CACCN Dynamics
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*From little to large; how important are tidal volumes?*

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They’re not just little adults.....
Littlest patients… biggest differences

- Small airways, same resistance equation
- Complaint chest wall
- Complaint lower airways, stiff alveoli
- Proportionally decreased FRC
- Diaphragmatic breathers
- Significant metabolic requirements – WOB up to 40% of CO
- New co-morbidities affecting respiration - BPD
Evolution of Pediatric Mechanical Ventilation

Time cycled, pressure controlled ventilation

- Inspiratory pressure constant
- Tidal volume dependent on lung compliance and airway resistance
- Continuous flow through circuit for spontaneous breathing
Evolution of Pediatric Mechanical Ventilation

- Volume ventilation of older children using “adult” ventilators
- Infants volume ventilated but switched to pressure ventilators for weaning because of poor sensitivity
Evolution of Pediatric Mechanical Ventilation

- Bourns LS-104 infant volume ventilator for neonates
- Tidal volume determined using a graph
1990s microprocessor technology
- Improved sensitivity
- “Hybrid modes”
- Flow sensors for infant ventilators
- Able to measure tidal volumes
- Start of move to volume targeting in neonates
Evolution of Pediatric Mechanical Ventilation

More terminology:

- Volume ventilation
- Volume control (VC)
- Volume guarantee (VG)
- Pressure regulated volume control (PRVC)
- Volume Limit

Important distinctions in how volume is measured and controlled.
Why Measure Tidal Volume in Pedes?

- Adult literature for ALI and ARDS (ARDSnet) pointed to reduction in mortality and morbidity with lower tidal volumes, decrease in VILI in ventilated patients.

- Need to prevent over-ventilation in neonates:
  - Prevent development of BPD
  - Prevent air leak
  - Prevent damage to alveolar epithelium
  - Prevent low PCO2 – reduce risk of IVH and PVL
Volume targeting – what volume?

- In adults Vt is calculated based on predicted body weight formula using height.
- In pedes practice seems to be based on actual body weight.
  - Influence of obesity
  - Influence of failure to thrive
  - Influence on ability to measure height.
- In neonates 4-6ml based on pulmonary function studies from early 1900s.
Volume targeting – where measured?
Volume targeting – what’s the proof?

Cochrane, 2011; volume target vs pressure control in neonates. 12 RCTs

• Second review of volume targeting
• Outcomes favour volume targeted ventilation
• Reduced death, BPD
• Reduced gd ¾ IVH/PVL (pooled)
• No increase in adverse effects

No comparable studies in pediatrics
Directions for research

• Efficacy of targeted Vt strategies for pediatrics
• Which volume provides the best target – inspiratory or expiratory?
• Effect of BPD and increased physiologic dead space on volume targeting
• Effect of BPD on ventilation of the pediatric patient
Meanwhile, in the adult world …
Long time appreciation of volutrauma and VILI

Barotrauma / Volutrauma / Atelectrauma

Over-distension of lung tissue
Secondary inflammatory response > Biotrauma

Gattionni and Protti, CMAJ (2008)
Ventilator-induced lung injury (VILI)

↑ ’ed VT well known to contribute to alveolar stress/strain > chemical mediator cascade > inflammation > biotrauma > multi-organ failure

Lower VTs = Less VILI = ↑ Survival!

- Lower VTs (<7 mls/kg IBW) have proven to↑ survival in ARDS
- 33% ↓ mortality (p < 0.001) (Armato NEJM, 1998)
- 9% ↓ mortality (p< 0.005) (ARDSnet, NEJM, 2000)
- Cochrane review (2013) ↓’ed 28 d mortality (RR 0.74, 95% CI .61-.88)

Piraino CSRT (2011)
Lower VTs may be better even WITHOUT ARDS?

- Gagic et al. (2004) Critical Care
- Retrospective cohort study; 332 patients WITHOUT ARDS were assessed
- 24% developed ALI/ARDS within 5 days
- Risk factors for development of ALI were ↑ VT, transfusion blood products, acidemia and hx of ILD
- OR 1.3 for each ml/kg VT > 6 mls/kg
- Females were more likely to have ↑ VT (p<0.001) and ALI, 29 vs 20% (p = 0.068)
Lower VTs may be better even WITHOUT ARDS?

- RCTs Determann et al. (2010) *Critical Care*
- 6 mls/kg vs 10 mls/kg IBW showed benefits for patients WITHOUT ARDS
- ↓ cytokine (IL-6) release (p=0.001)
- ↓ development of lung injury; 2.6% vs 13.5% (p = 0.01)
- Sedation, vasopressors, PEEP and FiO2 were not significantly Δ across groups
More evidence for Lower VTs

- Post-CV surgery
- 10 mls/kg vs 6 mls/kg IBW
- Time to extubate 7.5 vs 10.7 hr (p=0.10)

- extubation @ 6 hr = 33% (6 mls/kg) vs 20% (10 mls/kg) (p=0.02)
- Re-intubation rate = 1.3% vs 9.5% (p=0.03)

More evidence for Lower VTs

- Intra-operative
- Futier et al (2013) *NEJM*
- Lung protective vs non-lung protective strategy intra-op abdominal surgery in patients with moderate-high risk pulmonary complications
- ↓ post-op pulmonary and extra-pulmonary complications
- 10.5 vs 27.5% (p<0.001)
Lung Protective Ventilator strategy

• Open the lung ... and keep it open!
• Avoid de-recruitment
• Ventilate at the best compliance
• P_{plateau} < 30 \text{ cmH20}

Jones Resp Care (2008)
Open Lung Concept

Open Lung Concept

- VT < 7 mls/kg IBW
- Best PEEP
  - 2-3 cmH20 > Lower Inflection point on PV loop

With LOWER VTs, there is a risk for de-recruitment and atelectasis ... so Best PEEP and strategies to re-recruit are important!

- ALVEOLI study determined no survival benefit with higher PEEPs vs lower PEEPs

- Lung Recruitment manoeuvres
Ventilation strategies that apply Open Lung Concept

- Higher PEEP
- APRV
- HFO
- Lung Recruitment Maneuvers (LRM)

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Lung Recruitment Maneuver (LRM)

- Typically 30 cmH$_2$O PEEP x 30 sec., or 40 cmH$_2$O PEEP and 40 sec.
  - Alternative being incremental / decremental methods
- ↑ oxygenation without a Δ mortality
- Balance benefit with risks

Lung Recruitment Maneuver (LRM)

- Are lung units *recruitable*?
- May be determined by nature of lung injury
- Direct or *indirect*
- Prone positioning may be considered a type of LRM

↑ OXYGENATION IN most cases;
No sig. Δ mortality
↑ V/Q MATCHING

However, basic care of patient can be challenging

↑ risk of accidental extubation?

Raoof et al Chest (2010)
New evidence – Prone Positioning

- **Proseva study**
- Guerin *et al* (2013) *NEJM*
- Multi-centre prospective RCT
- Early application 16 hr prone positioning vs supine position in severe ARDS ($\text{PaO}_2/\text{FiO}_2 < 150$)
- ↓ 28 d (10% vs 32.8%, $p<0.001$); and 90 d mortality (23.6% vs 41% $p<0.001$)
- No $\Delta$ in complications between groups


References

- Determann, R. *et al* (2010). Ventilation with lower tidal volumes compared to conventional tidal volumes for patients without ALI; A preventative RCT. Critical Care 14: R1.
• https://www-clinicalkey-com.ezproxy.library.dal.ca/#!/ContentPlayerCtrl/doPlayContent/1-s2.0-S0031395513000394
Questions