Quantifying Unwanted Variation During Cardiopulmonary Bypass

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Disclosures

- I have no disclosures to report
The Northern New England Cardiovascular Disease Study Group exists to develop and exchange information concerning the treatment of cardiovascular disease. It is a regional, voluntary, multi-disciplinary group of clinicians, hospital administrators, and health care research personnel who seek to improve continuously the quality, safety, effectiveness, and cost of medical interventions in cardiovascular disease.
Background

Exposures

Temperature
Blood Pressure
Blood Flow
Oxygen Delivery
Hematocrit

End Organ Injury
What Is The Critical Threshold?
Hyperthermic perfusion during cardiopulmonary bypass and postoperative temperature are independent predictors of acute kidney injury following cardiac surgery.

Variables found to be independent predictors of AKI included CPB hyperthermia (Odds ratio [OR] 1.03 per minute increase p = 0.01) …
The best predictor for acute renal failure and peak postoperative serum creatinine levels was the lowest DO$_2$, with a critical value at 272mL · min$^{-1}$ · m$^2$. 

Methods. One thousand forty-eight consecutive patients undergoing coronary operations have been studied. For each patient we have recorded the lowest hematocrit on cardiopulmonary bypass, the correspondent lowest oxygen delivery, and the pump flow around the time of these determinations. The three variables have been explored in a multivariable model as possible risk factors for acute renal failure and postoperative serum creatinine levels increase. The role of transfusions in sions, only the lowest oxygen delivery remained an independent risk factor.

Conclusions. A high degree of hemodilution during cardiopulmonary bypass is a risk factor for postoperative renal dysfunction; however, its detrimental effects may be reduced by increasing the oxygen delivery with an adequately increased pump flow. 

A nadir DO2 level < 262 mL/minute/m2 ...was independently associated with AKI
What Is The Critical Threshold?

Lowest Hematocrit on Bypass and Adverse Outcomes Associated With Coronary Artery Bypass Grafting

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6,980 consecutive CABG patients at six medical centers.

(Ann Thorac Surg 2001;71:769–76)
What Is The Critical Threshold?

Loor et al, Habib et al
To date, little has been reported about the importance of duration of these exposures during CPB.
Aim

1. The aim of our pilot study was to move beyond nadir and quantify these exposures in minutes.

   Minutes of:
   
   MAP < 50 mmHg
   CI < 1.6 L/Min/M^2
   DO2 < 260 ml/Min/M^2
   SVO2 < 60%
   HCT < 22
   Art Temp > 37°C

2. Examine the relationship between these exposures quantified in minutes and AKI
Methods

• Single Center Study
• 313 Consecutive Cardiac Surgical Cases with CPB (Sept ’14-Feb ‘15)
• Exclusion Criteria
  <19yo
  DHCA cases
• Statistical Methods
  STATA v11.2
  • Wilcoxon Rank-sum (Mann-Whitney) test
  • nptrend
AKIN AKI Definition

- **Stage 1**
  - Increase in sCr by $\geq 0.3$ mg/dL or increase by 1.5-2 times from baseline

- **Stage 2**
  - Increase in sCr $> 2$-3 times from baseline

- **Stage 3**
  - Increase in sCr by $> 3$ times from baseline or absolute sCr $\geq 4$ mg/dL, with acute increase of $\geq 0.5$ mg/dL
<table>
<thead>
<tr>
<th>Parameter</th>
<th>MAP</th>
<th>SvO2</th>
<th>T Perf a</th>
<th>DO2i</th>
<th>VO2i/DO2i</th>
<th>HCT</th>
<th>Calc. Cardiac Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time Above</td>
<td>00:00</td>
<td>00:00</td>
<td>00:00</td>
<td>00:00</td>
<td>00:00</td>
<td>00:00</td>
<td>00:00</td>
</tr>
<tr>
<td>Maximum Limit</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum</td>
<td>96</td>
<td>92.0</td>
<td>37.0</td>
<td>362.15</td>
<td>19.61</td>
<td>32</td>
<td>2.50</td>
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<tr>
<td>Average</td>
<td>70</td>
<td>86.3</td>
<td>35.3</td>
<td>294.30</td>
<td>11.85</td>
<td>26</td>
<td>2.31</td>
</tr>
<tr>
<td>Minimum</td>
<td>37</td>
<td>78.0</td>
<td>32.0</td>
<td>69.72</td>
<td>6.47</td>
<td>23</td>
<td>0.01</td>
</tr>
<tr>
<td>Minimum Limit</td>
<td>50</td>
<td>60.0</td>
<td>50</td>
<td>260.0</td>
<td>22</td>
<td>1.60</td>
<td></td>
</tr>
<tr>
<td>Time Below</td>
<td>01:10</td>
<td>00:00</td>
<td>00:00</td>
<td>02:20</td>
<td>00:00</td>
<td>00:00</td>
<td>01:24</td>
</tr>
<tr>
<td>Bypass Time</td>
<td>86:00</td>
<td>86:00</td>
<td>86:00</td>
<td>86:00</td>
<td>86:00</td>
<td>86:00</td>
<td>86:00</td>
</tr>
<tr>
<td>Within Limits</td>
<td>99%</td>
<td>100%</td>
<td>100%</td>
<td>97%</td>
<td>100%</td>
<td>100%</td>
<td>98%</td>
</tr>
</tbody>
</table>
Flow of data

Connect Quality Report

NNE Registry
Flow of Data

Excel File

Dorothy
(Cardiac Database Coordinator)

Excel file converted for Access database

Combine Access Databases

Combined Excel File
### Results

<table>
<thead>
<tr>
<th>Condition</th>
<th>n</th>
<th>Capture Rate</th>
<th>Minutes (Mean)</th>
<th>Std Dev</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>DO2 &lt; 260</td>
<td>267</td>
<td>85.3</td>
<td>47.3</td>
<td>55.2</td>
<td>40.6 - 53.9</td>
</tr>
<tr>
<td>HCT &lt; 22%</td>
<td>312</td>
<td>99.6</td>
<td>18.8</td>
<td>43.2</td>
<td>14.0 - 23.6</td>
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<tr>
<td>CI &lt; 1.6</td>
<td>313</td>
<td>100</td>
<td>14.4</td>
<td>24.6</td>
<td>11.7 – 17.2</td>
</tr>
<tr>
<td>MAP &lt; 50mmHg</td>
<td>292</td>
<td>93.3</td>
<td>10.8</td>
<td>17.6</td>
<td>8.8 - 12.8</td>
</tr>
<tr>
<td>Temp &gt; 37</td>
<td>313</td>
<td>100</td>
<td>&lt;1</td>
<td>5.2</td>
<td>0 – 1.2</td>
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<tr>
<td>SvO2 &lt; 60%</td>
<td>305</td>
<td>97.4</td>
<td>&lt;1</td>
<td>4.2</td>
<td>0.2 – 1.2</td>
</tr>
</tbody>
</table>
Results

Terciles of D02<260 Duration; p = 0.044

nptrend

z = 2.02
Results

Terciles of HCT<22 Duration; p = 0.056

nptrend

z = 1.91
Limitations

• Small Sample Size (n = 313)
• Prolonged weaning period may overestimate low DO2 minutes
• AKI results not adjusted for other risk factors
Summary

• We were able to quantify the variation of 6 parameters in minutes for nearly all 313 patients. (96%)  
• Most frequent exposures were DO2 < 260 and HCT < 22%
• There was a significant trend of increased AKI with increased exposure to low DO2 (in minutes)
• There was a trend of increased AKI with increased exposure to low HCT (in minutes)
Thank you