Mechanical Ventilation Methods in Transport of Critically Injured Patients
Disclosures

- The opinions expressed on this document are solely those of the author(s) and do not represent an endorsement by or the views of the United States Air Force, the Department of Defense, or the United States Government.

- This study was conducted under a protocol reviewed and approved by the Wilford Hall Ambulatory Surgical Center IRB and in accordance with the approved protocol.

- The authors acknowledge Department of Defense Trauma Registry (DoDTR) for providing data for this study.
BACKGROUND
### Tidal Volumes for Ventilation of Patients with ARDS - ARDSNet ARMA Trial

#### Male Patients

<table>
<thead>
<tr>
<th>Height</th>
<th>ft in</th>
<th>in</th>
<th>cm</th>
<th>Pre Wt (Kg)</th>
<th>cc's per Kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>5'6&quot;</td>
<td>66</td>
<td>168</td>
<td>64</td>
<td></td>
<td>255 320 385 445 510 575 640</td>
</tr>
<tr>
<td>5'8&quot;</td>
<td>68</td>
<td>173</td>
<td>68</td>
<td></td>
<td>275 340 410 480 545 615 685</td>
</tr>
<tr>
<td>5'10&quot;</td>
<td>70</td>
<td>178</td>
<td>73</td>
<td></td>
<td>290 365 440 510 585 655 730</td>
</tr>
<tr>
<td>6'</td>
<td>72</td>
<td>183</td>
<td>78</td>
<td></td>
<td>310 390 465 545 620 700 775</td>
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<tr>
<td>6'2&quot;</td>
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<td>188</td>
<td>82</td>
<td></td>
<td>330 410 495 575 660 740 820</td>
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<tr>
<td>6'4&quot;</td>
<td>76</td>
<td>193</td>
<td>87</td>
<td></td>
<td>345 435 520 610 695 780 870</td>
</tr>
<tr>
<td>6'6&quot;</td>
<td>78</td>
<td>198</td>
<td>91</td>
<td></td>
<td>365 455 550 640 730 825 915</td>
</tr>
</tbody>
</table>

#### Female Patients

<table>
<thead>
<tr>
<th>Height</th>
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<th>in</th>
<th>cm</th>
<th>Pre Wt (Kg)</th>
<th>cc's per Kg</th>
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</thead>
<tbody>
<tr>
<td>5'</td>
<td>60</td>
<td>152</td>
<td>46</td>
<td></td>
<td>180 230 275 320 365 410 455</td>
</tr>
<tr>
<td>5'2&quot;</td>
<td>62</td>
<td>157</td>
<td>50</td>
<td></td>
<td>200 250 300 350 400 450 500</td>
</tr>
<tr>
<td>5'4&quot;</td>
<td>64</td>
<td>163</td>
<td>55</td>
<td></td>
<td>220 275 330 385 440 490 545</td>
</tr>
<tr>
<td>5'6&quot;</td>
<td>66</td>
<td>168</td>
<td>59</td>
<td></td>
<td>235 295 355 415 475 535 595</td>
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<td>183</td>
<td>73</td>
<td></td>
<td>290 365 440 510 585 660 730</td>
</tr>
</tbody>
</table>

### PEEP Titration Table - ARDSNet ARMA Trial

| PEEP FiO2 | 5 | 5 | 8 | 8 | 10 | 10 | 10 | 12 | 14 | 14 | 14 | 16 | 18 | 18 | 20 | 22 | 24 |
|-----------|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
|           | 0.3| 0.4| 0.4| 0.5| 0.5| 0.6| 0.6| 0.7| 0.7| 0.8| 0.9| 0.9| 0.9| 1   | 1  | 1  | 1  | 1  |

<----- Move across table to keep SaO₂ 92 – 96 % ------>

Patients falling in shaded area are not necessarily too sick for flight but risks and benefits should be considered as described in the CPG.

---

1. Increasing PEEP will decrease cardiac output and may cause significant hypotension in hypovolemic patients. Additional volume loading may be necessary to maintain hemodynamics.
2. This is a fairly accurate indicator of plateau pressure in our patient population. Plateau pressure is the correct parameter to follow but it cannot be easily measured with the Impact 754 ventilator.
3. Measuring the patient’s “wingspan” should be used as an estimate of height. Sternum to fingertip multiplied x 2.
4. A pH of 7.2 may be an appropriate target if hemodynamics are relatively normal.
Volume Control Ventilation

1. Set the I:E ratio at 1:2 to 1:4. Turning the inspiratory time knob on the Impact 754 all the way left will give 1:2 without having to adjust the inspiratory time.

2. Set PEEP and FiO₂ according to ARDSNet ARMA Trial PEEP table to achieve SaO₂ 92 - 96%¹. Note that the Impact 754 and LTV 1000 are limited to PEEP 20.

3. Set tidal volume at 6 cc/Kg and note peak inspiratory pressure (PIP)². If necessary, decrease tidal volume by 1 cc/Kg as needed to keep peak inspiratory pressure ≤ 35 cm H₂O (preferably ≤ 30). Do not go below 4 cc/Kg. Use table below as reference for appropriate tidal volume³.

4. Adjust respiratory rate to achieve pH ≥ 7.3⁴. The actual PCO₂ is not important, only the pH.

Pressure Control Ventilation

1. Set I time to achieve I:E ratio of 1:2 to 1:4.

2. Set PEEP and FiO₂ according to ARDSNet ARMA Trial PEEP table to achieve SaO₂ 92 - 96%¹. Note that the Impact 754 and LTV 1000 are limited to PEEP 20.

3. Set inspiratory pressure to achieve a tidal volume of 6 cc/kg. If this value is > 30 cm H₂O then decrease until it is ≤ 30 cm H₂O or until tidal volume is 4 cc/kg. Use table below as reference for appropriate tidal volume³.

4. Adjust respiratory rate to achieve pH ≥ 7.3⁴. The actual PCO₂ is not important, only the pH.
Study Aims

- Describe ventilator settings of patients transported by CCATT
- Evaluate the influence of ventilator settings on patient outcomes (through 30 days)
- Provide data to improve utilization of existing CPG and identify potential gaps
Study Design

- Retrospective review
  - CCATT medical records
  - Patients requiring mechanical ventilation
  - Transported 2007-2012
  - Trained data abstractors
    - Consensus review
    - Serial meetings
Data Collected

- **CCATT Records**
  - Demographics, injury description
  - Pre-flight vitals, labs, and oxygenation status
  - In-flight vitals, labs, interventions, and complications
  - Post-flight vitals and labs

- **Department of Defense Trauma Registry (DoDTR)**
  - ISS
  - Clinical events
  - Outcomes up to 30 days
  - Mortality
## Definitions of Complications

<table>
<thead>
<tr>
<th>Category</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hyperthermia</td>
<td>Body temperature ( \geq 100.5 , ^\circ\text{F} ) or ( 38 , ^\circ\text{C} )</td>
</tr>
<tr>
<td>Respiratory</td>
<td>- ( \text{SpO}_2 \leq 90% )&lt;br&gt;- Increase ( \text{FiO}_2 ) ( &gt;10% ) or increase oxygen ( \text{L/min} ) ( &gt;4% )&lt;br&gt;- Respiratory rate ( &gt;22 ) or ( &lt;10 , \text{bpm} )&lt;br&gt;- ( \text{pCO}_2 ) ( &lt;35 ) or ( &gt;45 ) or change of ( 10% ) from baseline</td>
</tr>
<tr>
<td>Hemodynamic</td>
<td>- ( \text{SBP} \leq 90 ) or ( \geq 180 ) or ( 20% ) change from baseline&lt;br&gt;- ( \text{MAP} \leq 65 ) or ( \geq 120 ) or ( 20% ) change from baseline&lt;br&gt;- ( \text{CVP} ) change from baseline of ( 5 )</td>
</tr>
<tr>
<td>Heart Rate</td>
<td>( &lt;60 , \text{bpm} ) or ( &gt;120 , \text{bpm} ) or ( 20% ) change from baseline</td>
</tr>
<tr>
<td>( \downarrow ) urine output</td>
<td>As determined by CCATT clinical provider</td>
</tr>
<tr>
<td>Bleeding</td>
<td>As determined by CCATT provider</td>
</tr>
<tr>
<td>Neurologic</td>
<td>As determined by CCATT provider to include: change in mental status, motor, cognitive, or sensory ability; seizure</td>
</tr>
</tbody>
</table>
Frequencies and proportions

- Chi-square or Fisher’s exact for categorical variables (%)
- T-test for continuous variables
  - Median [Interquartile Range]
- Significance set at p<0.05
RESULTS
Study Population

CCATT Records
- 2007-2012
- Role 3 to LRMC

Oxygen Support
- Ventilated 60%

Ventilation Mode
- Pressure Control 2%
- Volume Control 98%
  - 652 patients
Pre-Flight Tidal Volume

- **Greater than 8 cc per kg**
  - No differences in demographics
  - Higher ISS
  - No differences in pre-flight, in-flight, or post-flight oxygenation
  - No differences in pre-flight, in-flight or post-flight outcomes

![Bar chart showing 73% for 6-8 cc per kg and 27% for >8 cc per kg]
Proportion of Oxygen Saturation Values

Overall

Pre-flight

1

2

3

4

5

Post-flight

- >400
- 351-400
- 301-350
- 251-300
- 200-250
- 151-200
- 100-150
- 80-100
- <80

0

20

40

60

80

100
Oxygen Requirement

- Greater than 50%
  - No differences in demographics
  - Higher ISS
  - More likely to receive a paralytic and have a chest tube
  - Lower pre-flight PaO$_2$, but within reference range
  - More likely to have an in-flight respiratory event 33% vs 63%, p<0.0001
  - No differences in post-flight clinical events
  - More ventilator, ICU, hospital days
Greater than or equal to 10

- No differences in demographics
- Higher ISS
- More likely to receive a paralytic and have a chest tube
- Lower pre-flight PaO\textsubscript{2}, but within reference range
- More likely to have a pre-flight respiratory event
  7% vs 15%, p<0.02
- No differences in in-flight or post-flight clinical events
- More ventilator days
Non-Compliant

- Older (median 24 v. 25)
- Higher ISS (median 22 v. 27)
- No other differences in demographics
- More likely to have chest tube 19% vs 26%, $p=0.04$
- Higher rate of in-flight respiratory event 29% vs 50%, $p<0.0001$
<table>
<thead>
<tr>
<th>Outcome</th>
<th>Compliant median[IQR]</th>
<th>Non-Compliant median[IQR]</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post-Flight Respiratory Event</td>
<td>28% [3-6]</td>
<td>34% [3-8]</td>
<td>0.07</td>
</tr>
<tr>
<td>ARDS/ARF/VAP</td>
<td>2% [4-9]</td>
<td>9% [4-13]</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Post-Flight Coagulopathy</td>
<td>18% [4-9]</td>
<td>18% [4-9]</td>
<td>0.90</td>
</tr>
<tr>
<td>DVT/PE</td>
<td>9% [4-9]</td>
<td>11% [4-13]</td>
<td>0.63</td>
</tr>
<tr>
<td>Post-Flight Cardiac Event</td>
<td>16% [4-9]</td>
<td>16% [4-9]</td>
<td>0.99</td>
</tr>
<tr>
<td>Post-Flight Hemodynamic Event</td>
<td>24% [4-9]</td>
<td>25% [4-9]</td>
<td>0.76</td>
</tr>
<tr>
<td>Post-Flight Renal/Urinary Event</td>
<td>13% [4-9]</td>
<td>9% [4-9]</td>
<td>0.05</td>
</tr>
<tr>
<td>Ventilator Days</td>
<td>4 [3-6]</td>
<td>5 [3-8]</td>
<td>0.004</td>
</tr>
<tr>
<td>ICU Days</td>
<td>6 [4-9]</td>
<td>7 [4-13]</td>
<td>0.009</td>
</tr>
<tr>
<td>Hospital Days</td>
<td>12 [5-37]</td>
<td>14 [5-38]</td>
<td>0.82</td>
</tr>
<tr>
<td>Mortality</td>
<td>3%</td>
<td>5%</td>
<td>0.03</td>
</tr>
</tbody>
</table>
## Proportional Hazards

<table>
<thead>
<tr>
<th>Risk Ratio</th>
<th>Ventilator Days</th>
<th>ICU Days</th>
<th>Hospital Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>p-Value</td>
<td>0.03</td>
<td>0.02</td>
<td>0.75</td>
</tr>
<tr>
<td>Risk Ratio</td>
<td>1.21 (1.02-1.45)</td>
<td>1.21 (1.03-1.47)</td>
<td>1.03 (0.86-1.23)</td>
</tr>
</tbody>
</table>
ARDSNet Table Compliance
### ARDSNet Table

<table>
<thead>
<tr>
<th>Non-Compliant</th>
<th>Odds Ratio</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARDSNet Table</td>
<td>2.17 (1.01-4.95)</td>
<td>0.046</td>
</tr>
</tbody>
</table>
Limitations

- Data collected retrospectively
- Subjectivity despite trained abstractors
- Data missing or unavailable
Conclusions

- Over half of CCATT patients are mechanically ventilated
- Compliance with ARDSNet guideline is low
- Non-compliance is associated with increased
  - Ventilator days, ICU days, Mortality
- Dissemination of findings = Lives Saved!
Future

- Impact of ERC CPG/training
- Impact of closed loop ventilatory devices
- Impact of ERC hypoxia and hyperoxia on neurologic outcomes
Thank you

- Dr. Vikhyat Bebarta
- Dr. Shelia Savell
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- William Terry
- Avery Kester