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Bloodless Repair of Aortic Arch with Dual Aortic Cannulation in a Jehovah's Witness Patient

Melinda S. Valleley, CCP, MPS;* Kimberly R. Glogowski, CCP, MPS;* Kim F. Duncan, MD;† Andrea Dutoit, MD;‡ Corinna Hagedorn, CCP, MPS*

*The Departments of *Clinical Perfusion, †Cardiothoracic Surgery; and ‡Anesthesia, Children's Hospital and Medical Center, Omaha, Nebraska*

Abstract: Various methods for surgical repair of the aortic arch are described throughout the literature with many focused on cannulation techniques and degree of systemic cooling in an effort to reduce postoperative morbidities. Despite advancements in techniques, this surgery is still often associated with higher levels of blood loss and subsequent allogenic blood transfusions. Although blood products can be safely transfused to the majority of patients undergoing repair of the aortic arch, the complexity and risk is further multiplied when the patient is of Jehovah's Witness faith and refuses blood transfusions. This paper will detail our technique of surgical repair of the aortic arch in a Jehovah's Witness patient with dual aortic cannulation and our multidisciplinary approach to avoiding blood products.
Keywords: Jehovah's Witness, bloodless cardiac surgery, dual aortic cannulation, retrograde autologous prime. *J Extra Corpor Technol. 2017;49:206–209*

OVERVIEW

Surgical repair for aortic arch stenosis/hypoplasia has traditionally been performed using deep hypothermic circulatory arrest (DHCA). This method is used to provide a "safe" period for the cessation of circulation to the cerebral and somatic tissues, giving the surgeon time to achieve repair of the aortic arch. While this technique has been advantageous for a bloodless operative field in which to perform a difficult operation, it has not been without disadvantages. The process of DHCA requires substantial cardiopulmonary bypass (CPB) time in which to uniformly cool and subsequently rewarm the patient to normothermia. It is this process, along with the complex nature of the operation and the extended CPB time, which can cause significant derangements to the hemostatic system (1). In many patients, allogenic blood products can be safely transfused as needed to reverse coagulation abnormalities. However, in a Jehovah's Witness patient who refuses blood products due to their religious beliefs, this can make the surgical procedure significantly more complex. Although many institutions have safely and successfully adopted techniques to repair the aortic arch in the Jehovah's Witness population, none have described a dual aortic cannulation technique which avoids deep hypothermia. This paper will discuss a multidisciplinary approach that allows surgical revision of the aortic arch with mild hypothermia and continuous perfusion, obviating the need for blood products due to extreme cooling and prolonged bypass times.

DESCRIPTION

A 17-year-old, 57-kg Jehovah's Witness patient had been followed by our cardiology clinic for residual hypoplasia of the transverse aortic arch that included a modest arm–leg gradient. His past medical history included an end-to-end coarctation repair through a left thoracotomy in infancy. A mean gradient of 45 mmHg across the arch, along with an abnormal exercise study and magnetic resonance imaging, resulted in a recommendation for surgical revision given that the area did not appear suitable for stent placement (Figure 1). Several discussions were held between the medical specialties and the family in regard to his faith and the avoidance of blood product transfusion during surgery. Although there is a transfusion agreement at our institution to use blood products in the event of a life or death situation, all attempts are made to honor the

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Address correspondence to: Melinda S. Valleley, CCP, MPS, Department of Perfusion, Children's Hospital and Medical Center, 8200 Dodge Street, Omaha, NE 68114. E-mail: mvalleley@childrenshospital.org
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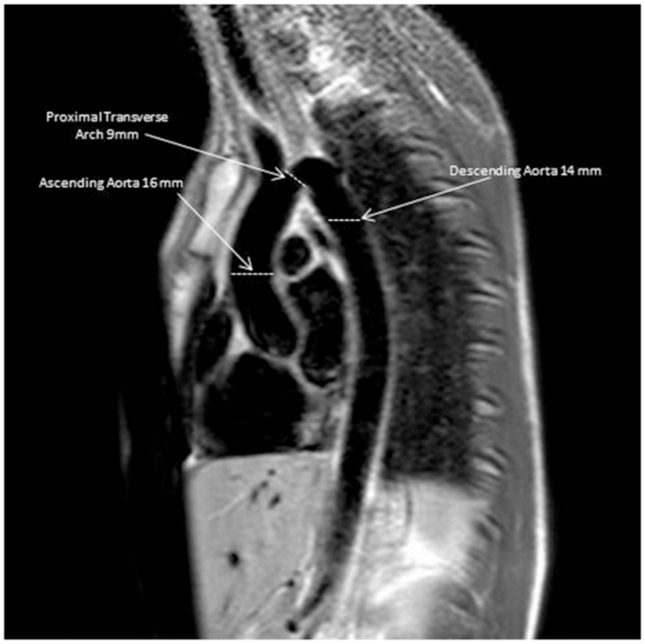

Figure 1. Magnetic resonance imaging of transverse arch.

patients' religious beliefs and avoid the use of any blood products. Given our current technique of repairing abnormalities of the aortic arch with dual aortic cannulation and mild hypothermic CPB in infants, it was felt this Jehovah's Witness patient would be a candidate for surgical repair at our institution (2).

Anesthesia, Perfusion, and Surgical Considerations

Our strategy was a multidisciplinary approach that allowed the safest method for repair of the aortic arch while avoiding the use of blood products. Anesthesia considerations included a narcotic-based anesthetic to minimize changes in systemic vascular resistance along with maintaining physiologic pH and mild hypothermia to limit perioperative fluid exposure. Patient monitoring included placement of the INVOS Cerebral/Somatic Oximeter (Medtronic, Minneapolis, MN) bilaterally on the forehead and on the left lower back for continuous monitoring of cerebral and renal oxygen saturations. Dual arterial lines were placed for monitoring of the upper/cerebral and lower/somatic systemic blood pressures. Cerebral pressures were monitored by placement of a right radial arterial line and somatic systemic blood pressures can be measured with either a femoral arterial line or, as in this case, a cardioplegia needle directly placed into the descending aorta at the time of cannulation.

Our current blood conservation technique does not include any preoperative measures to increase hemoglobin; however, intraoperatively 500 mL of autologous whole blood was withdrawn into a continuous closed circuit following central line placement. Minimal replacement crystalloid volume was needed during this as the patient remained hemodynamically stable, with the overall intraoperative crystalloid volume totaling 1,000 mL. This autologous blood was then used during modified ultrafiltration (MUF) and post-CPB for volume management. Dual antifibrinolytic therapy, per our standard CPB protocol, was dosed during surgery to limit blood loss related to fibrinolysis. A pre-CPB load of tranexamic acid was given to the patient (2,800 mg) and into the CPB prime (600 mg). During the operative procedure, tranexamic acid was dosed at 10 mg/kg/h. Once protamine reversal was achieved, a single dose of aminocaproic acid was given (5,000 mg). Following CPB, the patient's blood pressure was managed with sodium nitroprusside to limit post-anastomotic bleeding and was left intubated to control blood pressure fluctuations.

Perfusion technique for arch/dual cannulation consisted of our standard setup with no additional modifications to the CPB circuit. Our large pediatric/adult setup included a Terumo FX15 integrated oxygenator, 3/8 × 3/8 arterial-venous (AV) loop augmented with vacuum-assisted venous drainage, Terumo HCO5 hemoconcentrator, and Terumo Capiox cardioplegia system (Terumo Cardiovascular Group, Ann Arbor, MI). In addition, all tubing was X-Coated (Terumo Cardiovascular Group). The only required modification for CPB was to wye the arterial line for dual cannulation. This was accomplished at the surgical field and required placement of an additional connector and tubing to wye the arterial limb for the upper (innominate artery) and lower (descending thoracic aorta) cannulation. Prime volume consisted of 700 mL Plasmalyte-A, 50 mEq 8.4% $NaHCO_3$, and 5,000 IU of heparin. Following innominate arterial cannulation, retrograde autologous prime (RAP) was performed via our dual head cardioplegia system. By using our dual headed cardioplegia pump, we can RAP through our hemofilter to not only prime the entire circuit with the patient's own blood but to also remove any excess perioperative fluid administered. This technique resulted in a net prime volume of approximately 400 mL. Once the surgical repair was completed and the patient was separated from bypass, MUF was used to concentrate the residual circuit volume into the patient, rather than send it to the cell saver where coagulation factors are lost. Any residual volume in the bypass circuit was then chased with crystalloid to the cell saver where the blood was processed and transfused back to the patient via a continuous circuit.

Surgical strategy included a full sternotomy incision with mobilization of the ascending aorta along with the innominate, left carotid, and left subclavian arteries. Heparin was administered and followed by cannulation of the innominate artery with a 16 Fr. DLP arterial cannula (Medtronic). The right atrial appendage was then cannulated with a triple stage 29 Fr. venous cannula (Medtronic). The descending thoracic aorta was then exposed and also cannulated with a 16 Fr. DLP arterial cannula (Medtronic) and a 16 G DLP cardioplegia needle (Medtronic) for pressure monitoring (Figure 2). The arterial cannulae were then connected via the wyed arterial line.

Following RAP, CPB was initiated at approximately a 2.6–2.8 cardiac index. Cerebral perfusion was monitored with a right radial arterial line while somatic perfusion was monitored via a 16-G cardioplegia needle inserted in the descending aorta. Upper and lower body perfusion was balanced to keep the mean systemic blood pressure in both the radial and the descending aorta approximately 50–60 mmHg. The balance of systemic perfusion is accomplished by maintaining the same sized tubing, arterial perfusion cannula, and by adjustments at the surgical field with a partial tubing clamp to either the innominate or descending aortic tubing. A 16 Fr. vent (Medtronic) was placed into the dome of the left atrium into the left ventricle due to mild aortic insufficiency and a 16 G DLP cardioplegia needle was placed to provide continuous coronary perfusion, while balancing the flow from the left ventricular vent; allowing the heart to continue to beat throughout the repair. The proximal ascending aorta and the upper descending aorta were cross clamped and all head vessels were snared out. The patient was systemically cooled to 35°C. The aortic arch was then repaired and augmented inferiorly with a 16-mm Hemashield Dacron graft (W.L. Gore and Associates, Flagstaff, AZ) from approximately the upper third of the ascending aorta to the origin of the left subclavian.

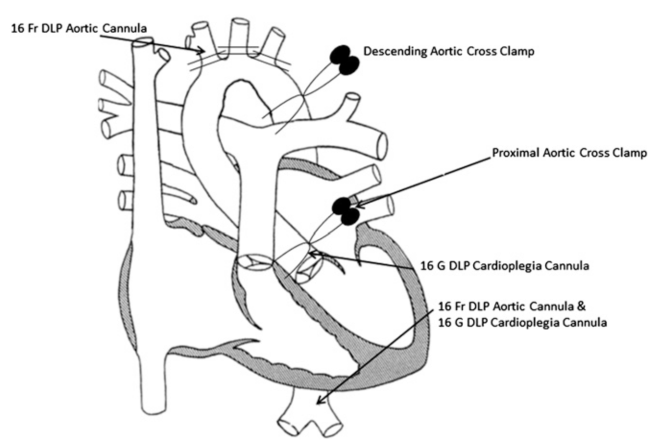

Figure 2. Dual aortic cannulation. Dual 16 Fr. DLP arterial cannula placed for cerebral (innominate artery) and somatic perfusion (descending thoracic aorta). 16 G DLP cardioplegia cannula used for monitoring somatic pressure in descending aorta. Second 16 G cardioplegia cannula added to proximal aorta for continuous coronary perfusion.

The head vessels were de-aired and both the proximal and descending aortic cross clamps were removed. Once the arch repair was completed, the descending aortic cannula was removed, allowing the innominate cannula to provide full CPB support. The patient was then weaned from CPB and MUF performed for approximately 15 minutes with a net volume of 800 mL removed. The total bypass time was 49 minutes with zero myocardial ischemic time and total operating room time of 365 minutes. The patient left the operating room with a hematocrit identical to his preoperative level of 39%, requiring no allogenic blood products to complete the operation. Postoperatively the patient remained intubated for blood pressure control, was extubated later that same day with no focal neurologic deficits, and discharged to home on postoperative day 3.

DISCUSSION

Although DHCA and selective cerebral perfusion (SCP) remain the most common techniques for repair of the aortic arch in neonates and adults, our institution has established an alternate technique that has obviated the need for systemic cooling and an interruption to somatic blood flow. Although we have used this technique frequently in our neonatal population for Norwood/arch reconstructions, our experience in the larger congenital adult population has been limited. However, given the need to avoid blood transfusions in this patient along with unnecessary systemic cooling and CPB times, we elected to perform his surgical repair at our institution utilizing this dual arterial cannulation technique.

Modifications for this technique are primarily surgical/cannulation related and do not require significant changes to perfusion setup. Important caveats include placing dual arterial patient lines for monitoring of both the upper and lower extremities. This can be accomplished with a right radial arterial line and either a femoral arterial line or an aortic root cannula directly placed in the descending aorta. Cannulation modifications are isolated to the arterial portion and venous cannulation remains unaffected. Initial arterial cannulation begins with the innominate artery and once this cannula placement is verified, descending aortic arterial cannulation can be accomplished. Communication is crucial during the operative period as there must be constant observation of the upper (radial) and lower systemic patient pressures (descending thoracic aorta) to maintain a balanced systemic flow. This is especially important once the distal aorta is clamped and the upper and lower circulations are "separated." In addition, the use of the INVOS Cerebral/Somatic Oximeter is helpful to monitor perfusion adequacy of both cerebral and systemic circulations and can be predictive of cannulation or flow/perfusion issues.

This technique of aortic arch repair with dual cannulation and minimal cooling has yielded several benefits. First, by avoiding aggressive cooling that is often associated with the traditional arch repair, we have significantly reduced our operative and CPB times as well as our overall need for blood product transfusion. The literature has well documented that extreme cooling for CPB procedures often results in a total derangement of the coagulation system that subsequently requires multiple transfusions to return hemostasis to normal (1). It is the transfusion of these blood products that can often lead to postoperative complications and is recognized that they can directly affect patient morbidities including intubation times, infection rates, and even overall hospital length of stay (3,4). Furthermore, the use of DHCA can be associated with cerebral dysfunction and injury especially for longer and more complex operations. As a result, many centers have abandoned DHCA in favor of SCP with a perfusate temperature between 20°C and 26°C. The primary advantage of this technique is the preservation of cerebral oxygenation and the reduction in neurologic complications that can be associated with the traditional technique of DHCA with retrograde cerebral perfusion (5). However, this technique is also not without potential complications and risk. Typical cannulation can involve a separate incision site for axillary cannulation and the potential need for a graft anastomosis for aortic cannula placement. Success is also contingent on perfusion pressures and flows, along with appropriate blood gas management (alpha-stat, pH-stat, or combination of both). Although many centers have had success with SCP at mild–moderate hypothermia, there have been concerns raised regarding the safe limits of ischemia for the spinal cord and viscera. Consequently, many have advocated the use of alternate perfusion strategies that provide lower body perfusion in an effort to improve protection of the spinal cord and preserve distal end organ function following surgery of the aortic arch (6–9).

We have found that by utilizing this dual cannulation technique, avoiding aggressive cooling, along with utilizing RAP and MUF, we have virtually eliminated the need for blood products during surgery of the aortic arch. While shorter CPB times and decreased hypothermia are key factors, one cannot disregard the impact of RAP and MUF. Several studies have shown these techniques to be effective and important adjuncts in decreasing autologous blood transfusions in cardiac surgery (10).

In conclusion, this technique is relatively new for our larger patient population and the specific benefits have yet to be studied in detail. However, we have found its application to be safe and pertinent in the avoidance of blood product transfusion for patients of Jehovah's Witness faith. This multidisciplinary approach to avoiding blood product transfusion and maximizing red cell recovery can result in a successful surgical technique that can be applied to all aortic arch revision patients regardless of size.

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