Resuscitative Endovascular Balloon Occlusion of the Aorta (REBOA) in a Pediatric Swine Model: Is 60 Minutes Too Long?

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Disclosure

The views expressed in this material are those of the authors, and do not reflect the official policy or position of the U.S. Government, the Department of Defense, the Department of the Air Force, or the University of California Davis.

The animals involved in this study were procured, maintained, and used in accordance with the Laboratory Animal Welfare Act of 1966, as amended, and the Guide for the Care and Use of Laboratory Animals, National Research Council. The work reported herein was performed under United States Air Force Surgeon General-approved Clinical Investigation Number FDG20180028A.
Introduction

- Resuscitative endovascular balloon occlusion of the aorta (REBOA)
Introduction

- Paucity of data on the use of REBOA in pediatrics patients

- **71% of deaths** due to a vascular injury were in the torso
  - **43% of the deaths** on the OR table

- 23% 24 hour mortality rate if transfused greater than 20mL/kg

Previously showed that Zone 1 REBOA in pediatric swine:
- Feasible
- Improved hemorrhage control
- Trend towards improved survival

What is the tolerable duration of Zone 1 REBOA in a pediatric patient?

Hypothesis: Pediatric swine would tolerate at least 60 minutes of Zone 1 REBOA.
Methods

Hemorrhage

- 60% TBV
- 60 minutes, n=5
- 30 minutes, n=3

Critical Care

4 hours

Zone 1

20-30 kg
Results – Survival After REBOA Deflation

- 60 minutes
- 30 minutes

p=0.99
# Results – End Laboratory Values

<table>
<thead>
<tr>
<th>Value</th>
<th>60R Baseline (n=5)</th>
<th>60R End (n=3)</th>
<th>p</th>
<th>30R Baseline (n=3)</th>
<th>30R End (n=2)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>White Blood Cell Count (x10⁹/L)</td>
<td>17.1 ± 3.7</td>
<td>25.2 ± 3.4</td>
<td>0.02</td>
<td>14.2 ± 2.3</td>
<td>21.4 ± 1.2</td>
<td>0.03</td>
</tr>
<tr>
<td>Hemoglobin (g/dL)</td>
<td>8.6 ± 0.7</td>
<td>8.5 ± 0.9</td>
<td>0.85</td>
<td>7.9 ± 2.0</td>
<td>8.0 ± 0.2</td>
<td>0.96</td>
</tr>
<tr>
<td>Carbon Dioxide (mEq/L)</td>
<td>30.7 ± 3.2</td>
<td>22.5 ± 4.1</td>
<td>0.02</td>
<td>29.7 ± 5.0</td>
<td>31.6 ± 0.1</td>
<td>0.65</td>
</tr>
<tr>
<td>Blood Urea Nitrogen (mg/dL)</td>
<td>7.8 ± 0.8</td>
<td>8.3 ± 2.9</td>
<td>0.70</td>
<td>10.0 ± 1.0</td>
<td>8.5 ± 0.7</td>
<td>0.17</td>
</tr>
<tr>
<td>Creatinine (mg/dL)</td>
<td>1.0 ± 0.1</td>
<td>1.7 ± 0.3</td>
<td>&lt;0.01</td>
<td>0.9 ± 0.1</td>
<td>1.2 ± 0.2</td>
<td>0.06</td>
</tr>
<tr>
<td>Alanine Transaminase (U/L)</td>
<td>17.1 ± 3.7</td>
<td>58.7 ± 16.8</td>
<td>0.32</td>
<td>17.0 ± 7.8</td>
<td>59.5 ± 16.3</td>
<td>0.34</td>
</tr>
<tr>
<td>Aspartate Transaminase (U/L)</td>
<td>8.6 ± 0.7</td>
<td>403.0 ± 245.2</td>
<td>0.01</td>
<td>17.0 ± 7.8</td>
<td>116.0 ± 36.8</td>
<td>0.02</td>
</tr>
<tr>
<td>Alkaline Phosphatase (U/L)</td>
<td>310.4 ± 124.4</td>
<td>266.7 ± 114.6</td>
<td>0.03</td>
<td>114.0 ± 7.8</td>
<td>158.5 ± 17.7</td>
<td>0.03</td>
</tr>
<tr>
<td>Creatinine Kinase (U/L)</td>
<td>335.4 ± 56.4</td>
<td>961.0 ± 170.7</td>
<td>&lt;0.01</td>
<td>432.7 ± 201.5</td>
<td>769.5 ± 178.9</td>
<td>0.15</td>
</tr>
</tbody>
</table>
Results - ABG

- **Results**
  - HCO₃⁻ (mmol/L)
  - Base Excess (mmol/L)
  - pH

**Graphs**
- The graphs show changes in HCO₃⁻, Base Excess, and pH over time for treatments at 60 minutes and 30 minutes.
- The x-axis represents time points (Baseline, End REBOA, 0.5hr CC, 1hr CC, 1.5hr CC, 2hr CC, 2.5hr CC, 3hr CC, 3.5hr CC, and 4hr CC).
- The y-axis for HCO₃⁻ and Base Excess ranges from 10 to 30 mmol/L, and for pH from 7.1 to 7.5.

**Legend**
- **60 minutes**
- **30 minutes**

**Annotations**
- **Significant changes** marked with asterisks: *
  - **p < 0.05**
  - **p < 0.01**
  - **p < 0.001**
  - **p < 0.0001**

**Institutional Values**
- UC Davis Health
- **Integrity - Service - Excellence**
Results - ABG

- Lactate (mmol/L)
  - Baseline
  - End REBOA
  - 0.5hr CC
  - 1hr CC
  - 1.5hr CC
  - 2hr CC
  - 2.5hr CC
  - 3hr CC
  - 3.5hr CC
  - 4hr CC

- Anion Gap (mmol/L)
  - Baseline
  - End REBOA
  - 0.5hr CC
  - 1hr CC
  - 1.5hr CC
  - 2hr CC
  - 2.5hr CC
  - 3hr CC
  - 3.5hr CC
  - 4hr CC

60 minutes
30 minutes
Results - Hemodynamics

- pMAP (mmHg)
- dMAP (mmHg)

**60 minutes**

**30 minutes**
Results - Hemodynamics

**HR (bpm)**

- **Baseline**
- **End REBOA**
- **30min CC**
- **1hr CC**
- **1.5hr CC**
- **2hr CC**
- **2.5hr CC**
- **3hr CC**
- **3.5hr CC**
- **4hr CC**

**CVP (mmHg)**

- **Baseline**
- **End REBOA**
- **30min CC**
- **1hr CC**
- **1.5hr CC**
- **2hr CC**
- **2.5hr CC**
- **3hr CC**
- **3.5hr CC**
- **4hr CC**

60 minutes
30 minutes
Results – Critical Care

![Graph showing norepinephrine levels for 60R and 30R](image)
Results – Critical Care

- 60 minutes
- 30 minutes
# Results – Tissue Injury on Histology

<table>
<thead>
<tr>
<th>Tissue</th>
<th>60R</th>
<th>30R</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart</td>
<td>Focal (1)</td>
<td>None (0)</td>
<td>0.37</td>
</tr>
<tr>
<td>Lung</td>
<td>None (0)</td>
<td>None (0)</td>
<td>0.57</td>
</tr>
<tr>
<td>Liver</td>
<td>Diffuse (4)</td>
<td>Diffuse (4)</td>
<td>0.43</td>
</tr>
<tr>
<td>Kidney</td>
<td>Locally extensive (3.5)</td>
<td>Locally extensive (3)</td>
<td>0.45</td>
</tr>
<tr>
<td>Duodenum</td>
<td>None (0)</td>
<td>None (0)</td>
<td>0.57</td>
</tr>
<tr>
<td>Ileum</td>
<td>Focal (1)</td>
<td>None (0)</td>
<td>0.29</td>
</tr>
<tr>
<td>Colon</td>
<td>Multifocal (2)</td>
<td>Focal (1)</td>
<td>0.31</td>
</tr>
<tr>
<td>Skeletal Muscle</td>
<td>None (0)</td>
<td>None (0)</td>
<td>0.50</td>
</tr>
<tr>
<td>Spinal Cord</td>
<td>None (0)</td>
<td>None (0)</td>
<td>0.57</td>
</tr>
</tbody>
</table>
Results - Fogarty

ER-REBOA

Fogarty
Discussion

- A longer duration of REBOA was not tolerated
- Near complete recovery after 30min of REBOA
- Did not recover after 60min of REBOA
  - Metabolic acidosis
  - Elevated lactate
  - Base deficit
  - Norepinephrine
  - Increased creatinine
  - Increased creatinine kinase
- Pediatric specific REBOA needs to be developed
Limitations

- Randomization
- End of study time
- Controlled hemorrhage model
- Femoral sheath placed prior to hemorrhage
Conclusion

- 30 minutes of REBOA may be tolerated by pediatric patients
- 60 minutes of REBOA may be too long
- The Fogarty catheter should be used with a wire if it is used as a REBOA device
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