What is the Optimal Hematocrit on Bypass for Children?

Gina M Whitney, MD
Why Is This Important?

• Increasing evidence that RBC transfusion is associated with adverse clinical outcomes

• Need to balance risk of allogeneic RBC exposure with risks of anemia and inadequate oxygen delivery on CPB
Transfusion in Coronary Artery Bypass Grafting is Associated with Reduced Long-Term Survival

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Fig 1. Frequency histogram displays the distribution of red cells transfused for the patient population.

(A) Days (y/day)
(B) Years after Isolated CABG
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Two ventricle repairs without arch reconstruction
  – April 1996 – July 2004
  – 270 patients
  – Looked at INTRAOPERATIVE blood products
    • 4-34 ml/kg LOW
    • 35-67 ml/kg MEDIUM
    • 68-364 ml/kg HIGH
  – Measured DMV
Competing Priorities

ENSURING ADEQUATE OXYGEN DELIVERY ON BYPASS

RISKS OF BLOOD PRODUCT EXPOSURE
Oxygen Consumption

\[ V_{E}CO_2 \]

Free Water (ml/h)  
\( K=6 \)

Cardiac Output (dL/min)  
\( K=3 \)

\[ kg^{3/4} \]

\[ VO_2 \]


## VO2: Anesthesia and Temperature

<table>
<thead>
<tr>
<th>Condition</th>
<th>VO2</th>
</tr>
</thead>
<tbody>
<tr>
<td>37° Unanesthetized</td>
<td>4 ml/kg/min</td>
</tr>
<tr>
<td>37° Anesthetized</td>
<td>2-3 ml/kg/min</td>
</tr>
<tr>
<td>28° Anesthetized</td>
<td>1-2 ml/kg/min</td>
</tr>
</tbody>
</table>
Physiology of $O_2$ Delivery on CPB

$$DO_2 = C_aO_2 \times CO$$

$$= S_aO_2 \times 1.39 \times Hb \times \text{ARTERIAL FLOW RATE}$$
Adequate Oxygen Delivery

![Graph showing the relationship between Oxygen Transfer and Hemoglobin and Flow rate (Capiox SX18). The graph includes lines for different Hematocrit (HCT) levels: 36%, 24%, and 18%. The x-axis represents Flow Rate (L/min), and the y-axis represents Oxygen Transfer (mL/min). The graph highlights the impact of varying Hematocrit levels on Oxygen Transfer at different Flow Rates.](Image)
WHAT IS THE EVIDENCE?
The influence of hemodilution on outcome after hypothermic cardiopulmonary bypass: Results of a randomized trial in infants


- Infants <9 mos. F age undergoing biventricular repair randomized to CPB Hct 20% or 30%. N=147

<table>
<thead>
<tr>
<th></th>
<th>Low Hct (20%)</th>
<th>High Hct (30%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ACTUAL HCT</strong></td>
<td>21.5 ± 2.9%</td>
<td>27.8 ± 3.2%</td>
</tr>
<tr>
<td><strong>NADIR CARDIAC INDEX</strong></td>
<td>2.8 ± 1.1 L/min/m²</td>
<td>3.1 ± 1.1 L/min/m²</td>
</tr>
<tr>
<td><strong>PSYCHOMOTOR DEVELOPMENT INDEX ≤ 70</strong></td>
<td>16/56 (29%)</td>
<td>5/53 (9%)</td>
</tr>
<tr>
<td><strong>MOTOR DEVELOPMENT INDEX ≤ 70</strong></td>
<td>4/59 (7%)</td>
<td>2/53 (4%)</td>
</tr>
</tbody>
</table>
Randomized trial of hematocrit 25% versus 35% during hypothermic cardiopulmonary bypass in infant heart surgery


• Noted that adverse outcomes seen primarily at Hct <20% in the 2003 study.
• RCT of 124 infants Hct 25% v. 35%. Does higher Hct benefit patient?

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<tbody>
<tr>
<td>ACTUAL HCT</td>
<td>24.8 ± 3.1%</td>
<td>32.6 ± 3.5%</td>
</tr>
<tr>
<td>PSYCHOMOTOR DEVELOPMENT INDEX ≤ 70</td>
<td>9/48 (19%)</td>
<td>10/58 (17%)</td>
</tr>
<tr>
<td>MOTOR DEVELOPMENT INDEX ≤ 70</td>
<td>1/47 (2%)</td>
<td>1/57 (2%)</td>
</tr>
</tbody>
</table>
• Used data collected during prior two RCT’s to look at relationship between Hct (continuous variable) and clinical outcomes

• Lowest safe level of hemodilution is based on overall CPB management strategy (temp, pH management)
The effect of hematocrit during hypothermic cardiopulmonary bypass in infant heart surgery: Results from the combined Boston hematocrit trials

A  
Intraoperative Fluid Balance (mL) vs. Hematocrit at Onset of Low Flow (%)

B  
Lactate 60' after Bypass (umol/L) vs. Hematocrit at Onset of Low Flow (%)

C  
Psychomotor Development Index vs. Hematocrit at Onset of Low Flow (%)

D  
Mental Development Index vs. Hematocrit at Onset of Low Flow (%)

P < .001
P = .08
P < .001, P = .42
P = .26

Children's Hospital Colorado
The effect of hematocrit during hypothermic cardiopulmonary bypass in infant heart surgery: Results from the combined Boston hematocrit trials

- Every 1 point increase in Hct associate with 11.8 ml decrease in intraoperative fluid balance
The effect of hematocrit during hypothermic cardiopulmonary bypass in infant heart surgery: Results from the combined Boston hematocrit trials

- Linear increase in PDI score with Hct up to 23.5%
- 1 point increase in Hct associated with 2.6 point increase in PDI score
What is the Optimal Hematocrit on Bypass for Children?

~23.5%

*Based on the best available evidence. This number may be modified upward or downward as part of an overall bypass strategy.*
Thank You!