Prone Position in ARDS

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Case Study

• A 39 yo F admitted to SFGH TICU s/p hanging, cardiac arrest, massive aspiration.

• Pre-prone management:
  – PEEP: +15, F_{iO_2}: 0.90
  – NMBA & Aeroprost 50 ng/kg/m
  
  – V_T: 530 mL (8.5); V_E: 17L/m
  
  – Pplat: 31 cmH_2O (ΔP: 16);
  – Crs: 33 mL/cmH_2O

  – ABG: 7.28 / 66 / 105
  – P/F = 117 ; V_D/V_T = 0.92, a/AP_{O_2} = 0.16
Percent Contribution of Ventral-Dorsal Lung Level to Total Area of the Lung by CT Analysis

Gattinoni Anesthesiology 1991
Increased Dorsal:Caudal Ventilation with Prone Position

Effects of Prone Position on Distribution of Pulmonary Perfusion

- Gravity: 1-25% of perfusion distribution

- Perfusion is Tissue Dependent.

- Regardless of body posture, perfusion always greater in dorsal lung regions.

- Vascular tree geometry dominant
  - 23 generations uneven branching angles/diameters that mimic airway structures (fractal geometry)

- Dorsal perfusion enhanced by regional ↑ expression of NO
Pulmonary Stress-Strain: Supine vs. Prone Position
Prone Positioning as LPV

Galiatsou 2006
"Inflammatory cell activity present throughout the lungs independent of the inflation status."

More even stress-strain distribution $\rightarrow \downarrow \uparrow$ amplifying inflammation

Gattinoni, 2013
Prone Positioning Greatly Reduces Pro-Inflammatory Mediator Release in ARDS

Chan (2007): RCT (N=22) ARDS-CAP, 72h PP

Mortality on ARDS Day 14 predicted by IL-6 (378 vs. 206 pg/mL)
Impact of PP in ARDS
(33 observational studies since 1976)

- **N = 735**

- Responders: 80% [57-100%]

- + Response both in Early & Late ARDS

- + Response both in ARDS_{pulm} & ARDS_{extpulm}

- ↑Pa_{O2}: 40 [26-52]; ↑Pa_{O2}/Fi_{O2}: 67 [8-161]

- Low incidence of adverse hemodynamic effects (2-4%)

- ↑secretion mobilization some patients

- Mixed results: effects on Pa_{CO2}, Crs, EELV
Impact on Mortality: PROSEVA Study

Multi-center RCT N = 466: **90 Day mortality ↓ 41 to 24%**
Adjusted RR for mortality 0.48 (SOFA);
↑ VFD 4 & 14 (D-28,D-90)
↑ No difference in complication rates

N Engl J Med 2013
Meta-Analyses of RCT

- 11 RCTs comparing PP to SP
  - PROSEVA study: 1st RCT + mortality benefit
  - Many studies Pre-LPV
  - Varying ARDS severity/etiology
  - Varying PP relative to onset of ARDS
  - Varying PP duration
  - Early stoppage in some studies

- Meta-analysis studies varied: reviewing 7, 9, 10 & 11 RCT’s
Meta-Analyses of RCT

• **Sud (2010)**: 10 studies; N = 1867,
  - ↓ Mortality P/F < 100 (RR: 0.84) effect up to P/F = 140
  - ↑ P/F: 27-39% over 3 days;
  - ↑ Pressure Ulcer (RR: 1.29)
  - ↑ ETT obstruction (RR: 1.58)

• **Lee (2014)**: 11 studies; N = 2246
  - ↓ Mortality (RR: 0.77)
  - PP > 10h (RR: 0.62)
  - + Effect: P/F < 150 (RR: 0.72)
  - ↑ Pressure Ulcer (RR: 1.49)
  - ↑ ETT obstruction (RR: 1.55)
Meta-Analyses of RCT

• **Beiter (2014):** 7 studies ; N = 2119
  - $\downarrow$ Mortality (RR: 0.66) only when $V_T \leq 8$ mL/kg
  - $\downarrow$ Baseline VT 1mL/kg PBW, $\downarrow$ Mortality risk 16.7%
  - PP $\geq$ 12h/day $\downarrow$ Mortality (RR: 0.71)

• **Hu (2014):** 9 studies; N = 2242
  - $\downarrow$ Mortality P/F $\leq$ 100 (RR: 0.71);
  - PEEP $\geq$ 10 (RR: 0.57)
  - PP $>$ 12h/day (RR: 0.54)
Prone Positioning, PEEP, RM: Manifestation of CREEP!

- Progressive ↑ in pulmonary volume occurring under constant airway pressure (lungs & chest wall).

- Viscoelastic property* of tissue that “yield” their shape over time under constant stress

- “Slow” gradual ↑ in Oxygenation

*think of the properties of caramel or drying glue

Van de Woestijne 1967, Respir Physiol
Recruitment = Pressure x Time

- Dynamic process, variable time course.

- Time Required: $\uparrow$ Viscosity = $\uparrow$ time necessary to open sequentially collapsed airways & alveoli

- Paw needed to recruit collapsed small airways is determined by:
  - Viscosity, thickness, surface tension of the airway lining fluid,
  - airway radius,
  - axial wall traction exerted by the surrounding alveoli,
  - presence of surfactant.
Increased PP Time Enhances Oxygenation
25% Early (≤ 4h); Late? No plateau in P/F after 8h

Responders

Non-Responders

Reutershan Clin Sci 2006
PP Enhances Effectiveness of PEEP in ARDS

Grannier et al Intensive Care Med 2003

![Graph showing the enhancement of PEEP effectiveness in ARDS](image)
PP Enhances Inhaled Vasodilators in ARDS

Johannigman 2001
Effect of Adding RM to Prone Positioning on PaO2/FiO2 in ARDS
Prone Positioning Unloads the Right Ventricle & Decreases PFO-Related Shunt

• **Cor-Pulmonale:** 22% of ARDS cases
  - ARDS+Cor-Pulmonale 60% vs. 36% Mortality
  - PP in ARDS pts w/ Cor-Pulmonale
  - 33% ↓RV size/ 18h in PP; ↑CI 2.9 to 3.4
  - Associated w/ ↑oxygenation, ventilation, Crs

• **PFO:** ~20% of ARDS case related to Cor-Pulmonale
  - Case Report of severe PFO by TE-Echocardiography
  - PP immediate ↓ in bubble emboli transversing artia &
  - ↑Pa\(_{O_2}/Fi_\text{O}_2\) 59 to 278 mmHg; ↓Pa\(_{CO_2}\) 54 to 30 mmHg

Viellard-Baron 2007 Cor Pulmonale; Legras 1999 PFO
Screening Criteria for PP: Trial of PEEP: 14-18 cmH\textsubscript{2}O in Patients with Pa\textsubscript{O}\textsubscript{2}/Fi\textsubscript{O}\textsubscript{2} < 150 on Fi\textsubscript{O}\textsubscript{2} > 0.60

Superimposed hydrostatic pressure in ARDS

Patients that have brisk oxygenation response to moderately high PEEP within a few hours don’t require PP

Cressoni 2014
Summary

• PP significantly \(\uparrow\) oxygenation 80% of ARDS
• Early application w/ LPV & > 12h \(\downarrow\) mortality
• Enhances PEEP, RM, inhaled Vasodilators
• Enhances LPV \textit{(max recruit, min overdistension)}
• Enhances Secretion clearance in some patients
• Skin erosion is a significant problem
• Hemodynamic AE’s and catheter loss relatively infrequent