Pros and Cons of Spontaneous Effort during Mechanical Ventilation

Andrew Bersten
Spontaneous respiratory effort

Heart lung interaction

Ppl becomes more negative during inspiration
  • Improves venous return
  • Increases LV afterload
  • Complex interaction with pulmonary circulation
Spontaneous respiratory effort

Respiratory effects

Diaphragm contraction during inspiration
• Optimizes matching of ventilation and perfusion
• Maintains diaphragm function and morphology
Spontaneous effort optimizes V/Q

Regional patterns of V and Q
Ventilation
- Less –ve Ppl gradient
- Diaphragm contraction

Perfusion
- Fractal anatomy
- Gravity

Graph shows the relationship between Flow (l.min⁻¹) and V/Q ratio across different regions of the lung (Bottom to Top).
Effects of Anesthesia and Paralysis on Diaphragmatic Mechanics in Man

Alison B. Froese, M.D., and A. Charles Bryan, M.D., Ph.D., F.R.C.P.(C)†

AWAKE SPONTANEOUS

ANAESTHETIZED SPONTANEOUS

PARALYZED
Spontaneous effort ‘maintains’ diaphragm function and morphology
Ventilator-induced diaphragm dysfunction (VIDD)

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Period of diaphragm inactivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brain dead donors</td>
<td>14</td>
<td>18-69 h</td>
</tr>
<tr>
<td>Thoracic surgery pts</td>
<td>8</td>
<td>2-3 h</td>
</tr>
</tbody>
</table>

Levine NEJM 2008;358:1327-35
Diaphragm is atrophied and weak, with adverse associations in general ICU patients

- Jaber *AJRCCM 2011;183:368-71*
  - Duration of mechanical ventilation associated with
    - Progressive ↓ phrenic twitch airway occlusion pressure
    - Progressive muscle fiber injury

- Supinski *Crit Care 2013* & Demoule *AJRCCM 2013*
- ↓ Phrenic twitch pressure
  - Associated with infection and mechanical ventilation
  - Extent associated with ↑ mortality and ↑ ICU LOS
  - BUT early weakness (by 24 h) suggests pre-existing disease
Regional lung weight - compressive atelectasis
Regional lung weight and pleural pressure
Compressive atelectasis in ARDS

Pelosi, Gattinoni, Pesenti, et al AJRCCM 1994;149:8-13
Regional lung weight and pleural pressure
Compressive atelectasis in ARDS

AWAKE SPONTANEOUS

ANAESTHETIZED SPONTANEOUS

PARALYZED
• Multicenter DBRCT
• Paralysis for 48 h (n=178)
  – vs placebo (n= 162)
• P/F ratio < 150
• No burden of added ICUAW
The disadvantages of spontaneous effort

- Can worsen gas exchange
  - Respiratory muscle oxygen consumption
  - Lung volume

- Patient-ventilator asynchrony

- Less control over lung stretch
  - Global tidal stretch
  - Regional factors
    - Regional Ppl and lung volume
    - Pendelluft
What determines end-expiratory lung volume
The Campbell diagram

Lung elastic recoil at FRC
• 70% surface tension

Chest wall elastic recoil
• Obesity
• Intra-abdominal pressure
Decreased lung volume and Ptp with expiratory effort in ARDS
Baedorf Kassis, Intensive Care Med 2018;44:534-6

Opioids increase abdominal muscle tone
Spontaneous effort – uncontrolled global stretch

Protocol
Tidal volume target 6 – 8 ml/kg PBW
Titrate PS ≥ 7 cmH\(_2\)O
Titrate PEEP to FiO\(_2\) table

93 patients received NIV for AHRF

Carteaux et al, CCM 2016;44:282-90
Asynchrony and self-inflicted lung injury

Asynchrony – common, poorly recognised
- Double trigger ➔ excessive tidal volume
- Flow starvation - ↓ Ppl
- Exacerbate regional stress
- Diaphragm injury
- Injurious ventilatory settings
- Additional sedation
- Association with poor outcomes
Spontaneous breathing (vs paralysis) exacerbates lung injury

T Yoshida et al CCM 2013;41:536-45

$V_T$ 5-7 ml/kg
Pplat $< 30$ cmH$_2$O

Paralysis
Spontaneous breathing

Despite protective and similar ventilation, spontaneous breathing
• ↑ bronchoalveolar lavage protein
• ↑ lung injury score
• ↑ dependent ventilation
• ↑ cyclic lung collapse
Spontaneous effort causes occult pendelluft

Yoshida T, et al. AJRCCM 2013;188:1420-7

Healthy lung
- Regional pleural pressure equally distributed
- SB = CMV

Lung injury
- \(\downarrow\downarrow\) dependent aeration
- More –ve dependent Ppl
  -13.0±4.4 vs -6.4±3.8 cmH\(_2\)O
Regional stress, injury and spontaneous effort

A Fluid-like behavior

B Solid-like behavior

Pes ≈ regional Ppl

Regional variation in Ppl
- Pendelluft
- Regional stress and hydrostatic forces
Regional stress, injury and spontaneous effort
Risk factors for SILI

• Lung volume loss
  • Smaller lung for $V_T$
  • $\uparrow$Pdi due to greater diaphragm curvature, longer muscle fibres
  • $\uparrow$SILI with low PEEP

• $\uparrow$Respiratory drive
  • $\uparrow$Pdi
    – Pendelluft, volutrauma, asynchrony, diaphragm injury
  • $\uparrow$V$_T$

• $\uparrow$Severity of ARDS
  • $\uparrow$injurious ventilatory settings
  • $\downarrow$SILI with mild lung injury
Early ARDS due to pneumonia
- Prolonged end-inspiratory hold
  - Initial fall in Paw to P1
  - Gradual fall in Paw to P2
  - Large P1-P2 gradient
  - Likely due to heterogeneity

- As PEEP ↑ from 5-12.5 cmH₂O
  - Increased P1-P2 gradient
  - Progressive convex Paw
Early ARDS due to pneumonia
- 10 cmH$_2$O PEEP
- Prolonged end-inspiratory hold
- Large slow fall from P1-P2
- Convex Paw

Following 2 days of CMV
- 10 cmH$_2$O PEEP
- Minimum P1-P2
  - Suggests less heterogeneity
- Convex Paw still persists
Clinical implications

• Spontaneous effort
  – Physiologic benefits
  – Potentially injurious if solid-like lung behavior
  – Given the priming effect of lung injury and the rapid repair possible if ongoing injury is minimised
    • Early and severe lung injury
      – Minimise spontaneous effort
      – Early intubation
      – Minimise NIV use
      – Avoid premature extubation
    • “Adequate” PEEP