Optimizing cardioplegia strategy for donor hearts

Charles E Johnson¹, Sherry C Faulkner¹, Juan Tucker¹, Michael L Schmitz², Roger BB Mee³ and Jonathan J Drummond-Webb¹

¹Pediatric and Congenital Heart Surgery, University of Arkansas for Medical Sciences, Little Rock, AR, USA; ²Section of Pediatric Cardiovascular Anesthesiology, University of Arkansas for Medical Sciences, Little Rock, AR, USA; ³Department of Pediatric and Congenital Cardiac Surgery, Cleveland Clinic Foundation, Cleveland, OH, USA

Variability in organ preservation strategy has thus far prevented meaningful analysis of clinical donor heart cardioplegia strategies. This paper describes our donor heart procurement protocol, techniques, and recovery team responsibilities. We present 21 patients receiving cardiac transplantation at our institution with an adopted cardioplegia protocol. The procurement team perfusionist ensures consistent attention to myocardial protection with standards that are similar to those applied to native hearts for all congenital heart surgeries. Perfusion (2004) 19, 65–68.

Introduction

In the USA, the United Network for Organ Sharing guidelines for procurement of donor hearts do not include protocols for infusion of cardioplegia or the types of myocardial preservation solution.¹ The accepted practice is to infuse a volume of cardioplegia without monitoring pressure in the aorta and, thus, the coronary arteries. This places the donor heart at risk for poor myocardial protection that may result from cardioplegia infusion pressures that are either too high or insufficient. We describe a controlled, consistent method of cardioplegia to the donor heart that limits the possibilities of under or over perfusion during donor heart procurement.

Materials and methods

From January 2001 to October 2002, 21 patients (Table 1) aged 21 days to 36 years and weighing between 3.5 and 71 kg (mean 19.3 kg) underwent orthotopic cardiac transplantation at our institution. This was a high-risk group of transplant recipients, with 24% bridged to transplant using extracorporeal membrane oxygenation. We have had no early donor heart failure in this group of patients, with a mean donor ischemic time of 179 min (range 68–298 min). Spontaneous resumption of sinus rhythm occurred in 76% of our patients following removal of the aortic crossclamp. The protocol for donor heart protection and preservation used was adopted from methods and principles of Dr Roger Mee and employed together with the senior author (JJDW) while at the Cleveland Clinic Foundation. Upon identification of a potential donor organ, the procurement team, consisting of a cardiovascular surgeon, assistant, and a perfusionist are transported to the referring hospital. The procurement team proceeds with harvesting of the heart following visual inspection of the donor organ. A crossclamp is applied to the ascending aorta of the donor in routine fashion and cardioplegia is administered.

Cardioplegia delivery system

A large suitcase has been adapted to hold cardioplegia equipment and supplies. A checklist of suitcase contents is performed prior to deployment (Figure 1). Cardioplegia is delivered by an RS-7800 mini pump (Renal systems, Inc., Minneapolis, MN). A cardioplegia reservoir (Gish Biomedical, Inc., Rancho Santa Margarita, CA), a pressure Display 60000 (DLP, Grand Rapids, MI), and a customized tubing pack (Medtronic, Minneapolis, MN) have been assembled to allow recirculation of Mee formula cardioplegia (Central Admixture Pharmacy

Address for correspondence: Jonathan J Drummond-Webb, Chief, Pediatric and Congenital Heart Surgery, Arkansas Children’s Hospital, 800 Marshall St., Slot #677, Little Rock, AR 72202-3591, USA
E-mail: Drummond-WebbJonathan@uams.edu

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Table 1 Demographics of transplant recipients

<table>
<thead>
<tr>
<th>Patient</th>
<th>Age</th>
<th>Gender</th>
<th>Weight (kg)</th>
<th>BSA</th>
<th>TST</th>
<th>DIT</th>
<th>Conv.</th>
<th>ECMO</th>
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<tbody>
<tr>
<td>1</td>
<td>5 year 3 months</td>
<td>M</td>
<td>13.2</td>
<td>0.572</td>
<td>287</td>
<td>162</td>
<td>Y</td>
<td>N</td>
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<tr>
<td>2</td>
<td>7 months 26 days</td>
<td>M</td>
<td>6.86</td>
<td>0.327</td>
<td>166</td>
<td>191</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>3</td>
<td>22 years 4 months</td>
<td>M</td>
<td>30</td>
<td>1.185</td>
<td>132</td>
<td>166</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>4</td>
<td>16 days</td>
<td>F</td>
<td>3.8</td>
<td>0.221</td>
<td>178</td>
<td>257</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>5</td>
<td>22 days</td>
<td>M</td>
<td>3.5</td>
<td>0.220</td>
<td>170</td>
<td>181</td>
<td>Y</td>
<td>N</td>
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<tr>
<td>6</td>
<td>5 years 9 months</td>
<td>F</td>
<td>9.17</td>
<td>0.428</td>
<td>137</td>
<td>234</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>7</td>
<td>20 years</td>
<td>M</td>
<td>20</td>
<td>1.87</td>
<td>112</td>
<td>137</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>8</td>
<td>9 years</td>
<td>M</td>
<td>30</td>
<td>0.975</td>
<td>184</td>
<td>213</td>
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<td>N</td>
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<tr>
<td>9</td>
<td>8 months 1 day</td>
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<td>8</td>
<td>0.358</td>
<td>129</td>
<td>70</td>
<td>Y</td>
<td>N</td>
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<tr>
<td>10</td>
<td>3 years 9 months</td>
<td>F</td>
<td>14</td>
<td>0.540</td>
<td>126</td>
<td>220</td>
<td>Y</td>
<td>N</td>
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<tr>
<td>11</td>
<td>36 years 5 months</td>
<td>M</td>
<td>56.6</td>
<td>1.72</td>
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<td>148</td>
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<td>0.292</td>
<td>104</td>
<td>176</td>
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<td>N</td>
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<td>0.512</td>
<td>124</td>
<td>199</td>
<td>Y</td>
<td>N</td>
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<tr>
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<td>M</td>
<td>71</td>
<td>1.83</td>
<td>162</td>
<td>112</td>
<td>N</td>
<td>N</td>
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<tr>
<td>15</td>
<td>3 years 7 months</td>
<td>F</td>
<td>14.6</td>
<td>0.611</td>
<td>123</td>
<td>129</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>16</td>
<td>15 years 7 months</td>
<td>F</td>
<td>37.2</td>
<td>1.317</td>
<td>128</td>
<td>199</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>17</td>
<td>1 year 3 months</td>
<td>F</td>
<td>8.2</td>
<td>0.394</td>
<td>115</td>
<td>191</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>18</td>
<td>9 months</td>
<td>M</td>
<td>10.4</td>
<td>0.394</td>
<td>225</td>
<td>298</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>19</td>
<td>9 years 10 months</td>
<td>M</td>
<td>28.8</td>
<td>1.04</td>
<td>167</td>
<td>207</td>
<td>Y</td>
<td>N</td>
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<tr>
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<td>1 years 2 months</td>
<td>M</td>
<td>11</td>
<td>0.470</td>
<td>111</td>
<td>207</td>
<td>Y</td>
<td>Y</td>
</tr>
</tbody>
</table>

Note: M = male, F = female, BSA = body surface area in m², TST = total surgical time for recipient in minutes, DIT = donor organ ischemic time in min, Conv. = spontaneous conversion to sinus rhythm, Y = yes, N = no, ECMO = extracorporeal membrane oxygenation utilized as a bridge to transplantation in the preoperative period.

Services, Inc., Carrollton, TX) through a metal coil placed in a bucket of ice. Multiple cardioplegia needles are included from a 4–9 Fr. size (Medtronic, Grand Rapids, MI) (Figure 2).

**Cardioplegia solution**
The Mee formulation of cardioplegia contains sodium chloride 3.54 g/L, dextrose monohydrate 7.32 g/L, potassium chloride 2.92 g/L, mannitol 6.54 g/L

**Perfusion Transport Checklist**

**Disposables:**
1. Gısh® venous reservoir
2. Transplant tubing pack
3. Cardioplegia table lines
4. Sterile male-male connectors
5. Scalpel blades
6. 60 ml sterile syringes
7. Tubing clamps
8. 365 ml bags of Dr. Mee's cardioplegia solution
9. 100 ml bottles of 25% albumin
10. 30 ml vials of cardioplegia buffer solution
11. AA batteries
12. DLP® pressure display sets
13. Pediatric cardioplegia cannula
14. Adult cardioplegia cannula

**Non-disposables:**
1. Gısh® reservoir holder
2. DLP® pressure monitor
3. Renal Systems® mini pump

Checklist completed by: __________________________
Date: __________________________
Restocked by: __________________________

Figure 1 Checklist utilized prior to deployment, as well as for restocking upon return.
and calcium chloride 135 mg/L. Total volume of each bag is 385 mL. To each bag of cardioplegia, 26 mL of modified buffer solution is added, which contains sodium carbonate 0.28 g/30 mL, and sodium bicarbonate 0.81 g/30 mL. Finally, 25% albumin (100 mL) is added for each bag of cardioplegia.

**Administration of cardioplegia**
Cardioplegia is transfused to the donor heart once the ascending aorta is crossclamped. Target flow is 110 mL/m²/min for 4 min. Pressure of cardioplegia is monitored closely to maintain a pressure in the aorta equal to the patient’s end diastolic pressure prior to initial incision in order to simulate the donor’s normal filling pressure of the coronary arteries. Temperature of the cardioplegia is maintained at 4°C. Upon completion of administration of cardioplegia, the heart is harvested in routine fashion.

**Discussion**
It is common practice to infuse cardioplegia into the aortic root of donor hearts without monitoring pressure. This practice may have evolved in part due to technical difficulties encountered in arranging for appropriate personnel and equipment for the procurement team at the donor institution. Without an accurate measurement of cardioplegia delivery, the donor heart is at risk for suboptimal myocardial protection and preservation. Drinkwater et al. found that infusion pressures of more than 120 mmHg caused marked dysfunction in the neonatal piglet model. Guyton et al. demonstrated that infusion pressures of more than 150 mmHg produced a significant fall in regional myocardial function. Low cardioplegia pressures can result in under perfusion/protection of the donor heart, resulting in ischemic myocardial damage while higher pressures can offer protection yet damage vascular endothelium. Furthermore, direct monitoring of cardioplegia infusion pressure is much more accurate than estimates derived by calibration of individual delivery systems.

As part of the procurement team, we routinely include a perfusionist who has undergone a skills validation for the use of the system. The perfusionist ensures accuracy of flow rates, temperature, and perfusion pressure of the cardioplegia. In this fashion, we enhance efficacy, quality, and uniformity of the myocardial preservation routine. Of all the members of the procuring cardiac transplant team, the perfusionist has the most experience in administering cardioplegia. This experience is essential.
when troubleshooting of cardioplegia delivery is required. Disadvantages include the added cost of supplies, as well as the need for air transport of additional personnel.

There are other methods that further enhance myocardial preservation during transport and preparation of the donor heart. The technique we describe does not utilize blood cardioplegia which has demonstrated superior myocardial protection ability in some studies. Blood cardioplegia could be prepared with blood from the donor, but that would be a daunting task for a procurement team with the time pressure of organ harvest. Future myocardial preservation could include any of a variety of new formulations, administration routines and techniques that limit reperfusion damage. However, standardization and consistency of existing techniques for donor heart recovery is necessary before such new methods can be assessed in a meaningful way.

Although the method of cardiopreservation we use appears to be successful, there is no objective measure to compare this to other equally successful cardioplegia strategies. However, with closer attention to standardization of cardioplegia administration protocols for the donor heart such as we describe, hopefully a comparison can be made among donor cardioplegia strategies. When comparative, consistent methods for donor heart preservation become more widespread, further refinement and meaningful analysis of clinically utilized donor heart preservation strategies can follow.

References

1 Personal communication with United Network for Organ Sharing (UNOS), 2003.