Mechanical Ventilation
Year in Review - 2014

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Memorial Hospital Jacksonville

I have no conflicts of interest to disclose,
just interesting conflicts
Mechanical Ventilation - Methodology
Year in Review - 2014

◊ Methods

➢ Online and manual search of relevant journals
➢ 152 articles concerning aspects of MVS screened

◊ Criteria for inclusion

➢ Clinical, adult human studies
➢ Clinically relevant

• Either: novel, controversial, confirmatory, pragmatic, cute
• Grading system...what I thought would be of interest
• Reviewed rigorous studies, smaller journals, debates, editorials
• “My Paper 20 Years Later” papers used as catalyst for review
  – Intensive Care Medicine
Summary of 2014 Update
(F/U of 2013 & 2012 Themes)

◊ NIPPV – not much to report this year
◊ Early tracheostomy
  ➢ Surprisingly, a positive pro-trache meta-analysis
◊ Lung protective strategies
  ➢ Further bashing of HFOV; ECMO enthusiasm
  ➢ Proning popularity
  ➢ ARDS – see Current Guidelines lecture
◊ Muscle fatigue – 20 years later
◊ Weaning – 20 years later
  ➢ Don’t wait...just automate
When is the optimal time to perform tracheosotomy on patients receiving MVS?

a) After 10 days in medical patients
b) After 14 days in medical patients
c) After 10 days in surgical patients
d) After 14 days in surgical patients
e) Before the insurance runs out!

The Origins of Mechanical Ventilation Via Tracheotomy

“But that life may...be restored to the animal, an opening must be attempted in the trunk of the trachea, in which a tube of reed or cane should be put; you will then blow into this, so that the lung may rise again and the animal take in air. ...and as I do this, and take care that the lung is inflated in intervals, the motion of the heart and arteries does not stop...”

Andreas Wesele Vesalius, 1543

Reward for resuscitating a nobleman…to be burned at the stake

To trache or not to trache
Sponsored by Intensive Care Society of the UK
- Early (1-4 days) vs late (>10 days) percutaneous tracheostomy

Multicentered, randomized trial with n = 909

Preliminary findings presented 3/2009 in Brussels
- International Symposium of Intensive & ED Medicine

Results
- No significant difference in mortality, LOS, VAP
  - Required less sedation
  - Only 45% of referred pts required procedure
  - Out of 100 pts, early tracheostomy resulted in 2.4 days less sedation but 48 more tracheostomies
Tracheostomy Practice in Adults with Acute Respiratory Failure (ARF)

Concise Definitive Review - 2012

◊ Critical appraisal of the literature, incl TracMan
◊ Conclusions
  ➢ Defer trache placement for > 2 wks after ARF
    • Exceptions:
      – Urgent need for surgical airway
      – Some neuro injured pts (stroke, trauma, etc)
  ➢ Percutaneous dilatational approach preferred
  ➢ No beneficial effects on ICU LOS nor length of MVS
  ➢ Lessens need for sedation & improves comfort & mobility
Early vs Late or No Tracheostomy – 2014

**ICU Mortality**

13 Trials    2,434 Pts    800 deaths


- p < 0.04 favoring early trache
- 18% relative, 5% actual improved survival
Early vs Late or No Tracheostomy - 2014
One Year Mortality & Caveats

◊ Caveats

- ICU LOS & MVS time shorter in early trache
  - But *not* hospital LOS
- Positive effects **limited** to only those pts with predicted mortality > 20% &/or when trached in <4days

◊ **Caution**...complications & unnecessary traches

Which ventilatory strategy often worsens the PaO2/FiO2 ratio in patients with ARDS?

a) Pressure controlled–inverse ratio ventilation
b) Prone position
c) Vt (6 ml/kg IBW) strategy
d) Nitric Oxide
e) High-frequency oscillatory jet vent
High-Frequency Ventilation
The “Ultimate” Lung Protective Strategy
High-Frequency Oscillation in Early ARDS
“OSCILLATE” Trial Investigators

◊ Randomized-controlled trial in 39 ICUs
  ➢ Canada & US > Mexico, Saudi Arabia, India
  ➢ Initial goal: 1200 patients
  ➢ Terminated after interim analysis of 500 patients
• Increased mortality in HFOV group
  (47% vs 35%, p=0.005)

◊ Methods
  ➢ Goals: PaO2: 55-80 mmHg; pH > 7.25
  ➢ Control Vt 6 ml/kg; Pplateau <35; high PEEP 20

HFOV vs Conventional MVS
30 – Day or Hospital Mortality
5 Trials        1,580 Patients

- HFOV significantly improved oxygenation in four studies
- No difference in barotrauma, but trend unfavorable for HFOV

Huang, et al. Crit Care 2014; 18L(R102)
“No” – Gattinoni

- Major point – needs to be individualized
  - IBW not good enough surrogate in ARDS
    - Better correlation in healthy lungs
  - Concerned about sedation & ATX

Lung Volumes Determined By CT scans

Ideal Body Weight
Vt Size & Weaning in Non-ARDS Patients


Meta-analysis 7 Studies 2,184 Pts

In-Hospital Survivorship not significantly different (p=0.071)
Prone Positioning in ARDS

Stocker et al. Chest 1997; 111:1008-17; 25 trauma ARDS pts
Prone Positioning in ARDS

Rationale, Indications, and Limits

CT Scans  Supine and Prone

Gattinoni L, Marini JJ, et al. AJRCCM 2013;188:1286-1293
PROSEVA Trial

Cumulative Probability of Survival

16% vs. 33%

PROSEVA Study - 2013

Why It Was So Successful

◊ Avoided pitfalls of previous ARDS studies
  ➢ Used as a preventative strategy, not as salvage mode
    • Started within 36 hours of ARDS & for >16 hrs qd
  ➢ Used only in the most severe ARDS patients
  ➢ Control group was “amazingly” well-matched
    • Almost too good to be real
  ➢ Control group MVS well done (low Vt strategy)

◊ Putting study in perspective of clinical ICUs
  ➢ Each ICU averaged 6.7 eligible ARDS patients / year
    • Each ICU averaged 49 ARDS patients / year

◊ Conclusions: Use It Early in Only the Most Severe
Prone Positioning Effects on All Cause Mortality
Prespecified Patient-Level & Trial Level Subgroups

◊ Methods

11 RCTs with n = 2341 (up to August 2013)
• Overall quality of evidence high; risk of bias low

<table>
<thead>
<tr>
<th>Variable</th>
<th>No. of trials</th>
<th>Deaths, n/N</th>
<th>RR (95% CI)</th>
<th>P value, %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Prone</td>
<td>Supine</td>
<td></td>
</tr>
<tr>
<td>Protective lung ventilation (&lt;8 ml/kg IBW)</td>
<td>6</td>
<td>154/510</td>
<td>209/506</td>
<td>0.74 (CI 0.59–0.95)</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>229/458</td>
<td>205/395</td>
<td>0.98 (CI 0.86–1.12)</td>
</tr>
<tr>
<td>Duration of prone positioning</td>
<td>6</td>
<td>191/565</td>
<td>243/547</td>
<td>0.77 (CI 0.64–0.92)</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>192/403</td>
<td>171/354</td>
<td>1.02 (CI 0.88–1.17)</td>
</tr>
<tr>
<td>Level of hypoxemia*</td>
<td>6</td>
<td>75/210</td>
<td>102/209</td>
<td>0.76 (CI 0.61–0.94)</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>75/274</td>
<td>102/268</td>
<td>0.74 (CI 0.48–1.16)</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>3/22</td>
<td>3/23</td>
<td>0.98 (CI 0.18–5.24)</td>
</tr>
</tbody>
</table>

*Severe ARDS = P/F < 100 mmHg

Deleterious Side Effects
Pressure ulcers, ETT obstruction, Dislodged chest tubes
Preventative Medicine

SECOND OPINION

BY ROB ROGERS

DO YOU RECOMMEND A TRIPLE BYPASS, DOCTOR?

YES...I RECOMMEND YOU BYPASS KFC, WENDY'S AND McDoNALD'S!
Feasibility & Effectiveness of Prone Position in Morbidly Obese Patients with ARDS


- Case-Control Study with 33 patients in each group
- Experienced French hospital
Feasibility & Effectiveness of Prone Position in Morbidly Obese Patients with ARDS


### Table 3—Characteristics and Complications of PP in Obese and Nonobese Patients

<table>
<thead>
<tr>
<th>Variable</th>
<th>All Patients (N = 66)</th>
<th>Obese Patients (n = 33)</th>
<th>Nonobese Patients (n = 33)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number of sessions by patient</td>
<td>2 (1-4)</td>
<td>3 (2-4)</td>
<td>2 (1-3)</td>
<td>.16</td>
</tr>
<tr>
<td>Total length of PP by patient, h</td>
<td>22 (10-37)</td>
<td>28 (14-42)</td>
<td>16 (9-30)</td>
<td>.34</td>
</tr>
<tr>
<td>Length per session by patient, h</td>
<td>8 (7-11)</td>
<td>9 (6-11)</td>
<td>8 (7-12)</td>
<td>.28</td>
</tr>
<tr>
<td>Patients with at least one complication, No. (%)</td>
<td>20 (30)</td>
<td>10 (30)</td>
<td>10 (30)</td>
<td>...</td>
</tr>
<tr>
<td>Overall complications, No.</td>
<td>51</td>
<td>25</td>
<td>26</td>
<td>...</td>
</tr>
<tr>
<td>Accidental extubation</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>...</td>
</tr>
<tr>
<td>Displacement of endotracheal tube</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>...</td>
</tr>
<tr>
<td>Loss of venous access</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>...</td>
</tr>
<tr>
<td>Loss of arterial access</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>...</td>
</tr>
<tr>
<td>Loss of urinary catheter</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>...</td>
</tr>
<tr>
<td>Loss of gastric tube</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>...</td>
</tr>
<tr>
<td>Forehead pressure ulcers</td>
<td>5</td>
<td>4</td>
<td>1</td>
<td>...</td>
</tr>
<tr>
<td>Chin pressure ulcers</td>
<td>10</td>
<td>4</td>
<td>6</td>
<td>...</td>
</tr>
<tr>
<td>Other pressure ulcers</td>
<td>6</td>
<td>3</td>
<td>3</td>
<td>...</td>
</tr>
<tr>
<td>Total pressure ulcers</td>
<td>16</td>
<td>7</td>
<td>9</td>
<td>...</td>
</tr>
<tr>
<td>Facial edema</td>
<td>8</td>
<td>4</td>
<td>4</td>
<td>...</td>
</tr>
<tr>
<td>Hemodynamic failure</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>...</td>
</tr>
<tr>
<td>Cardiac arrest</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>...</td>
</tr>
<tr>
<td>Bleeding</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>...</td>
</tr>
<tr>
<td>Vomiting</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>...</td>
</tr>
</tbody>
</table>

30% Overall Complication Rate in All Groups
Feasibility & Effectiveness of Prone Position in Morbidly Obese Patients with ARDS


**P/F ratio increased more in obese pts (p = 0.03)
Survival better in obese group by Kaplan-Meier analysis, $p = 0.0259$
Is Weaning an Art... 
...or a Science?

◊ Weaning
  ➢ often making a mountain out of a molehill

◊ Most patients (80%) do not need to be weaned

◊ Most “weaning failures” are the clinician’s failure to predict an imbalance between supply and demand

## “Weaning” or “Liberation”

### “Wean”
- to accustom to loss of mother’s milk
- get along without some special comfort or object of desire

### “Liberate”
- to free from domination; unload; unshackle; unburden; disencumber; disentangle; deoppilelate

### Working Definition

*Transition from mechanical support to stable spontaneous breathing*
**Weaning**

Once Daily T-piece SBT Favored Over IMV or PS

<table>
<thead>
<tr>
<th></th>
<th>RR favoring T-piece</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>T-piece vs IMV</td>
<td>2.83</td>
<td>&lt;0.002</td>
</tr>
<tr>
<td>T-piece vs PS</td>
<td>2.05</td>
<td>&lt;0.04</td>
</tr>
</tbody>
</table>

Esteban, Frutos, Tobin et al. NEJM 1995;332:345-50
Comparison of PSV, T-Piece, & SIMV

Brochard, et al. AJRCCM 1994;150:896-903
PS vs Trache Collar in LTACH Wean

Jubran A...Tobin. JAMA 2013;309:671-677

% Remaining on MVS

Proportion of Patients Remaining on Mechanical Ventilation

Weaning Duration, d

Log-rank $P = .016$

No. of patients at risk
<table>
<thead>
<tr>
<th>Pressure support</th>
<th>Tracheostomy collar</th>
</tr>
</thead>
<tbody>
<tr>
<td>152</td>
<td>160</td>
</tr>
<tr>
<td>101</td>
<td>82</td>
</tr>
<tr>
<td>45</td>
<td>37</td>
</tr>
<tr>
<td>17</td>
<td>18</td>
</tr>
</tbody>
</table>
**Extubation & the Myth of “Minimal Ventilator Settings”**

Tobin M. Am J Respir Crit Care Med. 2012;185:349-350

◊ **Pitfalls of extubation**
  - 20% require re-intubation, sometimes lethal
    • Flash pulmonary edema or respiratory distress
    • Upper airway edema / obstruction
  - Goal: avoid catastrophe in this small group of pts

◊ **Myth # 1: Low PS overcomes ETT resistance**
  - Upper airway Raw is increased from ETT induced mucosal swelling
    • WoB against edematous supraglottic airway is = WoB thru ETT
  - PS decreases inspiratory work of breathing (WoB)
    • 5 cm H2O reduces inspiratory WoB by 31 – 38%
    • 10 cm H2O reduces inspiratory WoB by 46 – 60%
  - Therefore, even a small amt of PS may be physiologically important
    • Most pts “should” be able to tolerate a 30 – 60% increase in inspiratory load....but some cannot
Post-Extubation Non-Obstructive Edema

Myth # 2: ETT eliminates physiologic PEEP

- PEEP = 0 at end-expiration in healthy adults
- PEEP can decrease WoB by up to 40%
  - PEEPi increases PaCO2 (Milic-Emili)
- PEEPe may be overcoming unrecognized PEEPi
- In pts w/ LV dysfxn, PEEP decreases pre & afterload
  - When extubated to ZEEP, can develop flash pulm edema
Work of Breathing (WOB)
Before & After Extubation from a T-Piece

Total WoB
Elastic WoB
Resistive WoB
(n = 16)

What you see is what you get:

- The breathing pattern before extubation (no PS, ZEEP) was the same as after extubation (n=50)

<table>
<thead>
<tr>
<th></th>
<th>Pre-Extubation</th>
<th>Post-extubation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Respiratory Rate</td>
<td>23.3 (5.3)</td>
<td>24.3 (5.5)</td>
</tr>
<tr>
<td>Vt (ml)</td>
<td>423 (139)</td>
<td>435 (169)</td>
</tr>
<tr>
<td>$V_1$ (liters)</td>
<td>9.32 (3.26)</td>
<td>9.74 (3.83)</td>
</tr>
<tr>
<td>% Rib Cage</td>
<td>52.1 (1.6)</td>
<td>51.0 (1.4)</td>
</tr>
</tbody>
</table>


Tobin still recommends 30 min T-Piece trials

- Alternative: Flow-by with no PS nor PEEP
PS vs T-piece for Weaning from MVS

◊ Methods: PS vs T-piece for SBT
   - SBTs in 9 RCTs; n = 622 PS vs n = 586 T-piece
   - PS gradually decreased bid; T-piece increased 2-8 hrs

◊ Results:
   - No diff: weaning success, ICU mortality, re-intubation
   - No diff: LOS in Hospital or long-term or in PNA
   - 3 / 4 studies: weaning faster with PS
   - 1 / 4 studies: weaning faster with Tpiece
   - SBT more successful with PS (RR1.09; CI1.02-1.17)

◊ Criticism: low quality studies
## The Decision to Extubate in the ICU


<table>
<thead>
<tr>
<th>Study (Reference)</th>
<th>Number of Extubations</th>
<th>Rate of Extubation Failure [% (n)]</th>
<th>ICU Mortality in Reintubated Patients [% (n)]</th>
<th>ICU Mortality in Nonreintubated Patients (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Esteban et al., 1997 (1)</td>
<td>.</td>
<td>19 (74)</td>
<td>27 (20)</td>
<td>3</td>
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<tr>
<td>Esteban et al., 1999 (2)</td>
<td>.</td>
<td>13 (61)</td>
<td>33 (20)</td>
<td>5</td>
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<tr>
<td>Epstein et al., 1997 (4)</td>
<td>.</td>
<td>14 (40)</td>
<td>43 (17)</td>
<td>12</td>
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<tr>
<td>Vallverdu et al., 1998 (3)</td>
<td>.</td>
<td>15.5 (23)</td>
<td>35 (8)</td>
<td>5.6</td>
</tr>
<tr>
<td>Thille et al., 2011 (6)</td>
<td>.</td>
<td>15 (26)</td>
<td>50 (13)</td>
<td>5</td>
</tr>
<tr>
<td>Frutos-Vivar et al., 2011 (14)</td>
<td>.</td>
<td>16 (180)</td>
<td>28 (50)</td>
<td>7</td>
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<tr>
<td>Funk et al., 2009 (38)</td>
<td>.</td>
<td>10 (26)</td>
<td>Not available</td>
<td>Not available</td>
</tr>
<tr>
<td>Tonnelier et al., 2011 (39)</td>
<td>.</td>
<td>10 (12)</td>
<td>Not available</td>
<td>Not available</td>
</tr>
<tr>
<td>Sellares et al., 2011 (34)</td>
<td>.</td>
<td>20 (36)</td>
<td>Not available</td>
<td>Not available</td>
</tr>
<tr>
<td>Peñuelas et al., 2011 (40)</td>
<td>.</td>
<td>10 (278)</td>
<td>26 (72)</td>
<td>5</td>
</tr>
</tbody>
</table>

◊ Extubation facts: 10-20% failure rate despite meeting all criteria

Associated with a 25-50% mortality rate
Automated Weaning with Closed Loop Systems
Cochrane Analysis - 2013
Rose L, et al. Cochrane Database of Systematic Reviews 2013 Jun6;6:CD009235

◊ Pooled data from 15 trials (1143 adults, 30 kids)

- **Weaning duration decreased** 32% (CI 19-46, p=0.002)
  - However, heterogeneity substantial
  - Significant only for mixed or MICU populations, not SICU
  - Significant for Smartcare/PS system only (p=0.02)

- **MVS duration reduced** 17% (CI 8-26, p<0.05)

- **ICU LOS reduced 11%** (CI 0-21, p < 0.05)

- Mortality & Hospital LOS *not* significantly improved

- Need multi-center randomized controlled trials
Automated Weaning with Closed Loop Systems

Cochrane Analysis - 2014


◊ Pooled data - 21 studies (1628 adults, 48 kids)
  2013: 1148 adults and 30 kids

➢ Weaning duration decreased by 30% (CI 13-45%)
  • Only in mixed or medical ICUs, not surgical
  • Only enough data to support Smartcare/PS

➢ What was different than 2013 review:
  • NO EFFECT on mortality, hospital LOS, re-intubation, NIPPV use
  • Reduced prolonged ETT (> 3 wks, RR 0.51) & traches (RR 0.90)

◊ Caveats

➢ Pooled data had high heterogeneity but quality of evidence high

➢ I never “Met an Analysis” that I could not use
  • Respiratory Therapist need to be diligent about job security
Wean Earlier & Automatically
Burns KE et al. AJRCCM 2013;187:1203-1211

% Successfully Extubated

Days to Successful Extubation
Pooled data from 10 trials (654 adults) up to 5/13

- Decreased (p < or = 0.05)
  - Weaning time by 2.68 days (moderate-quality evidence)
  - Time to successful extubation by 0.99 d (low-quality evidence)
  - ICU LOS by 5.7 d (CI -10.54 to -0.85, moderate-quality evidence)
  - Total MVS time by 1.68 d (low-quality evidence)
  - MVS > 14 & 21 d (p=0.05, low-quality evidence)

Caveats

- All 10 trials were small, albeit randomized
- Quality of evidence only low to moderate
Diaphragmatic Fatigue – 20 Years Later
Laghi, D’Alfonso, Tobin MJ. Intensive Care Med 2014;40:1220-1226

RESPIRATORY FAILURE

SUPPLY

DEMAND
ICU – Acquired Weakness

◊ Diaphragm biopsies from patients on MVS for 18-69 hrs vs 2-3 hrs (controls)
  ➢ Smaller slow-twitch & fast-twitch myosin heavy chain fibers
If SBT with Tpiece or CPAP 0 / PS 0 fails, then

- Rest on AC for 24 hrs (rests pt, nurses, physicians)
- Allow respiratory muscles to recover from stress

Induction of diaphragmatic fatigue required 24 hrs of rest to recover

20 Years Later: Withdrawal from MVS

*Weaning Intolerance*: RR>35; SaO2<90%; HR>140 or sustained increase or decrease of >20%; BPsys>200 or < 80; agitation/diaphoresis/anxiety (discoordinate breathing pattern)
Weaning Strategies

◊ It’s about time
◊ Wait until Monday
◊ Recovery room wean
◊ Sink or swim
◊ Untie their hands
◊ OOPS