Turning on a dime at the right time—Lessons learned about pacing critical care interventions

CCCF Toronto
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Jesse Hall MD
University of Chicago
Section of Pulmonary and Critical Care Medicine
Faculty Disclosures

Dr. Hall

• receives honoraria from the ACCP for board review course and SEEK

• receives honoraria from McGraw-Hill and Taylor-Francis publishing
A 45 y/o morbidly obese woman with diabetes is admitted to the hospital with hypoxemia and associated respiratory distress; a nasal swab is positive for H1N1 influenza. She deteriorates on the floor over 12 hours and is admitted to the ICU and intubated and you are present to stabilize her on the ventilator. She is 5’5” tall and weighs 125 kg.

Almost immediately after intubation her blood pressure falls to 85/50 and her heart rate rises to 130 bpm.

First measured P/F = 85 mm Hg
What have we learned about the care of such a patient?

- Traditional priorities: homeostasis compatible with survival, not necessarily ‘optimizing’ classic physiologic endpoints

- **Paradigm**—Early aggressive supportive rx
  - RRT
  - *EARLY* LPVS
  - *EARLY* goal directed therapy
  - *EARLY* abx
  - Life support devices
  - Sedation, analgesia, NMB, etc to tolerate the above
Factors Aggravating Lung Injury

Decreased Lung Volumes
- effects on surfactant
- recruitment/de-recruitment

Increased Volume (lung stretch)
- gross barotrauma
- diffuse alveolar damage
First definitive evidence that the specific techniques of mechanical ventilation influenced survival
Neuromuscular Blockers in Early Acute Respiratory Distress Syndrome

Laurent Papazian, M.D., Ph.D., Jean-Marie Forel, M.D., Arnaud Gacouin, M.D., Christine Penot-Ragon, Pharm.D., Gilles Perrin, M.D., Anderson Loundou, Ph.D., Samir Jaber, M.D., Ph.D., Jean-Michel Arnal, M.D., Didier Perez, M.D., Jean-Marie Seghboyan, M.D., Jean-Michel Constantin, M.D., Ph.D., Pierre Courant, M.D., Jean-Yves Lefrant, M.D., Ph.D., Claude Guérin, M.D., Ph.D., Gwenaël Prat, M.D., Sophie Morange, M.D., and Antoine Roch, M.D., Ph.D., for the ACURASYS Study Investigators*
Waveforms

Inactivity

Asynchrony

Stacked Breath

Stacked Breath

No Effort

Some Effort Present

Harmful Effort?

Imminent Danger?

Increasing levels of effort
Figure 1. Flow-time waveform over 1 min. This example represents five stacked breaths per minute. Percent stacked breaths is the number of stacked breaths divided by the total number of breaths (a stacked breath counting as single breath) occurring in 1 min. In this example, five stacked breaths are divided by 30 total breaths resulting in 16.7% stacked breaths.

Figure 2. Area under the curve calculation. Area under the flow-time waveform is the volume of the delivered breath. Computer software was used to calculate the area. The area under the curve (volume) in panel a is $a + b$. The area under the curve (volume) in panel b is $(a + b) - c$. Note that the expiratory flow between breaths is subtracted. Pressure waveforms are included.
Prone Positioning in Severe Acute Respiratory Distress Syndrome

Claude Guérin, M.D., Ph.D., Jean Reignier, M.D., Ph.D.,
Jean-Christophe Richard, M.D., Ph.D., Pascal Beuret, M.D., Arnaud Gacouin, M.D.,
Thierry Boulain, M.D., Emmanuelle Mercier, M.D., Michel Badet, M.D.,
Alain Mercat, M.D., Ph.D., Olivier Baudin, M.D., Marc Clavel, M.D.,
Delphine Chatellier, M.D., Samir Jaber, M.D., Ph.D., Sylvène Rosselli, M.D.,
Jordi Mancebo, M.D., Ph.D., Michel Sirodot, M.D., Gilles Hilbert, M.D., Ph.D.,
Christian Bengler, M.D., Jack Richcoeur, M.D., Marc Gainnier, M.D., Ph.D.,
Frédérique Bayle, M.D., Gael Bourdin, M.D., Véronique Leray, M.D.,
Raphaële Girard, M.D., Loredana Baboi, Ph.D., and Louis Azyac, M.D.,

for the PROSEVA Study Group*

May 20, 2013
Figure 2. Kaplan–Meier Plot of the Probability of Survival from Randomization to Day 90.
HFOV – Sensormedics 3100b
High-Frequency Oscillation in Early Acute Respiratory Distress Syndrome


Trial stopped after enrollment of 548 of planned 1200 patients
High-Frequency Oscillation for Acute Respiratory Distress Syndrome

Duncan Young, D.M., Sallie Lamb, D.Phil., Sanjoy Shah, M.D.,
Iain MacKenzie, M.D., William Tunnicliffe, M.Sc., Ranjit Lall, Ph.D.,
Kathy Rowan, D.Phil., and Brian H. Cuthbertson, M.D.,
for the OSCAR Study Group*

795 patients randomized to either HFOV or conventional MV
Figure 2. Probability of Survival from the Day of Randomization to Day 60 in the HFOV and Control Groups.

Figure 3. Kaplan–Meier Survival Estimates during the First 30 Study Days.
## Cesar Trial Results

<table>
<thead>
<tr>
<th></th>
<th>ECMO (90)</th>
<th>Usual Care (90)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Death or</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Severe Disability</td>
<td>Yes (bad)</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>No (good)</td>
<td>57</td>
</tr>
</tbody>
</table>

75% of ECMO pts (68/90) received ECMO
16 of 90 ‘ECMO’ pts improved without ECMO (presume in good outcome group???); 5 died before receiving ECMO
3 Usual Care pts withdrew from study before follow-up
*2 pts died during transport to ECMO center*
Cesar Trial

• Receiving Critical Care services at central referral center (with higher adherence to guideline-based therapy?) improves outcomes from severe respiratory failure
• How much attributable to ECMO?

Delay in appropriate abx and risk in hypotensive patients

Figure 1. Cumulative effective antimicrobial initiation following onset of septic shock-associated hypotension and associated survival. The x-axis represents time (hrs) following first documentation of septic shock-associated hypotension. Black bars represent the fraction of patients surviving to hospital discharge for effective therapy initiated within the given time interval. The gray bars represent the cumulative fraction of patients having received effective antimicrobials at any given time point.

Kumar et al; CCM 2006; 34:1589
Early goal-directed therapy in severe sepsis

<table>
<thead>
<tr>
<th></th>
<th>Standard RX (%)</th>
<th>Goal-directed RX (%)</th>
<th>OR</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>In hospital mortality</td>
<td>46.5</td>
<td>30.5</td>
<td>.58 (.38-.87)</td>
<td>.009</td>
</tr>
<tr>
<td>28 d mortality</td>
<td>49.2</td>
<td>33.3</td>
<td>.58 (.39-.87)</td>
<td>.01</td>
</tr>
<tr>
<td>60 d mortality</td>
<td>56.9</td>
<td>44.3</td>
<td>.67 (.46-.96)</td>
<td>.03</td>
</tr>
</tbody>
</table>

Rivers et al. NEJM 2001; 345:1368
A Randomized Trial of Protocol-Based Care for Early Septic Shock

The ProCESS Investigators*

• Multicentered ER-based RCT of 1341 patients with septic shock
  – protocol-based EGDT
  – protocol-based standard therapy that did not require the placement of a central venous catheter, administration of inotropes, or blood transfusions
  – usual care
• The primary end point was 60-day in-hospital mortality.
Process of Care

At 6 hours, incomplete adherence was recorded in:

- 48 of 404 patients in the EGDT group (11.9%)
- 19 of 435 patients in the standard-therapy group (4.4%)
## Process Trial

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Protocol-based EGDT (N = 439)</th>
<th>Protocol-based Standard Therapy (N = 446)</th>
<th>Usual Care (N = 456)</th>
<th>P Value†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Death — no./total no. (%)</td>
<td>44.3%</td>
<td>56.9%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>In-hospital death by 60 days: primary outcome</td>
<td>92/439 (21.0)</td>
<td>81/446 (18.2)</td>
<td>86/456 (18.9)</td>
<td>0.83‡</td>
</tr>
<tr>
<td>Death by 90 days</td>
<td>129/405 (31.9)</td>
<td>128/415 (30.8)</td>
<td>139/412 (33.7)</td>
<td>0.66</td>
</tr>
<tr>
<td>New organ failure in the first week — no./total no. (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cardiovascular</td>
<td>269/439 (61.3)</td>
<td>284/446 (63.7)</td>
<td>256/456 (56.1)</td>
<td>0.06</td>
</tr>
<tr>
<td>Respiratory</td>
<td>165/434 (38.0)</td>
<td>161/441 (36.5)</td>
<td>146/451 (32.4)</td>
<td>0.19</td>
</tr>
<tr>
<td>Renal</td>
<td>12/382 (3.1)</td>
<td>24/399 (6.0)</td>
<td>11/397 (2.8)</td>
<td>0.04</td>
</tr>
<tr>
<td>Duration of organ support — days§</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cardiovascular</td>
<td>2.6±1.6</td>
<td>2.4±1.5</td>
<td>2.5±1.6</td>
<td>0.52</td>
</tr>
<tr>
<td>Respiratory</td>
<td>6.4±8.4</td>
<td>7.7±10.4</td>
<td>6.9±8.2</td>
<td>0.41</td>
</tr>
<tr>
<td>Renal</td>
<td>7.1±10.8</td>
<td>8.5±12</td>
<td>8.8±13.7</td>
<td>0.92</td>
</tr>
<tr>
<td>Use of hospital resources</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Admission to intensive care unit — no. (%)</td>
<td>401 (91.3)</td>
<td>381 (85.4)</td>
<td>393 (86.2)</td>
<td>0.01</td>
</tr>
<tr>
<td>Stay in intensive care unit among admitted</td>
<td>5.1±6.3</td>
<td>5.1±7.1</td>
<td>4.7±5.8</td>
<td>0.63</td>
</tr>
</tbody>
</table>
Mortality Related to Severe Sepsis and Septic Shock Among Critically Ill Patients in Australia and New Zealand, 2000-2012

Kirs-Maija Kaukonen, MD, PhD, EDIC; Michael Bailey, PhD; Satoshi Suzuki, MD; David Pilcher, FCICM; Rinaldo Bellomo, MD, PhD
Incidence of ICU and Sepsis Admissions
Declining Mortality from Severe Sepsis

Figure 1. Mean Annual Mortality in Patients With Severe Sepsis

Error bars indicate 95% CI.
Is this a stage migration phenomenon? (Will Rogers effect)
Will Rogers Phenomenon

“The taxpayers are sending congressmen on expensive trips abroad. It might be worth it except they keep coming back.

-Will Rogers

“When the Okies left Oklahoma and moved to California, they raised the average intelligence of both states.”
Stage Migration Effect – Will Rogers

**Infection**
- Infection
- Sepsis
- Severe Sepsis (sepsis + organ dysfunction)

**Severe Sepsis and Septic Shock**
- Severe Sepsis
- Septic Shock
- Severe Sepsis (sepsis + organ dysfunction)
Functional Disability 5 Years after Acute Respiratory Distress Syndrome

Margaret S. Herridge, M.D., M.P.H., Catherine M. Tansey, M.Sc., Andrea Matté, B.Sc., George Tomlinson, Ph.D., Natalia Diaz-Granados, M.Sc., Andrew Cooper, M.D., Cameron B. Guest, M.D., C. David Mazer, M.D., Sangeeta Mehta, M.D., Thomas E. Stewart, M.D., Paul Kudlow, B.Sc., Deborah Cook, M.D., Arthur S. Slutsky, M.D., and Angela M. Cheung, M.D., Ph.D., for the Canadian Critical Care Trials Group
Outcomes after ARDS
Herridge, et al. NEJM 2011
Levine, NEJM 2009

Jaber et al. Am J Respir Crit Care Med 2011

- 55 ARDS pts, one yr after d/c
- At hosp d/c, 100% with cognitive and affective impairments
- At 1 yr, bodily pain, physical problems, impaired general health compared to normal controls
- At 1 yr, 30% still with generalized cognitive decline
Outcomes after ARDS
Herridge, et al. NEJM 2003

• Only 49% back to work at one year
• SF-36 below normal in all 8 domains at 3, 6 and 12 month ICU d/c follow up
• Improvements in most SF-36 categories, but almost none back to normal
This patient is NOT “STABLE”!!
This state is beneficial to whom???
# Intervention of Sedative Infusions in Critically Ill Patients Undergoing Mechanical Ventilation

## Abstract

**Background** Continuous infusions of sedative drugs in the intensive care unit may prolong the duration of mechanical ventilation, prolong the length of stay in the intensive care unit and the hospital, impede efforts to perform daily neurologic examinations, and increase the need for tests to assess alterations in mental status. Whether regular interruption of such infusions might accelerate recovery is not known.

**Methods** We conducted a randomized, controlled trial involving 128 adult patients who were receiving mechanical ventilation and continuous infusions of sedative drugs in a medical intensive care unit. In the intervention group, the sedative infusions were interrupted until the patients were awake, on a daily basis; in the control group, the infusions were interrupted only at the discretion of the clinicians in the intensive care unit.

**Results** The median duration of mechanical ventilation was 4.9 days in the intervention group, as compared with 7.3 days in the control group (P = 0.004), and the median length of stay in the intensive care unit was 6.4 days as compared with 9.9 days, respectively (P = 0.02). Six of the patients in the intervention group (9 percent) underwent diagnostic testing to assess changes in mental status, as compared with 16 of the patients in the control group (27 percent, P = 0.02). Complications (e.g., removal of the endotracheal tube by the patient) occurred in three of the patients in the intervention group (4 percent) and four of the patients in the control group (7 percent, P = 0.69).

**Conclusions** In patients who are receiving mechanical ventilation, daily interruption of sedative-drug infusions decreases the duration of mechanical ventilation and the length of stay in the intensive care unit. (N Engl J Med 2000;342:1471-7.)

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<table>
<thead>
<tr>
<th></th>
<th>Intervention (wake-up)</th>
<th>Control</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>68</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>MV duration, d</td>
<td>4.9 (2.5-8.6)</td>
<td>7.3 (3.4-16.1)</td>
<td>0.004</td>
</tr>
<tr>
<td>ICU LOS, d</td>
<td>6.4 (3.9-12.0)</td>
<td>9.9 (4.7-17.9)</td>
<td>0.02</td>
</tr>
<tr>
<td>Hosp LOS, d</td>
<td>13.3 (7.3-20.0)</td>
<td>16.9 (8.5-26.6)</td>
<td>0.19</td>
</tr>
</tbody>
</table>
Efficacy and safety of a paired sedation and ventilator weaning protocol for mechanically ventilated patients in intensive care (Awakening and Breathing Controlled trial): a randomised controlled trial

## Girard TD, et al. ABC Trial Results

<table>
<thead>
<tr>
<th></th>
<th>Intervention group (n=167)</th>
<th>Control group (n=168)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ventilator-free days</strong>*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>14.7 (0.9)</td>
<td>11.6 (0.9)</td>
<td>0.02</td>
</tr>
<tr>
<td>Median</td>
<td>20.0 (0 to 26.0)</td>
<td>8.1 (0 to 24.3)</td>
<td></td>
</tr>
<tr>
<td><strong>Time to discharge (days)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>From intensive care</td>
<td>9.1 (5.1 to 17.8)</td>
<td>12.9 (6.0 to 24.2)</td>
<td>0.01</td>
</tr>
<tr>
<td>From hospital</td>
<td>14.9 (8.9 to 26.8)</td>
<td>19.2 (10.3 to NA†)</td>
<td>0.04</td>
</tr>
<tr>
<td><strong>28-day mortality</strong></td>
<td>47 (28%)</td>
<td>58 (35%)</td>
<td>0.21</td>
</tr>
<tr>
<td><strong>1-year mortality</strong></td>
<td>74 (44%)</td>
<td>97 (58%)</td>
<td>0.01</td>
</tr>
<tr>
<td><strong>Duration of brain dysfunction (days)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coma</td>
<td>2 (0 to 4)</td>
<td>3 (1 to 7)</td>
<td>0.002</td>
</tr>
<tr>
<td>Delirium</td>
<td>2 (0 to 5)</td>
<td>2 (0 to 6)</td>
<td>0.50</td>
</tr>
<tr>
<td><strong>RASS at first successful SBT</strong></td>
<td>-1 (-3 to 0)</td>
<td>-2.5 (-4 to 0)</td>
<td>0.0001</td>
</tr>
<tr>
<td><strong>Complications</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Any self-extubation</td>
<td>16 (10%)</td>
<td>6 (4%)</td>
<td>0.03</td>
</tr>
<tr>
<td>Self-extubation requiring</td>
<td>5 (3%)</td>
<td>3 (2%)</td>
<td>0.47</td>
</tr>
<tr>
<td>reintubation‡</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reintubation‡</td>
<td>23 (14%)</td>
<td>21 (13%)</td>
<td>0.73</td>
</tr>
<tr>
<td>Tracheostomy</td>
<td>21 (13%)</td>
<td>34 (20%)</td>
<td>0.06</td>
</tr>
</tbody>
</table>

Data are mean (SD), n (%), or median (IQR). RASS—Richmond agitation-sedation scale. SAT—spontaneous awakening trial. SBT—spontaneous breathing trial. *Ventilator-free days from study day 1 to 28. †Greater than 25% of patients in the SBT group remained in the hospital at study day 28. ‡Reintubation within 48 hours of extubation.

Table 3: Main outcomes
# Benzodiazepine Use in Trials *

<table>
<thead>
<tr>
<th>Study</th>
<th>Control</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kress NEJM 2000</td>
<td>90 mg/day</td>
<td>53 mg/day</td>
</tr>
<tr>
<td>Girard ABC Lancet 2007</td>
<td>84 mg/day</td>
<td>54 mg/day</td>
</tr>
<tr>
<td>Mehta SLEAP JAMA 2012</td>
<td>82 mg/day</td>
<td>102 mg/day</td>
</tr>
<tr>
<td>OSCILLATE NEJM 2013</td>
<td>141 mg/day</td>
<td>199 mg/day</td>
</tr>
</tbody>
</table>

* All values converted and expressed as mean midazolam dose per patient, median for ABC study were 8 mg and 5 mg, respectively
SPICE Study – first 48 hours
mean 50 mg/d benzos

Log rank P=0.04

Panel B

Number at risk
Deeply sedated
215
172
160
158
158
157
154

Not deeply sedated
36
34
31
31
30
30
30

Shehabi AJRCCM 2012;186:724-31
Early physical and occupational therapy in mechanically ventilated, critically ill patients: a randomised controlled trial

William D Schweickert, Mark C Pohlman, Anne S Pohlman, Celerina Nigos, Amy J Pawlik, Cheryl L Esbrook, Linda Spears, Megan Miller, Mietka Franczyk, Deanna Deprizio, Gregory A Schmidt, Amy Bowman, Rhonda Barr, Kathryn E McCallister, Jesse B Hall, John P Kress
**Hospital Days**

- **Control**:
  - Number at Risk: 55, 51, 21, 13, 9, 4, 0

- **Intervention**:
  - Number at Risk: 49, 40, 21, 13, 8, 2, 1

**P = 0.048**

Lancet, May 2009
## Outcomes

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Intervention (n = 49)</th>
<th>Control (n = 55)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Return to independent functional status at hospital discharge, %</td>
<td>59</td>
<td>35</td>
<td>0.02</td>
</tr>
<tr>
<td>Barthel index score at hospital discharge</td>
<td>75 [7.5,95]</td>
<td>55 [0.85]</td>
<td>0.05</td>
</tr>
<tr>
<td>Independent ADL total at hospital discharge</td>
<td>6 [0,6]</td>
<td>4 [0,6]</td>
<td>0.06</td>
</tr>
<tr>
<td>ICU-AP at hospital discharge, %</td>
<td>31</td>
<td>49</td>
<td>0.09</td>
</tr>
<tr>
<td>Greatest ambulation distance, feet</td>
<td>110 [0,300]</td>
<td>0 [0,100]</td>
<td>0.004</td>
</tr>
<tr>
<td>Hospital delirium, days</td>
<td>2.0 [0.0,6.0]</td>
<td>4.0 [2.0,8.0]</td>
<td>0.02</td>
</tr>
</tbody>
</table>
Perceived Barriers

*Vasoactive infusion* during 22% of PT/OT sessions (81/361) in MICU

BMI = 30-39 in 25% (12/49)

BMI ≥ 40 in 14% (7/49)

<table>
<thead>
<tr>
<th>Renal Replacement</th>
<th>% Total PT/OT sessions in ICU</th>
</tr>
</thead>
<tbody>
<tr>
<td>HD or CVVH</td>
<td>13.85 (50/361)</td>
</tr>
<tr>
<td>CVVH</td>
<td>7.2 (26/361)</td>
</tr>
<tr>
<td>HD</td>
<td>6.6 (24/361)</td>
</tr>
</tbody>
</table>
## Therapy Detail

<table>
<thead>
<tr>
<th>Therapy Protocol Detail</th>
<th>Intervention (n = 49)</th>
<th>Control (n=55)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>PT/OT on MV (hrs/day)</td>
<td>0.32 [0.17,0.48]</td>
<td>0.0 [0.0,0.0]</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>PT/OT not on MV (hrs/day)</td>
<td>0.21 [0.08,0.33]</td>
<td>0.19 [0.0,0.38]</td>
<td>0.70</td>
</tr>
<tr>
<td>Days from intubation to first PT/OT encounter</td>
<td>1.5 [1.0,2.1]</td>
<td>7.3** [5.8,10.9]</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Shorter than the median ICU LOS (7.9 [6.1, 12.9] days)
37 year old male
cirrhosis,
aspiration with ARDS

- CXR 24 hours after intubation
- Assist Control
- Tidal Volume 400
- PEEP 12
- FiO2=70
Active rehabilitation and physical therapy during extracorporeal membrane oxygenation while awaiting lung transplantation: A practical approach*

David A. Turner, MD; Ira M. Cheifetz, MD, FCCM; Kyle J. Rehder, MD; W. Lee Williford, RRT; Desiree Bonadonna, BSE, CCP, LP; Scott J. Banuelos, MD; Stacey Peterson-Carmichael, MD; Shu S. Lin, MD, PhD; R. Duane Davis, MD; David Zaas, MD

Objective: Extracorporeal membrane oxygenation as a bridge to lung transplantation has traditionally been associated with substantial morbidity and mortality. A major contributor to these complications may be weakness and overall deconditioning secondary to pretransplant critical illness and immobility. In an attempt to address this issue, we developed a collaborative program to allow for active rehabilitation and physical therapy for patients requiring life support with extracorporeal membrane oxygenation before lung transplantation.

Design: An interdisciplinary team responded to an acute need to develop a mechanism for active rehabilitation and physical therapy for patients awaiting lung transplantation while being managed with extracorporeal membrane oxygenation. We describe a series of three patients who benefited from this new approach.

Setting: A quaternary care pediatric intensive care unit in a children’s hospital set within an 800-bed university academic hospital with an active lung transplantation program for adolescent and adult patients.

Patients, Interventions, and Main Results: Three patients (ages 16, 20, and 24 yrs) with end-stage respiratory failure were rehabilitated while on extracorporeal membrane oxygenation awaiting lung transplantation. These patients were involved in active rehabilitation and physical therapy and, ultimately, were ambulatory on extracorporeal membrane oxygenation before successful transplantation. Following lung transplantation, the patients were liberated from mechanical ventilation, weaned to room air, transitioned out of the intensive care unit, and ambulatory less than 1 wk posttransplant.

Conclusions: A comprehensive, multidisciplinary system can be developed to safely allow for active rehabilitation, physical therapy, and ambulation of patients being managed with extracorporeal membrane oxygenation. Such programs may lead to a decreased threshold for the utilization of extracorporeal membrane oxygenation before transplant and have the potential to improve conditioning, decrease resource utilization, and lead to better outcomes in patients who require extracorporeal membrane oxygenation before lung transplantation. (Crit Care Med 2011; 39:2593–2598)

Key Words: acute lung injury; acute respiratory distress syndrome; ambulatory; cystic fibrosis; extracorporeal membrane oxygenation; hypoxemia; lung transplant; pediatric; rehabilitation; respiratory acidosis; respiratory failure
Ambulatory veno-venous extracorporeal membrane oxygenation: Innovation and pitfalls

Jose P. Garcia, MD, Zachary N. Kon, MD, Charles Evans, MD, Zhongjun Wu, PhD, Aldo T. Iacono, MD, Brian McCormick, CPP, and Bartley P. Griffith, MD

Objective: End-stage lung disease and severe acute lung injury are complex entities that remain challenges to manage. Therapies include early institution of mechanical ventilation with positive end-expiratory pressure, permissive hypercapnia, pulmonary vasodilators, and complex fluid regimens. Veno-venous extracorporeal membrane oxygenation is an available treatment option for these patients but, in its conventional form, can be associated with significant complications. We present our early experience with an attempt to optimize extracorporeal membrane oxygenation, emphasizing reduced adjunctive mechanical ventilatory support and aggressive rehabilitation, with a goal of ambulation. This strategy has been enabled by the introduction of a dual-lumen draw and return cannula placed via the internal jugular vein.

Methods: The first 10 patients (mean age of 45.3 years, 8 male) treated with this strategy between January 1, 2009, and October 1, 2009, were retrospectively reviewed. The ambulatory extracorporeal membrane oxygenation strategy was initiated with an aim of minimal mechanical ventilation and aggressive rehabilitation. The patients were intended to be weaned from all respiratory support or bridged to transplantation.

Results: The mean duration of extracorporeal membrane oxygenation was 20 (9–59) days, with average mean blood flows of 3.5 (1.6–4.9) L/min, and levels of CO₂ removal and O₂ transfer of 228 (54–570) mL/min and 127 (36–529) mL/min, respectively. Six of 10 patients were weaned from respiratory support (N = 4) or underwent transplantation (N = 2) and survived to discharge from the hospital. The remaining 4 patients died of sepsis (N = 3) and withdrawal of care after renal failure (N = 1). Four of the 6 surviving patients were extubated and ambulatory while still on extracorporeal membrane oxygenation. During that time, 3 of the 4 patients exercised at the bedside, with the remaining patient able to undergo full cardiopulmonary rehabilitation, including treadmill walking.

Conclusions: Improvements in the durability of membrane blood oxygenators and pumps have prompted renewed consideration of extracorporeal membrane oxygenation in patients with severe lung disease. This report describes an attempt to augment extracorporeal membrane oxygenation with the goal of ambulation by minimizing mechanical ventilatory support and using aggressive in-and-out-of-bed rehabilitation. (J Thorac Cardiovasc Surg 2011;142:755-61)
FIGURE 2. Ambulatory ECMO circuit.
Enhancing recovery to independent status
What did we do?

• ARDSnet ventilation with sedation and NMB initially
• Volume loading initially only to restore BP
• Aggressive diuresis and off NMB within 24 h
• Initial antibacterials until cultures negative at 72 h and stopped
• Early wake up and mobilization
• Extubated at day 4 and up to chair
• Intermittent NIV until discharged to ward on day 5
• D/C to home on day 8
Summary

• Early aggressive interventions often needed but for less time than we often plan/imagine
  • Ventilator use (also vs NIV)
  • Associated bedrest and sedation/NMB
  • Antibiotics (broad vs short course)
  • Fluid resuscitation
  • Blood product resuscitation
  • Nutrition
  • Glucose control
• We need to learn much more about the arc of various disease processes
• We need to minimize unnecessary interventions
• We need to accelerate and make recovery more complete
• This is the crux of the debate over protocolized vs individualized care
Considering patterns of recovery

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- J Kress MD
- A. Pohlman RN, MS
- B. Gehlbach MD
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- L. Wood MD PhD
- S. Carson MD
- M. Franczyk, PT
- M. Robinson OT
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- F. Zimmerman MD
- J. Herlitz RN
- E. Van Cauter PhD
- W. Schweickert MD
- M. O’Connor MD
- S. Morgan RT
- J. Gilbertson PT, MHS
- J. Poston MD
- S. Patel MD