ARDS/ALI: Bundling Care to Impact Outcomes

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ARDS: a Component of the SIRS Continuum

"A syndrome of acute respiratory failure in adults characterized by non-cardiogenic pulmonary edema manifested by severe hypoxemia caused by right to left shunting through collapsed or fluid filled alveoli".
Ashbaugh, Bigelow, Petty, 1967

Definition...Acute Lung Injury

- Oxygenation - \( \text{PaO}_2 / \text{FiO}_2 < 300 \) regardless of PEEP levels
- Chest x-ray - Bilateral infiltrates seen on frontal chest x-ray
- PCWP - \(< 18\ \text{mmHg} \) and/or no clinical evidence of left atrial hypertension

**PaO\(_2\)/FiO\(_2\) Ratio**

- User friendly tool
- Crude assessment of the severity of lung injury
- Used in the definition of ALI/ARDS
  - ALI: \(\text{PaO}_2 < 300\) regardless of PEEP
  - ARDS: \(\text{PaO}_2 < 200\) regardless of PEEP

**Definition…Acute Lung Injury**

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**Definition…Acute Respiratory Distress Syndrome**

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- Chest x-ray - Bilateral infiltrates seen on frontal chest x-ray
- PCWP - \(< 18\) mmHg and/or no clinical evidence of left atrial hypertension

**Incidence of ARDS**

<table>
<thead>
<tr>
<th>Incidence of ARDS</th>
<th>Author/Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>75 per 100,000/year</td>
<td>NHLBI, 1979</td>
</tr>
<tr>
<td>64.2 per 100,000/year</td>
<td>Goss, 2003</td>
</tr>
<tr>
<td>25 per 100,000/year</td>
<td>Evans, 1988</td>
</tr>
<tr>
<td>3 per 100,000/year</td>
<td>Lewandowski, 1995</td>
</tr>
</tbody>
</table>

**Mortality Trends**

- 1967-1987 mortality ranges 55-65%
- 1990’s control groups of clinical trials on ARDS mortality ranges 31-44%

**Mortality Rates Decline in ARDS Patient**

<table>
<thead>
<tr>
<th>Years</th>
<th>Mortality Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1983-1987</td>
<td>53-68%</td>
</tr>
<tr>
<td>1989-1990</td>
<td>Slight decline</td>
</tr>
<tr>
<td>1991</td>
<td>Below 50%</td>
</tr>
<tr>
<td>1993</td>
<td>36%</td>
</tr>
</tbody>
</table>

Declining Mortality Rates…Why???

- Patients are less ill or less severely injured
- Patient populations are different in different studies
- Numerous changes in supportive therapy have had a small but additive effect

ARDS
GOOD NEWS
85% WHO RECOVER
HAVE NEAR NORMAL PULMONARY FUNCTION ONE YEAR LATER

One-Year Outcomes In Survivors in ARDS
- 109 ARDS survivors evaluated at 3, 6 & 12 months post illness
- Survivors young (45 years), Long ICU LOS (median 25 days) and APACHE II > 23
- Loss of 18% Body wt at d/c from ICU
- Muscle wasting & fatigue were reasons for functional limitations
- Lung function & spirometric’s normal 6 months
- CO2 diffusion capacity low for full 12 months
- Absence of steroid use, absence of illness acquired during ICU stay & MODS had better functional status.

Common Predisposing Conditions Associated With ARDS

Direct Injury:

- **Inhalation injuries:**
  - Acid Aspiration
  - Near Drowning
  - Smoke

- **Drugs:**
  - Paraquat
  - Heroin

- **Pneumonitis**
  - Bacterial
  - Viral (SARS)
  - Other

- **Pulmonary Contusion**
  - Oxygen Toxicity
  - Radiation

Indirect Injury:

- Sepsis Syndrome
- Multiple Transfusions
- Shock
- Multisystem Trauma
- Pulmonary Embolism
- Fat Embolism
- Pancreatitis
- Intracranial Hypertension
- Burns
- Bypass Surgery
- DIC


Incidence of ARDS

- Sepsis
- Aspiration
- Overdose
- Transfusion
- Fracture
- Contusion

Sepsis
Aspiration
Overdose
Transfusion
Fracture
Contusion
Pathophysiologic Characteristics in ARDS

- A permeability defect described as a diffuse, non-uniform injury to the alveolar epithelium and alveolar capillary membrane (mediator & ventilator induced)
- Acute changes in the caliber of smaller airways
- Direct injury to pulmonary circulation (mediator & ventilator induced)
- Defect in the body's ability to transport and utilize O₂ at tissue level

Ventilator Induced Lung Injury: Parenchymal Injury

Known or Suspected Factors:
- Peak lung volume > TLC seen with Pplat > 30 cmH₂O
- Lung volume < the alveolar collapse point
- High rate/frequency of lung inflation
- High FiO₂

Wet Lung

- Collapsed alveoli and compression atelectasis
- Pooled airway fluid
- Inactivation and/or depletion of surfactant

Pathophysiologic Changes Contributing to Hypoxemia

- Acute changes in the caliber of the small airways
- Injury to the pulmonary circulation
Changes in the Caliber of the Small Airways

- Early bronchoconstriction
- Increased airway resistance
- Altered compliance

Pulmonary Vascular Injury

<table>
<thead>
<tr>
<th>Cause</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stress fractures of capillaries</td>
<td>Leaky membranes</td>
</tr>
<tr>
<td>Unregulated vasoconstriction (mediators)</td>
<td>Increased PAP &amp; PVR</td>
</tr>
<tr>
<td>Vascular clogging obstruction (micro emboli)</td>
<td>Pulmonary hypertension/Right ventricular dysfunction</td>
</tr>
</tbody>
</table>

Pulmonary Hypertension

- Increase right ventricular work
- Increase right ventricular size
- Right ventricular shift
- Impedes left ventricle size
- Decrease stroke volume
- Decrease cardiac output
- Decrease Oxygen Delivery

ARDS

- Pansystemic microvascular injury
  - Edema formation
  - Increased permeability of the peripheral circulation
  - Endothelial injury of the GI tract
  - Systemic translocation of bacteria
  - Delivery of endotoxin to hepatic macrophages
  - Export of cytokines & mediators from the liver
  - MODS

Biochemical mediators PMN's

- O$_2$ extraction
- O$_2$ delivery
- Cellular anaerobic metabolism

MODS

Vollman, 1996

ARDS

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Biochemical mediators PMN's

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MODS

Vollman, 1991
Clinical Manifestations

- Refractory hypoxemia
- Pulmonary shunting
- Decreased lung compliance
- Diffuse alveolar and interstitial infiltrates
- Pulmonary hypertension
- Other organ system failures

Incidence of Organ Failure With ARDS

<table>
<thead>
<tr>
<th>Organ Failure</th>
<th>Incidence Rate</th>
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<tbody>
<tr>
<td>Renal</td>
<td>40.5%</td>
</tr>
<tr>
<td>Hepatic</td>
<td>12.95%</td>
</tr>
<tr>
<td>Central nervous system</td>
<td>7.30%</td>
</tr>
<tr>
<td>Gastrointestinal</td>
<td>7.30%</td>
</tr>
<tr>
<td>Hematologic</td>
<td>0.26%</td>
</tr>
<tr>
<td>Other</td>
<td>10.23%</td>
</tr>
</tbody>
</table>

ARDS Treatment Principles

- Prevent further injury
- Maintain adequate pulmonary oxygenation
- Optimize oxygen delivery

The Six P’s of ARDS Treatment

- PREVENTION
- PEEP
- PUMP
- PIPES
- PARALYSIS
- POSITION

PREVENTION....... A PART OF THE NURSES’ PATIENT ADVOCACY ROLE
Ventilator Associated Pneumonia

Risk Factor Categories

- Factors that increase bacterial burden or colonization
- Factors that increase risk of aspiration

PREVENTION……..
A PART OF THE NURSES’ PATIENT ADVOCACY ROLE

PREVENTING THE INVASION

- Handwashing
- Line care
- Oral care
- HOB

Strategies for Ventilating the ARDS Lung: Protect From Injury

- Oxygen exposure
- Pressure (Barotrauma)
- Volume (Volutrauma)
- Shear forces (Reopening & closing of alveoli) (Atelectrauma)

ARDS Network ALI/ARDS Ventilator Study

Methodology:
- Inclusion criteria: p/f ratio < 300, bilateral infiltrates, no cardiac cause, receiving mechanical ventilation
- Outcomes: mortality/VFD
- 841 patients randomized
- 12 ml/kg TV group – Plat < 50 cm H₂O
- 6 ml/kg TV group - Plat < 30 cm H₂O

ARDs Network
ARDs Network
ALI/ARDS Ventilator Study
ALI/ARDS Ventilator Study

Results:

- PEEP: no difference in average amount used
- Mortality: 31% (6 ml/kg TV) vs. 40% (12 ml/kg TV) p=0.007
- VFD: 12 + 11 vs. 10 + 11 (p=0.007)
- Greater organ failure free days in protective group
- Reduction in IL-6 levels by day 3
- Difficulty with agitation/high rates in the 6 ml/kg group

Recruitment Strategies

- Optimal PEEP
- 30-40 cm of CPAP for 30 seconds*
- Prone positioning

Contraindications: severe bronchospasm, bullous emphysema, untreated pneumothorax, unilateral lung dx, hemodynamic instability, unstable ICP

High Versus Low PEEP Study

Methodology

- 549 patients with ALI/ARDS
- Mechanical ventilation with low or high PEEP set according to predetermined tables of PEEP levels & FiO2 levels
- Tidal volume: 6/mL per kg of IBW
- At 171 patient enrollment/changed protocol because PEEP amounts were similar between groups
- Measured: 28 mortality, VFD

Results

- Trail stopped based on futility rule
- Group differences at baseline; High PEEP group; significantly older & lower PaO2/FiO2 ratio
- Mean PEEP day 1-4*
  - Low PEEP: 8.3 ± 3.2
  - High PEEP: 13.2 ± 3.5
- Mortality; Low PEEP= 27.5% (after adjustment)
  - High PEEP= 25.1% (after adjustment)

Ventilator Strategy Based on Lung Mechanics

Early Phase Ventilation

- Lower tidal volumes (6ml/kg)
- PEEP/higher levels
- Prone position
- Limit pressures < 35cm H2O (allow higher pressure if chest wall stiffer)
- Accept abnormal pH, allow PaCO2 to rise gradually

Late Phase Ventilation

- Reduce PEEP
- Prone position less effective
- Reduce fluids
- Need more FiO2
- Limit pressures
- High dose steroids over 3 weeks

* p<.001


### ARDS Network: Steroids for Persistent ARDS

**Methodology**
- Multicenter, randomize controlled trial
- 180 patients with ARDS for >7 days to 28 days
- P/F ratio < 200 on study day entrance
- Measured mortality at 60 days, VFD & Organ failure free days, biochemical markers of inflammation, fibroproliferation & infectious complications
- Receive a loading dose of 2mg/kg of PBW then .5mg/kg q 6hrs for 14 days or .5mg/kg q 12hrs for 7 days than tapering
- Weaning protocol utilized


**Results**
- Mortality:
  - Steroid group: 29.2% (95% CI, 20.8 to 39.4%)
  - Placebo group: 28.6% (95% CI, 20.3% to 38.6%)
- Methylprednisolone associated with higher mortality among patients enrolled at least 14 days post onset
- Methylprednisolone increased the # VFD (14 vs. 23 days), ICU free days and Shock free days during the first 28 days
- No increase in infectious rates
- Methylprednisolone was associated with higher rate of neuromuscular weakness


### “Salvage” Ventilatory Strategies

- PC-IRV
- ECMO
- ECCO² R-LFPPV
- IVOX

### Pressure Control

- Inspiration is terminated after a present pressure is obtained
- Tidal volumes vary
- Increased inspiratory time versus expiratory time
- Sedation/Paralysis may be necessary to achieve ventilation if using inverse ratio

**Goal:**
- Lung protective strategy lower tidal volumes and controlled pressures
- Recruitment of collapse alveoli

Haas et al, Respir Care 1995;40:716

### Dual Control within a Breath

- **Volume-assured support**
- **Pressure augmentation**
  - When breath is triggered, ventilator targets pressure support
  - Ventilator monitors delivered tidal volume
    - If delivered tidal volume=set tidal volume, the breath is a pressure support breath
    - If the tidal volume<set volume when the flow decreases to the set peak flow, flow will remain constant until the volume is delivered

### Bi-Level Ventilation

- Establishes 2 levels of PEEP
- Cycle between the 2 pressure levels can be synchronized to patients breathing at either level
- Settings/parameters: PEEP High, PEEP low, Release rate and ratio of high to low PEEP
- Timing setting: Time high or time low (ratio)
- Breath types: mix spontaneous(pressure support) or mandatory (pressure controlled)
High Frequency Ventilation

- HFJV: frequency < 150/min
- HFO: frequency > 150/min
- HFO ventilation achieves gas exchange by utilizing sub-dead space tidal volumes providing a less traumatic method of recruiting and stabilizing lung volumes

High Frequency Oscillation Study

Methodology
- 17 adult patients with ALI who failed conventional ventilation
- Examined safety and efficacy of a new HFO ventilator
- Measured PaO2/FiO2 ratio, oxygen index and systemic & PA pressures

Results: 76% of the patients improved their oxygenation
- Failure to response to HFO was highly specific for death

Fort et al Crit Care Med 1997;25:937-947

Measures to Improve Oxygen Delivery

- Fluid Administration
- Transfusions
- Inotropic agents
- Vasopressors?
- Measures to improve SaO2

Early Goal Directed Therapy

Methodology: 263 severe sepsis patients

- Early Goal-Directed Therapy (EGDT)
  - Continuous ScvO2 monitoring & tx with fluids, blood, inotropes &/or vasoactives to maintain:
    - ScvO2 > 70%, SaO2 > 9/6%, Hct > 30%, CI/VO2
    - CVP ≥ 8-12
    - MAP ≥ 65
    - UO ≥ .5ml/kg/hr

- Standard Therapy
  - CVP ≥ 8-12
  - MAP ≥ 65
  - UO ≥ .5ml/kg/hr

Early Goal-Directed Therapy Results

- Standard Therapy, n=133
  - 49.2% mortality
  - P = 0.01*

- EGDT, n=130
  - 33.3% mortality

NNT=7


*Key difference was in sudden CV collapse, not MODS

Evidence of Early Goal Directed Therapy

- First 6 hours of EGDT:
  - 1500cc more fluid
  - 64% received blood products vs. 18.5%
  - 13.7% received inotropes vs. 0.8%
  - No difference in vasopressor or mechanical ventilation


Measures to Improve O₂ Delivery

- Fluid Management
  - Colloid vs. Crystalloids
  - Dry vs. Wet

ARDS Network: Fluid Management Strategies in ALI

Methodology
- Multicenter randomized trial
- 1000 patients
- Compared conservative and liberal fluid management using explicit protocols over a 7 day period
- Primary endpoint: measure mortality at 60 days
- Secondary endpoints: VFD, OFD & lung physiology

Results
- Mortality:
  - Conservative: 25.5%
  - Liberal: 28.4% (95% CI, -2.6 to 8.4% p=0.30)
- Cumulative Fluid balance:
  - Conservative: -136 ± 491 ml
  - Liberal: 6992 ± 502 ml (p<0.0001)
- Conservative: ↑ VFD (14.6 + 0.5 vs. 12.1 ± 0.5 p >0.01)
  ↓ ICU days (13.4 + 0.4 vs. 11.2 ± 0.4 p<0.001)

Colloid Versus Crystalloid

**Methodology**
- 6997 critically ill patients
- Randomized to receive 4% albumin or normal saline for intravascular resuscitation over a 28 days period
- Outcome measured: Death from any cause during the 28 days post randomization


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**Results**
- Similar baseline characteristics
- 726 deaths in albumin group
- 729 deaths in normal saline group (p=0.87)
- Proportion of patients with new single & multiple organ failure were similar (p=0.85)
- No difference in #ICU days, # hospital days, # of days on vent or days of CRRT


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**Rule of Thumb for Fluid Management**

Fluids should be given to the septic type patient as long as there is improvement in CI, DO2, VO2 & clearance of Lactic acid.
When it ceases, inotropic support should be considered.

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**PARALYSIS**

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**Balancing Oxygen Supply and Demand**

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**O₂ Supply Debt**

© Vollman 2001
Activities That Increase VO₂

- Dressing change 10%
- Physical exam 20%
- Agitation 18%
- Bath 23%
- Chest X-ray 25%
- Suctioning 27%
- Increased work of breathing 40%
- Weigh on sling scale 36%
- Position change 31%
- Linen change – occupied bed 22%
- Chest physiotherapy 35%

Strategies to Optimize Patient’s Tolerance to Activities

- Space activities
- Monitor for signs of intolerance
- Pre/post hyperoxygenate
- Determine if the intervention is essential
- Control variables that increase consumption
  - Pain management
  - Agitation management
  - Partial temp regulation
  - Shivering

Maximizing effective use of sedation through protocols

- Protocol-directed group vs. non protocol-directed group
  - Less time on mechanical ventilation
  - Shorter ICU LOS
  - Shorter hospital LOS
  - Decreased need for tracheostomy

Potential Negative Consequences of Paralysis

Method
- Case-controlled study /10 patients with prolonged blockade
- Examined rate of recovery, outcome, hospital utilization, charges and costs secondary to neuromuscular blockade weakness (NMW)

Results:
- No difference between NMW vs. control group in # and duration of paralytic episodes or doses used
- Ventilation, ICU and hospital time significantly longer in NMW group
- No difference in mortality
- Hospital charges: NMW/1,320,460.0 vs. Control/$214,830.00

**POSITION**

“Minimal Physiologic Mobility Requirement”

Move Every 11 Minutes During Sleep


**UNDERSTANDING THE IMPACT OF A STATIONARY SUPINE POSITION**

1990’s CLRT Research

Methodology
- 12 adult healthy baboons were randomized to CLRT or control for 11 days
- Mechanically ventilated, paralyzed and sedated and received normal supportive therapy
- Measured x-ray results, cultures, bronchioalveolar lavage, oxygenation indices, pulmonary function and lung volumes

Anzueto A et al Crit Care Med 1997;25(9):1560-1564

1990’s CLRT Research Results

- No significant difference in hemodynamics, gas exchange or pulmonary function
- Day 7 the control group showed patchy atelectasis
- Day 11 two animals showed persistent radiological abnormalities. Bronchoalveolar lavage day 7 and 11 revealed significant increase in neutrophils
- Lung pathology in control group showed areas of bronchiolitis with 5 of 7 of the control animals demonstrating surrounding bronchopneumonia

Anzueto A et al Crit Care Med 1997;25(9):1560-1564

**Do We Achieve Q2 Hours?**
“Effect of Frequency of Manual Turning on Pneumonia”

• Q 2 hour manual turning standard of care still not met.
• Patients were turned a mean of 9.64 times out of a possible 23 times.
• A turn was defined as movement from supine to either side, one side to the other side, or from bed to chair.
• No degree of turn was quantified.
• None of the patients had been proned.
• Pneumonia occurred in 49% of the patients at the end of the 3-day period.


Body Position: Clinical Practice vs. Standard

• Methodology
  - 74 patients/566 total hours of observation
  - 3 tertiary hospitals
  - Change in body position recorded every 15 minutes
  - Average observation time 7.7 hours
  - Online MD survey
• Results
  - 49.3% of observed time no body position change
  - 2.7% had a q 2 hour body position change
  - 80-90% believed q 2 hour position change should occur but only 57% believed it happened in their ICU

Krishnagopalan S. Crit Care Med 2002;30:2588-2592

Ventilation

Major Factors Influencing Distribution of Ventilation

➢ Gravity/weight of the lung
➢ Compliance/airway resistance
➢ Heterogeneous lung disease

Supine Position:

- Distribution becomes more uniform from apex to base
- Dependent lung ventilation > non-dependent
- Reduction in FRC

Reduction in FRC in the Supine Position

- Influence of the abdominal contents on the diaphragm
- Position of the heart and relationship of the supporting structures to the lung and its influence on pleural pressure gradients

Differences in FRC Based on Position

<table>
<thead>
<tr>
<th>Position</th>
<th>FRC Decline</th>
<th>Mean Decrease</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sitting to Supine</td>
<td>30%</td>
<td>800 ml</td>
</tr>
<tr>
<td>Sitting to Lateral</td>
<td>15-20%</td>
<td>450 ml</td>
</tr>
<tr>
<td>Sitting to Prone</td>
<td>15-20%</td>
<td>450 ml</td>
</tr>
</tbody>
</table>
PERFUSION

Factors Influencing Regional Distribution of Perfusion

- Cardiac output
- Pulmonary vascular resistance
- Gravity/body position

Distribution of Perfusion

Upright Position:
Blood flow decreases as it moves from base to apex with virtually little or no flow at the apices

Blood Flow Changes with Position

Supine position: Distribution becomes more uniform. Zone 3 maintained throughout the lung. Greater vertical perfusion gradient.

Lateral position: Similar to supine except lung transforms to zone 2 approximately 18 cm above the most dependent part of the chest.

Prone position: Zone 3 maintain throughout the lung. Reduced gravitational flow noted

CLINICAL RESEARCH

- Supine vs. Head Elevation
- Supine vs. Lateral
- Supine vs. Prone

Supine vs. Degrees of Head Elevation Research

- Rabow, et. al. 1972
- Vaughan, et. al. 1976
- Dalrymple, et. al. 1979
- Russell 1981
- Ciresi, et. al. 1981
- Gui, et. al. 1982
- Marti & Ulmer 1982
- Minh, et. al. 1986
- Burns, et. al. 1994
Position to Facilitate Weaning in Patients with Large Abdomens
- 19 intubated patients
- Large abdomens r/t obesity, distention & ascites
- CPAP &/or PSV
- Positioned: 0°, 45°, 90°, & RT at 45°

Results: RT at 45° significantly larger tidal volumes & lower respiratory rates than 90°


Lateral Positioning Research
- Patients with predominantly unilateral lung disease improved their PaO₂ when positioned with the GOOD LUNG DOWN
- Patients with more bilateral involvement showed higher PaO₂'s in the right lateral position


Lateral Positioning Research
- Good lung down mean PaO₂: 106.1 ± 12.7 mmHg
- Supine mean PaO₂: 66.8 ± 3.3 mmHg
- Bad lung down mean PaO₂: 58.5 ± 2.7 mmHg


Take Home Points: Positioning for Unilateral Lung Disease
- Patients with unilateral lung disease from a consolidated pneumonia type process oxygenate better with the good lung down.
- Patients with other types of unilateral lung dysfunction may not benefit from this positioning technique
- CABG patients should be repositioned at least every 2 hours
- More research is necessary looking at specific unilateral lung disease populations

Supine vs. Degrees of Head Elevation Research for Prevention of Ventilator-Associated Pneumonia

Risk Factor Categories for Nosocomial Pneumonia
- Factors that increase risk of aspiration
- Factors that increase bacterial burden or colonization
HOB Research

Methodology:
- 86 patients
- Randomly assigned to supine position or HOB 45 degrees (39 semi recumbent, 47 supine)
- Monitored clinical suspected & microbiologically confirmed nosocomial pneumonias

Results:
- Microbiologically confirmed nosocomial pneumonia lower in the semi recumbent group 2/39 (5%) vs. 11/47 (23%)
- Supine position & enteral nutrition were independent risk factors for VAP & had the greatest number of VAP’s 14/28 (50%)

Drakulovic MB. et. al. Lancet. 1999;354:1851-1858

Lateral Positioning Research

- Bilateral lung disease
- Unilateral lung disease

Meta-Analysis CLRT

Methodology
- 419 Patients
- 6 Studies:
  - Fink MP. Chest, 1990;97:132
  - Nelson LD. Clin Inten Care, 1992;3:248
  - Summer WR, J Crit Care, 1989;4:45
- Outcomes Measured:
  - Pneumonia, embolus, pressure sores, ARDS, atelectasis, mortality hours intubated ICU days, ICU charges, hospital days

Meta-Analysis CLRT

Results

• CLRT vs. Conventional Turning
  – 50% reduction in incidence of pneumonia (p <0.002)
  – 35% reduction in time intubated (p <0.04)
  – 24% reduction in ICU stay (p<0.02)


CLRT Research

Methodology

• 106 medical ICU patients
• Assigned to 5 DRG groups (sepsis, stroke, COPD, metabolic coma, drug OD)
• Randomly assigned CLRT vs. conventional bed with DRG group
• Rotated > 18 hours per day
• Measured morbidity, time on vent, ICU, LOS, hospital LOS, incidence of pneumonia
• Higher APACHE II scores in bed therapy group

DeBoisblanc BP et al Chest 1993;103:1543

Results

• Significant reduction in nosocomial pneumonia in CLRT group (9% vs. 22%)*
• Greatest in sepsis DRG (3% vs. 22%)**
• With higher APACHE II scores no difference in LOS, morbidity, mortality, or time on ventilator

* p=0.05
**p=0.04

2000’s CLRT Research

Methodology

• 37 patients mechanically ventilated long term
• Randomized assigned to CLRT or q 2 hour turning
• CLRT > 18 hours, 30 degree’s, q 2hr percussion/vibration for 10 minutes
• HOB at 30 degree’s

Results

• Development of pneumonia (p=0.03)
  • CLRT 17.6%
  • Control 50%
• Longer time to develop pneumonia if it appeared
  • ≥29 days vs 8 vs 12 days +2
• No difference in mortality


Results

• Improvement in P/F ratio 31 ± 42 vs 6 ± 76 (p=.03)
• Lower VAP rate 0 vs 5 (p < .001)
• Shorter ICU LOS 22 ± 8 days vs 27 ± 12 days (p =.09)
• No difference in mortality

2000’s CLRT Research
Methodology
- 234 Medical-Surgical-Trauma patients
- 137 control, 97 rotation, 22 did not tolerate
- Dialed 40 degrees, > 18hrs, 10min/5min/10min cycle vs. q 2hr with pillows
- HOB degree not mentioned
- Measured incidence of VAP, lobar atelectasis & cost

Results
- Incidence of VAP p=.002
- Incidence of lobar atelectasis p=.02
- No difference in ICU LOS, Hospital LOS or mortality
- Rotation average of 5 days


Quality Improvement Project
Union Hospital
Union, NJ
November 1999-March 2000
Presented at 2001 NTI/AACN

Pre-Union Hospital Project
Data...Driving the Change
Situation Analysis
- Placement on CLRT was late
- Inconsistent protocol usage
- No internal monitoring of outcomes
- Lack of staff education on CLRT
- Cost of care for pneumonia was rising
- Concern about spending on CLRT beds
- Data collection on non-rotated patients

The Union Hospital Project
The Process
- Literature review
- Evaluate patient population
- Redesigned existing protocol
- Predicus™ Pneumonia Risk Evaluation tool
- Empowered nursing to order CLRT
- Posted algorithm in all patient rooms
- CLRT tracking tool
- Team to follow & measure outcomes

Union Hospital Ventilator Days
86 Fewer Vent Days

Union Hospital ICU LOS
79 Fewer ICU Days
Implementing a CLRT Protocol: Evaluation of the Outcomes

- Retrospective/post protocol prospective analysis
- Acuity impact on length of stay and cost of care control through use of APACHE II
- Placed within 24-48 hours based on meeting initiation criteria
- Demographic characteristics of pre (n=22) & post (n=36) were similar except for time of placement of CLRT 13.6% vs. 61%


Rotation Therapy Outcome Studies

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<thead>
<tr>
<th>Institution</th>
<th>Key Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stanford Univ MC 1994: ICU</td>
<td>Decreased ICU LOS by 5.2 days, Decreased Days of Pneumonia by 52%</td>
</tr>
<tr>
<td>Cape Fear Valley MC 1994</td>
<td>Decreased H &amp; ICU LOS, Decreased Vent Days 48 fewer NP year of the 6 month bed study, Lag time effect: decreased days on therapy</td>
</tr>
<tr>
<td>Sarasota Memorial 2001</td>
<td>Decreasing LAG time resulted in 14% decrease in HLOS, Vent Days, &amp; 20% decrease of SMR (standard mortality ratio)</td>
</tr>
<tr>
<td>Medical Center of Georgia 2002</td>
<td>Decrease Vent Days, Decreased Hospital LOS, Decrease ICU LOS by 5-6 days.</td>
</tr>
</tbody>
</table>

Systematic method of approaching placement & removal of rotational therapy

Lateral Rotation: Summary of Research Findings

- Lateral rotation is effective in reducing the incidence of pneumonia, atelectasis, time on the vent and stay in the ICU
- The earlier the patient is placed on the therapy during their acute illness the better the response
- CLRT appears to have some benefit on oxygenation variables, however more research is required
- The absolute answer on the degree of rotation and the frequency of rotation to achieve the beneficial effect is not available
Methods

- Retrospective analysis of data collected on 62 CLRT patients
- Mean Apache III score 76.74 ± 33.65/Median 71.5
- 45% overall mortality rate
- Dx: ARDS, pneumonia & respiratory failure
- Medical Critical Care area, Trauma & Thoracic Surgery
- Examined change in PaO2/FiO2 ratios based on:
  - Number of hours spent in rotation over course of therapy
  - Degree of rotation (defined as highest degree patients achieved while on therapy)

Cagle, Pieper & Vollman NTI 1993

Results

- 58% improved oxygenation status
- Average days spent in rotation 4.6 ± 2.3
- Mean hours in rotation 68.45 ± 48.57
- Positive correlation between hours spent in rotation and improvement in PaO2/FiO2 status
- Mean degree of rotation 29.5 ± 6.81
- No correlation noted between degree & improvement in ratio

Cagle, Pieper & Vollman NTI 1993

Comparison of Clinical Outcomes in Pulmonary Complications for CLRT via 2 Therapeutic Beds

- Compare outcomes of VAP and Vent LOS with CLRT using 2 different beds
- 12 bed Mixed ICU, 99 intubated patients
- Retrospective analysis of 100% of patients receiving CLRT over a 2 year period (single reviewer)
- Compared outcomes in patients receiving CLRT via TriaDyne and SpO2RT

Fortune D. 2003, White Paper
Chandler Regional Hospital Catholic Health Care West

Comparison of Clinical Outcomes in Pulmonary Complications for CLRT via 2 Therapeutic Beds

- TriaDyne
  - Mean LOS 3.12 days
  - Incidence of VAP while on the Bed: 3
  - VAP % during use of TriaDyne 8.8%

- SpO2RT
  - Mean LOS 2.68 days
  - Incidence of VAP while on the bed: 1
  - VAP % during use of the SpO2RT 1.5%

Fortune D. 2003, White Paper
Chandler Regional Hospital Catholic Health Care West

Chlorhexidine vs. Povidone Iodine for Catheter Site Care

<table>
<thead>
<tr>
<th>Study Reference, Year</th>
<th>Risk Ratio (95% CI)</th>
<th>Catheters, n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mard et al (1), 1991</td>
<td>0.15 (0.05–0.46)</td>
<td>441</td>
</tr>
<tr>
<td>Shiedan et al, 1993</td>
<td>1.05 (0.07–14.67)</td>
<td>346</td>
</tr>
<tr>
<td>Melfi et al, 1995</td>
<td>0.87 (0.33–2.37)</td>
<td>1167</td>
</tr>
<tr>
<td>Atkins et al (3), 1996</td>
<td>0.44 (0.15–1.21)</td>
<td>213</td>
</tr>
<tr>
<td>Logan et al (2), 1997</td>
<td>0.53 (0.36–0.80)</td>
<td>407</td>
</tr>
<tr>
<td>Mard et al, 1991</td>
<td>0.75 (0.26–2.21)</td>
<td>378</td>
</tr>
<tr>
<td>Raskolnik and Malik, 2009</td>
<td>0.32 (0.16–0.68)</td>
<td>809</td>
</tr>
<tr>
<td>Overall (95% CI)</td>
<td>0.49 (0.29–0.82)</td>
<td>3589</td>
</tr>
</tbody>
</table>

Review of Inventions to Reduce VAP in Critically Ill Patients
• Evidence-based systematic review of the literature 1966 - 2001
• Data extract on study design, intervention & outcomes
• Results: Strategies that reduce VAP
  – Semirecumbent position
  – Stress ulcer prophylaxis
  – Aspiration of subglottic secretions
  – Selective digestive decontamination
  – Rotational therapy


WHEN TO STOP CLRT
• When the patient no longer fits the criteria that placed them on CLRT
• When the patient can be mobilized into an upright position without hemodynamic compromise

What is Your Next Move!!!!
Combate deconditioning through progressive positioning when CLRT treatment is completed

In the Research… 1997 and 2000
Maximize Therapeutic Intervention
• Up-in-chair positioning
  – Branson, ACCP 1997
    • Pulmonary mechanics
    • Lung volumes
    • Gas exchange
  – Hospital Research Association, SCCM 2000
    • 92% standard of care
    • 90% not completed as ordered

Airway Clearance
Part of the Complete Preventive & Treatment Pulmonary Strategies

Manual vs. Mechanical Bed CPT
Methodology
• 24 patients with respiratory failure demonstrating segmental, lobular or unilateral entire lung atelectasis
• Ventilated or spontaneously breathing
• 17 patients rotated with q 4 hour percussion at 9 beats for 20 min/18hours per day
• 7 patients turned q 2 hours with q 2hr CPT

Manual vs. Mechanical Bed CPT

Results
- Complete or partial resolution
  - CLRT 14/17 (82%)*
  - Control 1/7 (14%)
- P/F ratio changes over 4 days
  - CLRT 207 to 318
  - Control 181 to 112
- Bronchoscopy required
  - CLRT 0**
  - Control 3

*p < 0.004 **p < 0.002


HFCWO

- Increased sputum mobilization*
- Improved pulmonary function*
- Cost effectiveness
  - Decreased hospitalizations*, ICU days
  - Decreased antibiotic/oxygen needs
- Safety / efficacy in multiple disease states*
- Safety in ICU/post cardiac surgery*
- Improved weaning from vents
- Combining with other airway clearance therapies*

King, Warwick, Landon, Ploppis, Allen, Brierley

Positioning CLRT, Bed P&V and HFCWO

In the ICU setting:
- For prevention of pulmonary complications use CLRT
- For patients requiring CLRT that have infiltrates/atelectasis provide CLRT w/ P&V Therapy from the Surface
- If CLRT with P&V module does not help improve or effectively address airway clearance therapy, provide the Vest for HFCWO along with CLRT

In the Medical-Surgical care area:
- For airway clearance therapy provide the Vest for HFCWO
- Use CLRT for select immobile patients

2005 - Progressive Patient Positioning

- Old way
  - Admission, bed, immobilized, supine, complications
- New way
  - Lateral rotation
  - HOB elevation
  - Full-chair position
  - Bed egress/weight bearing
  - Bedside chair
  - Ambulation
  - Enhanced recovery

Where Does The Prone Position Fit into A Mobility Program?

When the patient’s alveoli have been recruited through conventional means & the FiO2 remains in an unsafe range

The goal of prone positioning is to reduce the iatrogenic complications of mechanical ventilation
Review of Prone Research Research up to 2004

- 651 patients turned prone (1105 total)
  - 17 studies (46 total)
  - 58% abdomen free (versus 80%)
  - 50% volume ventilation (versus 93%)
  - 50% pressure controlled

RESULTS:
71% reported a response >20% change in P/F ratio or 10mmHg increase in PaO2 within 1 to 2 hours
Time in prone position 30 minutes to 20 hours
Trend of complications associated with > time spent in the prone position


Purposes

- Identify a safe, maneuverable and effective technique to position patients prone
- Determine if the suspended prone position improves oxygenation in the adult patient with acute respiratory failure

PHASE I

PRODUCT EVALUATION STUDY
1980's Prone Positioning Research…

Methodology
- 15 critically ill ARDS patients
- Served as their own control
- Randomly assigned position
- ABG's at baseline & 20 mins
- Respiratory & hemodynamics measured
- Manual turning performed with a frame using 3 individual/abdomen unrestricted

Ventilator Settings

Tidal Volume: 600 to 900cc
Oxygen: 40% to 100%
A / C rate: 10 to 25 / min
PEEP: 5 to 20 cm of H2O

Results:

Responders (9): 
- \( \text{PaO}_2 \): 89.1 \( \pm \) 14.1 to 122.0 \( \pm \) 27.4
- Shunt: 32.2 \( \pm \) 5.3 to 27.1 \( \pm \) 5.3

Non-Responders (6): 
- \( \text{PaO}_2 \): 82.8 \( \pm \) 15.3 to 72.6 \( \pm \) 10.3
- Shunt: 31.7 \( \pm \) 11.3 to 34.7 \( \pm \) 12.0

No difference in hemodynamics seen between positions

Differences in Pulmonary & Hemodynamic Variables between R & NR

<table>
<thead>
<tr>
<th>Variable</th>
<th>R</th>
<th>NR</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{PaO}_2 )</td>
<td>45.8 ( \pm ) 10.4</td>
<td>51.2 ( \pm ) 12.2</td>
<td>0.22</td>
</tr>
<tr>
<td>RR</td>
<td>4.1</td>
<td>3.9</td>
<td>0.07</td>
</tr>
<tr>
<td>HR</td>
<td>27.4 ( \pm ) 9.5</td>
<td>22.2 ( \pm ) 16.0</td>
<td>0.30</td>
</tr>
<tr>
<td>Plate</td>
<td>27.4 ( \pm ) 9.5</td>
<td>55.6 ( \pm ) 17.5</td>
<td>0.26</td>
</tr>
<tr>
<td>PR (cmH2O / hr)</td>
<td>31.5 ( \pm ) 13.9</td>
<td>41.0 ( \pm ) 10.8</td>
<td>0.001</td>
</tr>
<tr>
<td>MAP</td>
<td>89.7 ( \pm ) 12.1</td>
<td>98.0 ( \pm ) 14.4</td>
<td>0.28</td>
</tr>
<tr>
<td>( \text{PaCO}_2 )</td>
<td>37.0 ( \pm ) 7.1</td>
<td>31.3 ( \pm ) 3.4</td>
<td>0.02</td>
</tr>
<tr>
<td>Plate</td>
<td>25.4 ( \pm ) 3.0</td>
<td>24.9 ( \pm ) 2.1</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Demographic Differences of Non-Responders

- Additional lung pathologies
- Trend toward longer stay in ICU & time on vent
2001 Prone Positioning
Gattinoni et. al.
Methodology
- Study Period: 1996-1999
- 304 patients with Acute Lung Injury/Acute Respiratory Distress Syndrome randomized to receive 6 hours of prone positioning q 24 for 10 days or supine position with q 2 hour lateral positioning
- Entrance criteria: modified ALI/ARDS definitions

Results
- 10 day mortality: 21% vs. 25% (RR 0.84 CI 0.56 to 1.27)
- Hospital d/c mortality: 50.7% vs. 48% (RR 1.05 CI 0.84 to 1.32)
- 6 months mortality: 62.5% vs. 58.6% (RR 1.06 CI 0.88 to 1.28)
- Significant increase in PaO2/FiO2 ratio in the prone group
- No difference in organ dysfunction
- % of patients with new or worsening pressure ulcers per patient was worse in the prone group

Study Concerns
- Was the study methodology relevant?
- Testing an intervention using 1996-1999 ventilator management
  - TV: 10.3/ml/kg
  - Average PEEP: <10cm
- Majority of patients entered into the study were primary respiratory pathology vs. secondary
- Were the patients in the prone position a sufficient period of time?
  - Average time prone: 7.0 ± 1.8

Study Concerns
- Was the study powered sufficiently?
  - Stopped early with recruitment problems
  - Deviations from the protocol/41 patients non-compliant with the study protocol
- Were the most appropriate patients study?
  - Altered ALI/ARDS criteria
  - Post-hoc analysis showed sicker patients had a significant improvement in mortality

2001 Prone Positioning
Gattinoni et. al.
Methodology
- Measured: Primary endpoints: mortality at 10 days, hospital D/C & 6 months
  - Secondary endpoints: PaO2/FiO2, ratio reduction, organ failure & incidence of complications

Study Concerns
- • Was the study methodology relevant?
  - Testing an intervention using 1996-1999 ventilator management
    - TV: 10.3/ml/kg ± 2.9 (s)
    - Average PEEP: <10cm
  - Majority of patients entered into the study were primary respiratory pathology vs. secondary
- • Were the patients in the prone position a sufficient period of time?
  - Average time prone: 7.0 ± 1.8

Prone Positioning 2004
Guerin C. et al
Methodology
- Study conducted: Dec 1998-2002
- 791 ARF patients, multicenter trial, unblended, randomized
- 413 prone, 378 supine (8 hours per day)
- Patient in supine group could cross over to prone if P/F ratio < 100 for > 12 hours, or < 60 for 1 hr or on 100% FiO2
- P/F ratio <300, hemodynamically stable & no contraindications to the prone position
- Measured 28 day all cause mortality, duration of mechanical ventilation, incidence of VAP & oxygenation
Prone Positioning 2004
Guerin C. et al

Results
- No difference in mortality
- No difference in ventilation days
- Reduction in VAP in the prone group*
- Significantly higher P/F ratio for 28 days in the prone group

Limitations
- Most patient’s in supine group crossed over
- Mechanical ventilation was not performed using a pre-determined algorithm (Tidal volume 8 ml/kg & tidal volume in pressure control 11ml/kg)
- Only in prone position for 8.6 hours for total of 4.6 days

*P < 0.045

Barriers to Mobility Strategies
- Human or Technological Resources
- Hemodynamic instability
- Knowledge/Priority

Human & Technological Resources
- Pain
- Personnel
- Aging personnel
- Use of Lift teams
- Fear
- Lines and tubes

Hemodynamic Instability
Is it a Barrier to Positioning?

Hemodynamic Status
- No differences noted in hemodynamic variables between supine & positions
- Lateral turn results in a 3-9% decrease in SVO2 which takes 5-10 minutes to return to baseline
- Appears the act of turning has the greatest impact on any instability seen
- Minimize factors which contribute to imbalances in oxygen supply & demand
- Perform a trial turn?

Patients at Risk for Intolerance to Positioning
- Elderly
- Diabetes with neuropathy
- Prolonged bedrest
- Low Hb an cardiovascular reserve
- Prolonged gravitational equilibrium


Reported Complications for 746 Prone Turn Cycles

- 12 studies noted critical events
- > 12 hours in the prone position associated with more complications
- One-half of the studies reported cutaneous & structural problems
  - dependant edema
  - pressure ulcers: chin & chest
  - contractures (9 days prone, 56 days prone)

Curley M. AJCC, 1999;8:397-405

Reported Complications for 746 Prone Turn Cycles (cont’d.)

- 8 episodes of hemodynamic instability (1.1%)
- 3 episodes of extubation (.4%)
- 2 episodes of \( \Delta \) in SaO2 (.3%)
- 2 atypical atelectasis (.3%)
- 1 obstructed ET tube (.1%), 1 kinked ETT (.1%), 1 CVC dislodgment (.1%), 1 femoral hemodialysis catheter dislodgment (.1%), 1 SVT (.1%)

Curley M. AJCC, 1999;8:397-405

Prone Positioning

Evidence Based Medicine
Evidence Based Practice
Clinical Effectiveness

IHI/VHA Change Strategy

- Care Bundles
  - Grouping of care elements for particular symptoms, procedures or treatments
  - Strong science, good methodology, poor process
  - Bundle characteristics
    - Solid evidence
    - Relatively easy & inexpensive
    - Individual components defined well
    - Process not defined well

The Vent Bundle…Getting Started

- Applying evidence-based practice
- 5 activities that when done 100% of the time has shown a reduction in
  - VAP
  - LOS
  - Time on Vent
  - Cost
- HOB 30°, DVT prophylaxis, PUD prophylaxis, Sedation vacation, Spontaneous breathing trial (added components in some areas of the country (oral care & mobility)
What does the DVT Science Tell Us?

- Patients who are critically ill or mechanically ventilated are at high risk for DVT and should receive some form of thromboprophylaxis.
- Multiple therapies for DVT prophylaxis were consistently reported to reduce the risk of DVT.
- With prevention we can reduce mortality, hospital LOS and associated costs.

DVT Prevention: SCD’s vs. Aspirin

- Methodology: 122 patients unilateral or bilateral total knee arthroplasty
  - Compared efficacy of 2 methods for DVT prevention; pneumatic planter compression & aspirin or aspirin alone
  - Venograms performed on post-op day 4 & 7
  - Compliance assessed via internal timing device
- Results:
  - 59% prevalence with aspirin alone
  - 27% prevalence with aspirin & pneumatic compression
  - Study group 0% proximal thrombi, 14% in control
  - Compliance: In study group patients those with no DVT’s wore the device 19.2 hours/day compared with 13.4 hours/day

What does the PUD Science Tell Us?

- Patients who are mechanically ventilated are at high risk for upper GI bleed and evidence supports prophylaxis.
- Multiple therapies for PUD have proven effective.
- GI bleed results in an additional 5 day LOS and there is a 13% relative increase in mortality with significant GI bleed.

What does the Sedation Evaluation Science Tell Us?

- Daily interruption of sedative drug infusions decreases the duration of mechanical ventilation and LOS in the ICU.
- In the group that had daily interruption, the duration of mechanical ventilation was reduced by 33% (2.4 days) and ICU LOS was reduced by 35% (3.5 days).

What does the Daily Spontaneous Breathing Trial Science Tell Us?

- Daily screening of respiratory function followed by a trial of spontaneous breathing if the patient meets the criteria can result in a reduction of time on the ventilator, reduced complications and costs.
- In a study that look at daily screening followed by a trial if criteria met resulted in 1.5 days less on the ventilator. Complications post extubation were less in the SBT group.
Pharmacological Management

- Modulation Therapies
  - Antioxidants
  - NSAIDS
  - IL-1 receptor antagonist
  - Neutrophil Elastase Inhibitor
  - Xigris (Activated Protein C) if in Severe Sepsis

Drotrecogin Alfa (Activated) Significantly Improved Survival in PROWESS

- 31% mortality for drotrecogin alfa (activated) patients vs 44% for standard therapy patients at 28 days.

Surfactant Replacement

- Goal: Lowers surface tension
- Decrease atelectasis
- Provides a greater area for gas exchange

- Concerns: Cost, Delivery method, Dose required

Multicenter Surfactant Trial

- NEJM 1996;334:1417-21
Phase III Multicenter Nitric Oxide Study

Methodology:
- 385 ARDS patients
- Randomized to receive 5 ppm of NO or placebo
- Measured: alive & off assisted breathing (extubated for 72 hours)

Results:
No difference in population demographics
Treatment: 10.70 days alive/off assisted breathing  
Mortality: 23%
Placebo: 10.64 days alive/off assisted breathing  
Mortality: 20%

Liquid Ventilation

- Enhances recruitment of atelectatic lung regions
- Lavages exudate from peripheral airways

Partial Liquid Ventilation:  
a Non-Controlled Phase 1 Study

Methodology
- 10 adult patients with ARDS
- Receiving ECMO
- Dose range 2.5 to 10 ml/kg

Results
- Reduction in shunt
- Improved compliance
- 50% survival
- Complications: 1 pneumothorax and 1 mucus plug

Learn the value of teamwork and how much people contribute to each other’s success.