High Frequency Ventilators in a Newborn Piglet Lung Injury Model

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Background: High frequency percussive ventilation (HFPV) is well suited for transport of critical newborns with severe lung disease. Experience and post hoc analysis in a previous similar study suggest gas exchange (especially oxygenation) may improve more rapidly after HFPV is initiated than after high frequency oscillatory ventilation (HFOV) is started. This study tests that hypothesis, as well as the effect of a recruitment maneuver as each HF ventilator is initiated.

Methods: 3-7 day old Yorkshire piglets are intubated, sedated, paralyzed and placed on conventional ventilation (CMV). Lung injury is induced by repeated saline lavage until pO2 is < 50 mmHg then CMV at injurious settings is done for 1.5 hours. Lavage is then repeated if needed. HFOV (3100A) or HFPV (Infant Bronchotron), by randomization, is then initiated at mean airway pressure (MAP) of 20 cmH2O and blood gases are obtained every 5 minutes for ½ hour. This is then repeated on the other HF ventilator. The process is repeated yet again on each HF ventilator using a recruitment maneuver of MAP = 22, 24, 26, 28, then 30 for 1 minute each then back to MAP of 20. Between runs, the airway is opened to ambient air for 1-2 minutes and lavage repeated as needed to return to pO2 < 50. CxR and pulmonary mechanics (resistance and compliance) are recorded initially, after injury, and after 30 minutes of HF ventilation for comparison. Frequency of 7 Hz, tidal volume 3.5 ml/kg, and FiO2 1.0 are used throughout. Power is 80% to detect a 1.3 SD difference between groups in pO2 change over time, α=0.05, by repeated measures ANOVA. Secondary endpoint is improvement in pCO2.

Preliminary results: 13 of 16 animals have been completed. This graph shows average pO2’s over time for the 13 animals. Statistical comparison will be done and formal conclusions drawn after the remaining animals are completed which hopefully will be possible prior to the conference.
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Nothing to Disclose
Background

• HFV is a useful management strategy for respiratory failure
  – May work when conventional ventilation fails

• Advantages of HFV
  – Small tidal volume at rates above physiologic
    300 to 900 bpm (5-15 Hz)
    • Tidal volumes may be less than dead space
  – May adequately ventilate with less volutrauma and lower peak pressures
3100A vs. Bronchotron

how quickly does each improve gas exchange?
Background

• HFOV (3100A) is in widespread use
  – Transporting patients nearly impossible

• HFPV (Bronchotron) offers possibility of transport
  – Small, light, pneumatic (no electrical requirement)
  – Can be built into transport incubator
HFV Transport

- HFOV not very transportable

- Case report of HFJV in transport (Scuderi, 1992)

- Case series of HFPV ventilation experience at PCMC (Honey, 2007)

- “Hidden Mortality” of ECMO Candidates (Boedy, 1990; DiGeronimo, 2005)
Sensormedics 3100A

Adjustable parameters

- Mean Airway Pressure (cmH₂O)
- ΔP (cmH₂O)
- frequency (Hz)
- I-time (%)
- bias flow
Bronchotron

- HFPV – High Frequency Percussive Ventilation
- Adjustable parameters
  - Percussion (ΔP)
  - Flowrate (F)
  - PEEP Valve (Mean Airway Pressure)
Motivation for this study

- Previous study by Messier et al (2009) showed no difference in ventilation or oxygenation between these two devices in a saline lavage model in neonatal piglets.
- *Post Hoc* analysis suggested a hypothesis that HFPV improved oxygenation faster than HFOV after being initiated.
- Users’ anecdotal reports agree; also that HFPV ventilates better with lower ∆P.
Messier Results
HFOV blue; HFPV red; time points q 5 minutes
Initial Lung Recruitment

• How to manage MAP when initiating HFV
  – Found stepwise MAP increase for recruitment maneuver to be best method

• Does type of HFV matter?
Study Questions

1. Is there a difference in the rate of improvement in oxygenation between the Bronchotron and the 3100A?

2. Is there a difference in the rate of improvement in ventilation between the Bronchotron and the 3100A?

3. Does stepwise recruitment maneuver instead of fixed starting pressure affect the answers to those two questions?
Animal Preparation

• Randomize 3-7 day old, 2.5-4kg Yorkshire piglets to initial Sensormedics 3100A or Bronchotron

• Intubate, anesthetize, place arterial line and bladder cath, paralyze/sedate

• Stabilize on conventional ventilation
Initiate Lung Injury

- Measure initial dynamic C and R using Florian respiratory monitor

- Repeated saline lung lavage until PaO$_2$ was <50 mmHg on FiO$_2$ 1.0

- Ventilate on injurious settings on CMV for 1.5 hours

- Open airway to ambient air to derecruit; relavage if necessary until PaO$_2$ < 50 mmHg
Test Initial HFV

• Start initial HFV at MAP of 20 cmH\textsubscript{2}O, frequency of 7 Hz, and V\textsubscript{t} of 3.5 ml/kg

• Record ABGs q 5 min x 30 min

• Derecruit lungs again (open to ambient, relavage if necessary) before next run

• Repeat C and R measurements after injury and between runs
Test Alternative HFV

- Ventilate animal with second HFV, using same settings

- Repeat one more run on each HFV, this time after a recruitment maneuver:
  - One minute each on MAP of 22, 24, 26, 28, and 30 cm $H_2O$, then back to 20 for rest of run

- Euthanize animal
Statistics

• Repeated Measures ANOVA

• 16 animals required to detect a 1 SD difference in oxygenation between ventilator groups: $\alpha = 0.05$ $\beta = 0.20$
  – and to detect a 1.3 SD difference in interaction between time and oxygenation (rate of improvement)
Progress to date

• 13 of 16 animals have been completed
• 6 additional animals did not tolerate the procedure and were/will be replaced
  – Died during preparation or procedure or unable to improve oxygenation
• No final analysis or conclusions can be made at this point, but…
Oxygenation vs. time

The graph shows the oxygenation levels over time for different conditions:
- HFOV
- HFPV
- HFOV rec
- HFPV rec

The x-axis represents time in minutes, while the y-axis shows the oxygenation levels. The graph illustrates how each condition affects oxygenation over time.
Ventilation vs. time

Graph showing ventilation over time with different conditions.
$\Delta P$ vs. animal to give $V_t$ 3.5/kg

![Graph showing $\Delta P$ vs. animal giving $V_t$ 3.5/kg with three different lines: HFOV DP, HFPV DP, and HFPV gauge. The x-axis represents animal numbers from 1 to 13, and the y-axis represents pressure values.](image-url)
Questions