Critical Care and the Severely Burned

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Care is a crucial part in the treatment of severely injured patients. Such persons have all of the typical findings seen in general critical care units such as issues with infection and indwelling catheters, but often with a twist,... instance, resuscitation volumes are often gargantuan with associated consequences. Furthermore, once this hurdle has been crossed, infections and complications associated with the wounds lie in wait. Recent studies have shown that the systemic response to burn is very close to those with other injuries, but it has the advantage in that the injury can be relatively easily quantitated. Therefore, some have stated that severe burn is the universal critical care, at least for injury.

This presentation will highlight some of the critical care issues that are commonplace in burns and some of the solutions that have been developed. Perhaps some of these can be implemented not only in the severely burned, but also other critical care populations.
Burns in the USA

Year


360000 380000 400000 420000 440000 460000 480000 500000 520000 540000

27% decline
Burn Mortality

Per Capita Deaths (100,000)


Year

0.8 0.9 1.0 1.1 1.2 1.3 1.4

22% decline

(100,000)
Resuscitation Morbidity
## Outcomes

<table>
<thead>
<tr>
<th></th>
<th>Control Group (n=62)</th>
<th>BRG Group (n=56)</th>
<th>( p ) value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extremity Fasciotomies</td>
<td>68%</td>
<td>80%</td>
<td>0.1705</td>
</tr>
<tr>
<td>Myonecrosis</td>
<td>30%</td>
<td>27%</td>
<td>0.6439</td>
</tr>
<tr>
<td>ACS</td>
<td>16%</td>
<td>5%</td>
<td>0.06201</td>
</tr>
<tr>
<td>Mortality</td>
<td>31%</td>
<td>18%</td>
<td>0.1071</td>
</tr>
<tr>
<td>Composite Endpoint</td>
<td>36%</td>
<td>18%</td>
<td><strong>0.0315</strong></td>
</tr>
</tbody>
</table>
Hypothesis

• The use of information technology coupled with computer decision support systems (CDSS) provides better fluid management for severely burned patients during resuscitation and leads to better outcomes.
Measured Responses
\[ I_t = I_{t-1} + e \times IRC_t/UOC_t / 2 \times Y_{\text{weight}} \times Y_{\text{tbsa}} \times BM \times G_UO \]

\[ Y = A + \frac{C}{(1 + Te^{-B(X-M)})^{1/T}} \]

\[ BM = I_{t-1}/(\text{TBSA} \times 10) \]

\[ G = 1 - Ae^{-(X-B)^2 / C^2} \]

Infusion at time (t)
Infusion at time (t-1)
Infusion Rate Constant at time (t)
Urinary Rate Constant at time (t)

Sigmoid Models
Burn Modifier
Gaussian Modifier
Example: Over-resuscitation
Volume Comparisons

**Volume Comparison (ml)**

- ICU Volume in 24 Hours
- Total Volume Post ICU Admission
- Total 48 Hour Volume

**Ratio Comparison (ml/kg)**

- Resuscitation in 24 hours (ml/kg)
- Total 48 Hour Resuscitation (ml/kg)

**Ratio Comparison (ml/kg/%tbsa)**

- Resuscitation in 24 hours (ml/kg/%tbsa)
- Total 48 Hour Resuscitation (ml/kg/%tbsa)

$p<0.05$

‡$p<0.05$

Control
CDSS
Urine Output

UOP Comparison

Hours Post Burn

Control  CDSS  Linear (Control)  Linear (CDSS)
Utilisation

Difference between DSS Recommendation and Actual Infused Values

‡ p<0.05 from Baseline
Wound or Inflammation

CNS

Inflammatory Mediators

Endocrine Response
- ↑↑ Catecholamines
- ↑↑ Glucocorticoids
- ↓ Androgens
- ↓ Growth Hormone

Systemic Response
- ↑↑ Metabolic Rate
- ↑ Temperature
- ↑ Glucose Flux
- ↑ Protein Catabolism
The Effect of Prolonged Euglycemic Hyperinsulinemia on Lean Body Mass in the Severely Burned

Muscle Protein Kinetics

\( R_d, R_a, \text{ Net Balance} \)

\( N=13 \)

Data presented as mean±SEM

*\( p=0.01 \)

†\( p<0.01 \)
Anabolic Agent Effect

Graph showing the difference in \( \mu \text{mol/min/100cc leg} \) between Non-Drug and Drug groups. The graph indicates a statistically significant difference (*) with \( p < 0.01 \).

- Non-Drug group: \( N = 135 \)
- Drug group: \( N = 249 \)

The graph highlights the effect of anabolic agents on muscle metabolism.
Lower Mortality with Better Glycemic Control

- Average glucose level: Avg > 150 (n=41) vs Avg < 150 (n=47)
- Mortality comparison:
  - Avg > 150: 0%
  - Avg < 150: 10%

* = p < 0.05
Impact of Glucometer Error

- Ideal Goal (80–110 mg/dL)
- Uncorrected Glucose
- Corrected Glucose

Glucose (mg/dL)
Glucose Control After Formula Implementation

% Blood Glucose < 80 mg/dL

- SICU:
  - 2005-06: 3.8%
  - 2006-07: 7.7%

- BICU:
  - 2005-06: 19%
  - 2006-07: 8.0%
Variability Groups

Mean variability score
50±8%

Low Variability
$V < 50\%$
n=23

High Variability
$V \geq 50\%$
n=26
Mean SD in Blood Glucose

*\( p < 0.001 \)
Outcome Measures

% Mortality

- Low Variability
- High Variability

\[ p < 0.05 \]
Blood Glucose (mg/dL) vs. Time Since Admission (Hours)

- **Avg. Glucose Values**
- **24 Hour Linear Regression**
- **Post 24 Hour Linear Regression**

Blood Glucose (mg/dL) vs. Time of Day Sample (Hours)

- **Avg. Glucose Values**
- **24 Hour Linear Regression**
- **Post 24 Hour Linear Regression**
Diurnal Patterns Observed

Blood Glucose (mg/dL)

- Cosine Regression
- Filtered Serum Measurements

**Peak:** 5 pm  
**Trough:** 5 am

*p < 0.001*
Insulin and Glucose Patterns

**Insulin Pattern:**

\[ \text{Insulin} = 0.0129 \times \text{Time} + 4.263 - 0.3363 \cos\left(\frac{\text{Time} - 11.58}{24} \times 2\pi\right) \]

**Glucose Pattern:**

\[ \text{Glucose Cosine Model} = -0.0021 \times \text{Time} + 116 + 5.9 \cos(\text{Time} + 7) \times \pi/12 \]

**Key Points:**
- **Offset = 5 Hours**
- **Peak:** Midnight
- **Trough:** Noon
Survivors v Non-Survivors

Glucose Value (mg/dL)

- Live Patients
- Died Patients

R² Live = 0.82
R² Died = 0.50

- Glucose (Live Patients)
- Live Model
- Glucose (Died Patients)
- Died Model
Causes of Death in Burns

- Immolation and overwhelming damage at the site of injury, with relatively immediate death
- Death in the first few hours/days due to overwhelming organ dysfunction associated with burn shock
- Death due to medical error at some time during the hospital course
- Development of progressive multiple organ failure with or without infection, highlighted by the development of acute respiratory distress syndrome
- Development of overwhelming infectious sepsis from the burn wound or other source in the days/weeks following injury. This form is highlighted by cardiovascular collapse
Burn Infection
ISR- Historical

1986-95 Frequency of Infections

- Blood: 26%
- Pneumonia: 25%
- Urinary tract: 14%
- Bronchitis: 10%
- Wound infection: 5%
- Other: 22%

### Most Common Pathogens Recovered from Blood of 92 Burn Patients January 2003 to May 2006

<table>
<thead>
<tr>
<th>Organism</th>
<th>n</th>
<th>No. of isolates</th>
<th>Multi-drug resistant isolates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td></td>
<td>n</td>
</tr>
<tr>
<td>Pseudomonas</td>
<td>36</td>
<td>96</td>
<td>38</td>
</tr>
<tr>
<td>Klebsiella</td>
<td>34</td>
<td>83</td>
<td>59</td>
</tr>
<tr>
<td>Acinetobacter</td>
<td>44</td>
<td>67</td>
<td>45</td>
</tr>
<tr>
<td>Staph aureus</td>
<td>23</td>
<td>37</td>
<td>28</td>
</tr>
</tbody>
</table>
## Predictors of Mortality for Bacteremic Burn Patients

<table>
<thead>
<tr>
<th>Risk factor</th>
<th>Univariate</th>
<th></th>
<th></th>
<th>Multivariate</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Relative risk</td>
<td>95% CI</td>
<td>( p ) Value</td>
<td>Relative risk</td>
<td>95% CI</td>
<td>( p ) Value</td>
</tr>
<tr>
<td>Age</td>
<td>1.03</td>
<td>1.00–1.06</td>
<td>0.03</td>
<td>1.06</td>
<td>1.02–1.09</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>TBSA burned (%)</td>
<td>1.03</td>
<td>1.01–1.05</td>
<td>&lt;0.01</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Injury Severity Score</td>
<td>1.05</td>
<td>1.01–1.08</td>
<td>0.01</td>
<td>1.08</td>
<td>1.03–1.13</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Bacteremia with more than one organism</td>
<td>1.92</td>
<td>0.82–4.53</td>
<td>0.14</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Multiple episodes of bacteremia</td>
<td>0.34</td>
<td>0.12–1.03</td>
<td>0.051</td>
<td>NS</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Bacteremia with a MDRO</td>
<td>2.78</td>
<td>1.13–6.83</td>
<td>0.03</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Bacteremia with <em>Pseudomonas aeruginosa</em></td>
<td>2.25</td>
<td>0.96–5.3</td>
<td>0.06</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Bacteremia with <em>Klebsiella pneumoniae</em></td>
<td>2.71</td>
<td>1.14–6.49</td>
<td>0.03</td>
<td>3.72</td>
<td>1.3–10.6</td>
<td>0.01</td>
</tr>
<tr>
<td>Bacteremia with <em>Acinetobacter</em></td>
<td>0.48</td>
<td>0.21–1.11</td>
<td>0.08</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Bacteremia with <em>Staphylococcus aureus</em></td>
<td>0.79</td>
<td>0.30–2.06</td>
<td>0.63</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>
# Clinical Predictors

## Correlation of Vital Signs

<table>
<thead>
<tr>
<th></th>
<th>Time of culture</th>
<th>Previous 0-6 hours</th>
<th>Previous 6-12 hours</th>
<th>Previous 12-18 hours</th>
<th>Previous 18-24 hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blood culture growth</td>
<td>101.4 (2.0)</td>
<td>101.9 (1.7)</td>
<td>101.0 (1.6)</td>
<td>100.8 (1.5)</td>
<td>100.9 (1.5)</td>
</tr>
<tr>
<td>No blood culture growth</td>
<td>101.5 (1.7)</td>
<td>102.0 (1.5)</td>
<td>101.1 (1.3)</td>
<td>101.1 (1.3)</td>
<td>101.2 (1.5)</td>
</tr>
</tbody>
</table>

( ) - standard deviation
### Clinical Predictors

#### Correlation of Vital Signs

<table>
<thead>
<tr>
<th></th>
<th>WBC (10^3 cells/mm³)</th>
<th>Neutrophil Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Time of culture</td>
<td>Previous 24 hours</td>
</tr>
<tr>
<td>Positive blood culture</td>
<td>14.1 (8.1)</td>
<td>83.2 (9.5)</td>
</tr>
<tr>
<td></td>
<td>13.1 (7.0)</td>
<td>82.9 (8.5)</td>
</tr>
<tr>
<td>Negative blood culture</td>
<td>14.1 (7.7)</td>
<td>80.1 (9.5)</td>
</tr>
<tr>
<td></td>
<td>13.9 (7.4)</td>
<td>80.4 (8.0)</td>
</tr>
</tbody>
</table>

( ) - standard deviation
Renal Support
Kaplan-Meier Curve

Log Rank \( p = 0.0174 \)
VDR-4 Characteristics

Pressure-limited
Time-cycled
Flow-interrupted
Pneumatically powered
<table>
<thead>
<tr>
<th>Outcome</th>
<th>HFPV (n=31)</th>
<th>Conventional (n=31)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vent Free days*</td>
<td>12 +/- 9</td>
<td>11 +/- 9</td>
<td>ns</td>
</tr>
<tr>
<td>Days Free of MODS*</td>
<td>15 +/- 11</td>
<td>15 +/- 10</td>
<td>ns</td>
</tr>
<tr>
<td>Death (%)</td>
<td>6 (19)</td>
<td>6 (19)</td>
<td>ns</td>
</tr>
<tr>
<td>Rescue (%)</td>
<td>2 (6)</td>
<td>9 (29)</td>
<td>0.02</td>
</tr>
<tr>
<td>VAP (%)</td>
<td>10 (32)</td>
<td>16 (52)</td>
<td>0.12</td>
</tr>
<tr>
<td>Barotrauma (%)</td>
<td>0 (0)</td>
<td>4 (13)</td>
<td>0.04</td>
</tr>
</tbody>
</table>

Mean +/- SD
Ireal Skin Substitute

• Ready off the shelf
• Easy handling
• Excellent graft take
• Doesn’t scar
• No donor sites