Continuous NIRS Measurement of Regional Oxygen Saturation (rSO$_2$) for Assessment of Blood Pressure During Hemorrhagic Hypotension in a Swine Model

University of Texas Medical Branch, Galveston, TX

Presented at 34th Annual Conference on Shock
June 11 - 14, 2011
In early trauma care there are only intermittent assessments of hemodynamics. A non-invasive continuous means of assessing severity of shock is needed.

Tissue oxygenation using near infrared spectroscopy (NIRS) may provide a clinically useful means to assess end organ ischemia and correlate with global ischemia.
Our ongoing objective is to determine the value of cerebral oxygenation saturation (rSO2) as an index of occurrence and severity of hemorrhagic hypotension.
Cerebral rSO2 was monitored with two cerebral oximetry sensors using a 2 channel Nonin EQUANOX 7600.

The dual-emitter targets the cerebral cortex and utilizes four wavelengths of light to measure the balance of oxyhemoglobin and deoxyhemoglobin.
Anesthetized with Propofol.
Ventilated to an ETCO2 of 35-45 mmHg.
Surgically placed catheters:
   - Right and left Femoral arterial catheters
   - Right and left Femoral venous catheters
   - Carotid artery catheter
   - Pulmonary Artery Catheter
Splenectomized.
Retrospective analysis of changes in rSO$_2$ and mean arterial pressure (MAP) of anesthetized, instrumented swine subjected to hemorrhagic shock with and without ongoing resuscitation.
Tissue Oxygenation for Shock Monitoring

Pros

• Measure of tissue perfusion
• Noninvasive and continuous
• Effective trend monitor
• Small and portable

Cons

• Disposable probes have recurring cost
• Large variability of pre shock values i.e. single number has limited value
Series 1: Hemorrhage Alone

Protocol: Continuous hemorrhage (1ml/kg/min) without resuscitation until cardiovascular collapse.
Fig 1 - 4 Pigs – 2 sensors each

% Baseline vs Time

- rSO2
- MAP

% Baseline vs Minutes

Minutes: 0 to 25

Baseline: 100 to 75
### Table 1 - Hemorrhage Alone Linear Regression Analysis

<table>
<thead>
<tr>
<th>Animal</th>
<th>CrSO2</th>
<th>$r^2$</th>
<th>$\Delta$mmHg/$\Delta%$ Crso2</th>
</tr>
</thead>
<tbody>
<tr>
<td>176</td>
<td>Left</td>
<td>0.866</td>
<td>1.8</td>
</tr>
<tr>
<td></td>
<td>Right</td>
<td>0.513</td>
<td>7.8</td>
</tr>
<tr>
<td>175</td>
<td>Left</td>
<td>0.822</td>
<td>4.1</td>
</tr>
<tr>
<td></td>
<td>Right</td>
<td>0.845</td>
<td>2.5</td>
</tr>
<tr>
<td>2370</td>
<td>Left</td>
<td>0.386</td>
<td>10.2</td>
</tr>
<tr>
<td></td>
<td>Right</td>
<td>0.944</td>
<td>3.4</td>
</tr>
<tr>
<td>2365</td>
<td>Left</td>
<td>0.966</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>Right</td>
<td>0.937</td>
<td>4.3</td>
</tr>
<tr>
<td>MEAN</td>
<td></td>
<td>0.785</td>
<td>4.5</td>
</tr>
<tr>
<td>SD</td>
<td></td>
<td>0.216</td>
<td>3.0</td>
</tr>
</tbody>
</table>
Fig 2 – 4 Pigs – 2 Sensors each

Decreased MAP and rSO$_2$

- MAP, n=4 Pigs
- rSO$_2$, n=4 Pigs, 8 Sensors
Series 2: Hemorrhage + Resuscitation

Protocol: Three 40 minutes periods with intermittent hemorrhage and goal directed fluid resuscitation target MAP = 80 mmHg to a target endpoint.
Fig 3 - Representative Experiment
Pig 2333
MAP, Hextend Treatment

Hemorrhage Protocol 4-1-3-2 SBP

mmHg

Target BP

Hem. Rate
Hextend

mL/kg/min

Minutes
**Fig 4 - Representative Experiment**

**MAP, Cardiac Output, and Brain/Muscle O₂**

**Invasive**
- **mmHg**
- **L/min**

**Noninvasive**
- **% O₂**
  - Left rSO₂
  - Right rSO₂

**Noninvasive**
- **% O₂**
  - Muscle SₜO₂
Fig 5 - 3 Pigs – 2 sensors each

% Baseline MAP vs % Baseline rSO₂

y = 0.284x + 0.72
R² = 0.313
Summary of Results

Series 1: Hemorrhage alone

A 5% decrease occurred for MAP and rSO2 in 1.2±0.4 and 9.7±5.2 minutes respectively (Fig 1).

Regression analysis showed high rSO2-MAP correlation (r2 > 0.8) in 6 out of 8 data sets (Table 1).

MAP decreased 4.5 mmHg ±3 for each percent decrease in rSO2.
Series 2: Hemorrhage + Resuscitation

MAP decreases were more modest during hemorrhage with resuscitation; rSO2 and MAP were less correlated (Fig 3).
NIRS measured rSO2 displayed similar patterns of change parallel to MAP. However, rSO2 decreases were delayed versus MAP with a variable sensitivity. Falls in rSO2 >5% indicated severe hypotension during unresuscitated hemorrhage.

rSO2 was a less sensitive index during hemorrhage with resuscitation.
Conclusion

Noninvasively measured tissue oxygen provided trends comparable to invasive arterial blood pressure and continuous cardiac output monitoring.

Tissue oximetry generally provided excellent trend monitoring, with absolute measurements having less diagnostic value.
Continuously measured rSO2 may provide early warning of hemorrhagic hypotension due to the advantage of continuous NIRS monitoring versus intermittent cuff BP measurements.
Funded by:
Moody Center for
Traumatic Brain and
Spinal Cord Injury
Research
Extra Slides
NIRS

• A spectroscopic technique that utilizes the near-infrared region of the electromagnetic spectrum as well as measures the absorption fraction at multiple wavelengths of NIR light by a specimen of interest

• Organic groups that contain N-H, O-H, and C=O bonds absorb NIR light,

• Hemoglobin composed of 4 polypeptide groups (N-H) each containing a heme (O-H, C=O)
Tissue O2 via NIRS?

Sensor emits light that scatters in the tissue

Oxygenated and deoxygenated hemoglobin absorb light differently

Sensor measures the difference in absorption in the light returned
InSpectra™ StO2 Tissue Oxygenation Monitor
The **InSpectra™ StO₂ Sensor**

Disposable sensor can be used on multiple monitors, facilitating patient flow.

Sensor connects to optical cable with simple twist-and-lock motion.

Release liner makes adhesive-backed sensor easy to apply.

The **InSpectra StO₂** sensor is applied over the patient’s thenar eminence (the muscle below the thumb).