Acute Normovolemic Hemodilution:
Doernbecher Children’s Hospital Strategy and Experience
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Objectives

• Provide a brief overview of the ANH process at Doernbecher Children’s Hospital
• Outline our experience with ANH in the pediatric population

Definition

Acute Normovolemic Hemodilution (ANH):

post induction, pre-heparin, preoperative withdrawal of whole blood which is simultaneously replaced with crystalloid or colloid volume yielding a decrease in red cell volume
**Bloodless cardiac surgery and the pediatric patient: a case study**

AL. Gao, IR. St. Orso, F. Fitzgerald, U. Gollan, LI. Brown, and J. Sher.

J. Extra Corporeal Technol. 2014 Mar-Apr; 30-43

**Bloodless Extracorporeal Membrane Oxygenation in the Jehovah’s Witness Patient**

Thomas J. Ponder, BS, CCP; Vincent J. Glorioso Jr., BS, CCP, FFP, and Margaret Deane, MD

Bloodless pediatric cardiopulmonary bypass for a 2.3 kg patient whose parents are of Jehovah’s witness faith.


**Strategic and operational aspects of a transfusion-free neonatal arterial switch operation.**

Schanker M, Cone J, Faltyj M, Habel M

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**Blood Transfusions in Pediatric Cardiac Population**

- **Association of Complications With Blood Transfusions in Pediatric Cardiac Surgery Patients**
  - Renal failure
  - Low cardiac output syndrome
  - Infection
  - Excessive post op bleeding
  - Increased hospital length of stay

Blood transfusion determines postoperative morbidity in pediatric cardiac surgery applying a comprehensive blood-sparing approach.

Mathias Boden, MD, Marian Kokoska, MD, Wolfgang Bervenick, DCC, Edith Scheinost, MD, Michael Bechstein, MD, Hermann Kopp, MD, MD and Bjorn Henschel, MD, MD


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**Pros vs Cons of ANH**

**PROS**
- Preservation of native clotting factors & platelet function
- Use of allogenic blood products
  - ↓ inflammation
  - ↓ cytokines
  - ↓ risk of hemolytic transfusion reaction
  - ↓ TRALI
  - ↓ TACO
- ↓ Costs

**CONS**
- Hemodilution
- ↓ CaO₂
Blood Conservation Techniques

ANH Collection

- After induction and line placement, Anesthesia collects 10mL/kg into a CPD collection bag at a ratio of 10:1
- Agitated on blood rocking device upon collection
- Stored at room temperature in the room during the case

Collection Bags

- ANH Collection in 10:1 Blood to CPD Ratio
- 60mL Syringes
- 250mL CPD Bag
- 450mL CPD Bag
**Blood Product Transfusion During CPB**

- Hct
- MAP
- SvO₂ <55
- NIRS <25%
- Qp Flow
- Rising Lactate?

* The acceptable parameters vary from patient to patient. *

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**ANH Reinfusion**

- Off CPB (under filled)
- Perfusion takes back venous line and starts concentrating the circuit volume (via in line hemoconcentrator - not MUF)
- Concentrated circuit volume reinfused
- Anesthesia gently begins Protamine administration
- Surgeon/Perfusion flush arterial line contents
- Timing of the Protamine titration is imperative for complete reversal since we’re giving back circuit concentrate (contains heparin)
- Once all of the circuit volume is in, Protamine is finished and ANH is reinfused

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**ANH Challenges**

- Not enough room for volume (Lasix, leveling off the table, coming off CPB underfilled with as little residual volume as possible)
- Slower Protamine administration
- If bleeding after Protamine is in - sometimes give products prior to giving the ANH back (complex cases)
**Thromboelastograph (TEG)**

Normal Baseline

**Thromboelastograph (TEG)**

Rewarm

**Thromboelastograph (TEG)**

Post Protamine/ Post ANH Reinfusion
### TEG Comparisons

<table>
<thead>
<tr>
<th></th>
<th>Baseline- Pre ANH Pre CPB</th>
<th>Rewarm</th>
<th>Post Protamine/ Post ANH</th>
</tr>
</thead>
<tbody>
<tr>
<td>R time</td>
<td>8.8</td>
<td>15.2</td>
<td>8.7</td>
</tr>
<tr>
<td>Angle</td>
<td>65.5</td>
<td>40.7</td>
<td>59.7</td>
</tr>
<tr>
<td>MA</td>
<td>55.4</td>
<td>41</td>
<td>47.1</td>
</tr>
</tbody>
</table>

Normal Ranges: R= 5-10min Angle= 52-67° MA= 55-74mm

### Retrospective Observational Study

- **Single Center Cohort**
- **Patients** 0-18yo undergoing CPB between November 2013- November 2014
- **ANH group** (n=24) vs **Non-ANH group** (n=59)

### Retrospective ANH Study

<table>
<thead>
<tr>
<th>Variable</th>
<th>Adjusted Difference</th>
<th>P</th>
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</thead>
<tbody>
<tr>
<td>Primary endpoint</td>
<td>mEq/L</td>
<td>%</td>
</tr>
<tr>
<td>Total blood products transfused</td>
<td>-13.8</td>
<td>-10.2-15</td>
</tr>
<tr>
<td>Packed red blood cells</td>
<td>-11.6</td>
<td>-12.1-13</td>
</tr>
<tr>
<td>Fresh frozen plasma</td>
<td>-8.8</td>
<td>-8.1-10</td>
</tr>
<tr>
<td>Platelets</td>
<td>-8.4</td>
<td>-13.3-4</td>
</tr>
<tr>
<td>C-reactive protein</td>
<td>-9.25</td>
<td>-5.8-1.26</td>
</tr>
<tr>
<td>Secondary endpoints</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Estimated blood loss in first 6h, mEq/L</td>
<td>-6.18</td>
<td>-8.77-1.79</td>
</tr>
<tr>
<td>Estimated blood loss in first 24h, mEq/L</td>
<td>-6.06</td>
<td>-2.44-15.6</td>
</tr>
<tr>
<td>Maximum lactate in 24 h, mmol/L</td>
<td>-0.3</td>
<td>-0.91-0.12</td>
</tr>
<tr>
<td>Hematocrit at 72 h, %</td>
<td>-0.7</td>
<td>-1.1-0.4</td>
</tr>
<tr>
<td>Creatinine at 72 h, mg/dL</td>
<td>0.04</td>
<td>0.0001-0.1</td>
</tr>
<tr>
<td>Creatinine at 72h, mg/dL</td>
<td>0.25</td>
<td>-0.0.02-0.8</td>
</tr>
<tr>
<td>Venous return index score</td>
<td>-4.33</td>
<td>-7.3-2.14</td>
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<tr>
<td>Duration of cannular support, h</td>
<td>-8.87</td>
<td>-16.6-16.6</td>
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<tr>
<td>Duration of ventilation, h</td>
<td>-3.02</td>
<td>-4.8-13.7</td>
</tr>
<tr>
<td>Hospital length of stay, days</td>
<td>-2.5</td>
<td>-4.5-0.5</td>
</tr>
</tbody>
</table>
Collaboration

Conclusion

- ANH in pediatrics has the potential to be safe and successful.

THANK YOU
### Hematocrit Calculations Excel Sheet

<table>
<thead>
<tr>
<th>Patient Weight (kg)</th>
<th>Body Surface Area (m²)</th>
<th>Cardiac Index (m²/min/m²)</th>
<th>Cardiac Index (m²/min/m²) Post-ABX</th>
<th>Cardiac Index (m²/min/m²) Post-ABX + 0.52</th>
</tr>
</thead>
<tbody>
<tr>
<td>16.2</td>
<td>0.38</td>
<td>4.18</td>
<td>4.18</td>
<td>4.18</td>
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<tr>
<td>18</td>
<td>0.42</td>
<td>4.30</td>
<td>4.30</td>
<td>4.30</td>
</tr>
<tr>
<td>20</td>
<td>0.46</td>
<td>4.42</td>
<td>4.42</td>
<td>4.42</td>
</tr>
</tbody>
</table>

### Vasoactive Inotropic Score

Calculation:

1. Warmsky IS = dopamine dose (µg/kg/min) + dobutamine dose (µg/kg/min) + 100 × epinephrine dose (µg/kg/min) + 10,000 × vasopressin dose (U/kg/min) + 100 × norepinephrine dose (µg/kg/min)

2. VAS = IS + 10 × milrinone dose (µg/kg/min) + 10,000 × vasopressin dose (U/kg/min) + 100 × norepinephrine dose (µg/kg/min)

3. VAS = IS + 10 × milrinone dose (µg/kg/min) + 10,000 × vasopressin dose (U/kg/min) + 100 × norepinephrine dose (µg/kg/min)
**Statistical Analysis**

- Main predictor: use of ANH
- Bivariate Analysis comparing baseline demographic characteristics and intraoperative variables between the ANH and the usual care group
- We used two-sample Student's t-test for continuous variables and chi-square for categorical variables.
- Primary endpoint analysis: blood product transfused (mL/kg) we used simple regression analysis with robust variance estimation
- A multivariate linear regression model with robust variance estimation was then fitted to compare the differences between the ANH and usual care group and adjust for a priori defined potential confounders including age, ASA classification, and RACHS-1 score.
- Since age spanned across a wide range of values, in exploratory analyses, we modeled age using different functional forms (continuous, categorical, and ordinal categorical).
- A two-sided alpha level of 5% was required for statistical significance.

**Other Considerations**

- Patient volume status
  - Volume overload
  - “dry”
- Hemodynamic tolerance during removal
- Pre-operative Hematocrit
- Resultant Hematocrit calculation
- Anticipated complexity of surgical repair/ cardiopulmonary bypass time
- Complete correction vs mixing post op

**References**