Objectives

- Why is effective myocardial preservation so difficult to quantify?

- What metrics are available that show a preferential benefit to a myocardial preservation technique?

Disclosure: None
Myocardial Protection

Preliminary Communication

ELECTIVE CARDIAC ARREST

The term congestive heart failure must be the unaided correction of cardiac abnormalities under direct vision. Toward this end are being developed many techniques for working within the bloodless heart and for excluding the possibility of air embolism from these maneuvers. Among these measures against air embolism is the induction of ventricular fibrillation in order to prevent the ejection of the heart any air that may be within its cavities. A most valuable contribution to this problem and indeed to the whole problem of intracardiac surgery would be made if the heart could be arrested and restarted at will, suffering no damage during periods of arrest and cessation of coronary blood flow. Binger drew attention in 1888 to the effect of the different cations on the heart beat, and Hooper in 1920 suggested that potassium inhibition induced by an excess of potassium chloride could be used to stop the heart when its beat was disorganized by ventricular fibrillation. He recommended a solution of calcium chloride as an antidote to potassium when re-starting the heart. This work has been revived by Montgomery et al. in order to reverse ventricular fibrillation in hypothermic patients. We have not been able fully to substantiate these findings but have, by modifying this basic technique, succeeded in evolving a reliable method of stopping and re-starting the heart at both normal and reduced body temperatures.

The Lancet, Volume 266, Issue 6879, 2 July 1955, Pages 21-23
D.G. Melrose, B. Dreyer, H.H. Bentall, J.B.E. Baker

Myocardial Protection

History

1955

EXTRACORPOREAL CIRCULATION

Clamp is opened and closed so as to maintain level in reservoir

Acetylcholine

To Coronary Sinus

Coronary Sinus Level

To Coronary Sinus Catheter

To Arterial Catheter

Arterial Line from Oxygenator

40 to 55 cm.
Myocardial Protection Challenges

Quantifying Intraoperative Protection

✓ Most research uses *in vitro* preparations with models rarely reflecting clinical reality

✓ Procedural differences apparent with varying responses related to disease state or cardiac pathology

✓ Ischemia – Reperfusion – Cytolytic features

✓ Complex injury related to varying affecters:
  - Free oxygen radicals (autolytic proteases)
  - Inflammation PMN cells (leukotrienes)

Non-specific injury unrelated to ischemia/reperfusion

Lack of target assessors that can be rapidly determined

Surrogate markers of ischemic injury are useful but lack specificity or direct correlation to clinical outcome

- Troponin
- MKB
- H+, electrolytes
- Arrhythmias
- Low-output syndrome
- Inotropes
- Mechanical support
Myocardial Protection

Heart Failure

http://myheart.net/heart-disease/heart-failure/


Pediatrics

The Neonatal Heart: Developmental Differences, Response to Ischemia, and Protection during Cardiopulmonary Bypass

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Ann Arbor, MI


Keywords: myocardial ischemia, neonatal heart, myocardial protection, anaerobic metabolism, cardioplogia

RECOVERY OF LEFT VENTRICULAR FUNCTION AFTER HYPOTHERMIC GLOBAL ISCHEMIA. AGE-RELATED DIFFERENCES IN THE ISOLATED WORKING RABBIT HEART.

EL Bove and AH Stammers
Myocardial Protection

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Myocardial Protection

Original Article

Does the Type of Cardioplegic Technique Influence Hemodilution and Transfusion Requirements in Adult Patients Undergoing Cardiac Surgery?

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SpecialtyCare, Nashville, Tennessee

J ExtraCorp Tech 2017 (in press)

Abstract: During cardiac surgery, myocardial protection is performed using diverse cardioplegic (CP) solutions with and without the presence of blood. New CP formulations extend ischemic intervals but use high-volume, crystalloid-based solutions. The present study evaluated four commonly used CP solutions and their effect on hemodilution during cardiopulmonary bypass (CPB). Records from 16,670 adult patients undergoing cardiac surgery with CPB between February 2016 and January 2017 were reviewed. Patients were classified into one of four groups according to CP type: 1. Blood to crystalloid (4:1), microplegia (MP), del Nido (DN) and histidine-tryptophan-ketoglutarate (HTK). Covariate-adjusted estimates of group differences were calculated using multivariable logistic and linear mixed effects regression models. The primary end point was intraoperative transfusion of autologous red blood cells (RBCs), with a secondary end point of intraoperative hematoctrit change. Among all patients, 8,359 (50.1%) received 4:1, 4,009 (27.6%) MP, 1,344 (20.1%) DN, and 370 (2.2%) HTK. Both 4:1 and MP were more likely to be used in patients undergoing coronary revascularization surgery, whereas DN and HTK were more often in patients undergoing valve surgery ($p < .001$). The highest volume of crystalloid CP solution was seen in the HTK group, 2,000 [1,754, 2,250], whereas MP had the lowest, 50 [33, 77], $p < .001$. Intraoperative usage was as follows: HTK—44.3%, DN—43.7%, MP—41.1%, and 4:1—34.0%, $p < .001$. There were no statistically significant differences on the primary outcome risk of intraoperative RBC transfusion. However, statistically significant differences among all but one of the pair-wise comparisons of CP methods on hematoctrit change ($p < .05$ or smaller), with MP having the lowest predicted drift (−7.8%) and HTK having the highest (−9.4%). During cardiac surgery, the administration of different CP formulations resulted in varying intraoperative hematocrit changes related to the volume of crystalloid solution administered. Keywords: myocardial preservation, cardioplegia, microplegia, del Nido cardioplegia, hemodilution. J Extra Corp Technol. 2017;49:000-000

Myocardial Protection

SCOPE Registry

- Jan 16 to Sep 17
- 212 Hospitals
- 21,265 Cases
- Adult Patients
Myocardial Protection

21,265 Cases Jan 17-Sep 17

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Trends in Cardioplegia Type

2015 2016

0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10000

8888 4955 3613 1175 550 268 792 320 166 527 11

4 to 1  del Nido None Other 1:4 HTK 10:1 Cysaluid Mod del Nido 1:1

Microplegia del Nido Mod del Nido

8766 8350 4700 4450 2850 3340 20 100

4 to 1 Microplegia del Nido Mod del Nido
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First On-CPB Hematocrit

![Chart showing hematocrit levels for different cardioplegia categories.](chart1.png)

Myocardial Protection

Subset Analysis by Cardioplegia Category

N=16,670

![Pie chart showing distribution of cardioplegia categories.](chart2.png)
### Myocardial Protection

#### Cardioplegia Use (%)

*n=16,670*

<table>
<thead>
<tr>
<th></th>
<th>4 to 1</th>
<th>Microplegia</th>
<th>del Nido</th>
<th>Custodiol (HTK)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CABG 1ª</td>
<td>68.2</td>
<td>70.5</td>
<td>45.7</td>
<td>37.3</td>
<td>0.001</td>
</tr>
<tr>
<td>AVR</td>
<td>10.1</td>
<td>10.1</td>
<td>21.1</td>
<td>25.9</td>
<td>0.001</td>
</tr>
<tr>
<td>MVR</td>
<td>6.3</td>
<td>4.9</td>
<td>10.8</td>
<td>14.9</td>
<td>0.001</td>
</tr>
<tr>
<td>Urgent</td>
<td>21.3</td>
<td>28.6</td>
<td>17.2</td>
<td>32.2</td>
<td>0.001</td>
</tr>
</tbody>
</table>

#### Timing by Cardioplegia Type

<table>
<thead>
<tr>
<th></th>
<th>CPB Time (median)</th>
<th>Cross Clamp Time (median)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 to 1</td>
<td>100</td>
<td>73</td>
</tr>
<tr>
<td>Microplegia</td>
<td>103</td>
<td>77</td>
</tr>
<tr>
<td>del Nido</td>
<td>91</td>
<td>66</td>
</tr>
<tr>
<td>Custodiol (HTK)</td>
<td>104</td>
<td>82</td>
</tr>
</tbody>
</table>

*p=ns*
Myocardial Protection

Crystalloid Volume

Crystalloid Volume (mL)

4.1  MP  DN  HTK

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Crystalloid Volume by CPB Time

4.1 Blood Crystalloid Ratio

Custodiol

del Nido

Micoplegia

Post.CPB.Time..Total.CPB.Time
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Crystalloid Volume by XC Time

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Ultrafiltration Use

Use (%)  p=.001  Volume (median)

4 to 1  Microplegia  del Nido  HTK

41.2  83.7  84.9  2900

1500  1200  2000
**Myocardial Protection**

Change in Hematocrit by CP Type

![Graph showing change in hematocrit by CP type.](image)

<table>
<thead>
<tr>
<th>Group</th>
<th>Prediction Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>4:1</td>
<td>7.6% (7.4%, 7.8%)</td>
</tr>
<tr>
<td>MP</td>
<td>7.6% (7.4%, 7.8%)</td>
</tr>
<tr>
<td>DN</td>
<td>9.4% (9.2%, 9.6%)</td>
</tr>
<tr>
<td>HTK</td>
<td>9.4% (9.2%, 9.6%)</td>
</tr>
</tbody>
</table>

**Statistical significance of group-wise comparisons**

- 4:1 vs. HTK: p = 0.001
- 4:1 vs. MP: p = 0.001
- 4:1 vs. DN: p = 0.001
- 4:1 vs. HTK: p = 0.001

**Probability for RBC Transfusion Rate**

![Graph showing probability for RBC transfusion rate by CP type.](image)

<table>
<thead>
<tr>
<th>Group</th>
<th>Predicted Probability of RBC Transfusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>4:1</td>
<td>7.5%</td>
</tr>
<tr>
<td>MP</td>
<td>6.4%</td>
</tr>
<tr>
<td>DN</td>
<td>8.3%</td>
</tr>
<tr>
<td>HTK</td>
<td>8.1%</td>
</tr>
</tbody>
</table>

All group-wise comparisons p = 0.37 or larger
### Limitations

- Analysis of data from an observational registry with prospective data without randomization
- Techniques for cardioplegia delivery techniques were not standardized across centers
- Not a longitudinal study so lacks clinical outcomes
- Transfusion protocols varied across hospitals

### Conclusions

- The comparison of myocardial preservation techniques is difficult to assess and perioperative assessment remains elusive
- The use of del Nido and HTK cardioplegic formulations has resulted in extended ischemic times with superior preservation to other methods
- del Nido cardioplegic techniques are increasing in use by 17% per year with a reduction of 4 to 1 and microplegia by 5% each
- The use of microplegia resulted in higher on CPB hematocrits and trended towards lower RBC transfusion rates