How-to-do-it

Surgical technique to avoid circulatory arrest and direct arch vessel cannulation during neonatal aortic arch reconstruction

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Abstract

Deep hypothermic circulatory arrest (DHCA) has been used routinely for surgery involving the aortic arch. Recently, techniques have been developed that avoid circulatory arrest and maintain low-flow cerebral perfusion (LFCP) in an attempt to avoid the potential neurological sequelae associated with DHCA. We describe a technique of LFCP that avoids circulatory arrest and direct cannulation of the arch vessels. Five patients underwent reconstruction of the aortic arch with concomitant biventricular intracardiac repair. The distal ascending aorta was cannulated and patients were systemically cooled. The cannula was advanced into the innominate artery and snared in place prior to opening and reconstructing the aorta with continuous LFCP. In all five patients, we completely avoided circulatory arrest and direct cannulation of the arch vessels. All patients survived and there were no adverse neurological outcomes.

Keywords: Aortic arch reconstruction; Circulatory arrest; Continuous low-flow cerebral perfusion

1. Introduction

Aortic arch reconstruction has traditionally required deep hypothermic circulatory arrest (DHCA). Because of the potential adverse consequences associated with its use [1], we and others have been exploring techniques of continuous low-flow cerebral perfusion (LFCP) as a means of avoiding circulatory arrest [2–8]. We describe our experience with aortic arch reconstruction using a technique for avoiding circulatory arrest that does not involve direct cannulation of the head vessels. This technique was evaluated in patients undergoing aortic arch reconstruction with concomitant intracardiac repairs.

2. Methods

This technique was performed in five patients undergoing surgery on the aortic arch between November 1999 and June 2000. The patients had a variety of intracardiac defects associated with aortic arch obstruction (Table 1).

2.1. Surgical technique

After median sternotomy and full heparinization, the right side of the distal ascending aorta was cannulated with a flexible 8F aortic cannula (Bio-Medicus, Medtronic, Minneapolis, MN) approximately 5 mm proximal to the takeoff of the innominate artery (Fig. 1a). Standard bicaval cannulation was performed for venous drainage. Following institution of cardiopulmonary bypass (CPB), the patent ductus arteriosus was ligated. During systemic cooling to 18°C, the ascending aorta was cross-clamped, cold crystalloid cardioplegia was infused into the aortic root to arrest the heart and the intracardiac defects were repaired. The aortic cannula was then advanced into the innominate artery and snared in place. The left subclavian and left common carotid arteries were snared and a vascular clamp was applied to the descending aorta following their mobilization. Low-flow cerebral perfusion was maintained at 0.4–0.8 l/min per m² via the innominate artery while the patient was under deep hypothermia (Fig. 1b). The undersurface of the distal ascending aorta was opened, and the incision was carried through the entire aortic arch and into the upper descending thoracic aorta. The dural tissue was excised. Removal of the clamp on the descending aorta or the snare on the left carotid artery during the period of LFCP resulted in brisk back-bleeding suggesting significant communication between the innominate and the left-sided head vessels as well as lower extremity vessels. The distal ascending aorta,
The aortic arch and proximal descending aorta were augmented with a pulmonary homograft patch and 6-0 Prolene running sutures (Fig. 1c). After de-airing the distal ascending aorta by removing the clamps on the distal descending aorta, the aortic cannula was pulled back from the innominate artery into the ascending aorta. The head vessels were unsnared and full CPB was reestablished. The patients were rewarmed and successfully weaned from CPB. LFCP was maintained for 30 ± 12 min at a nasopharyngeal temperature of 18.6 ± 0.9°C. The CPB time was 227 ± 103 min (range 133–404 min) and the aortic cross-clamp time was 115 ± 23 min (range 79–139 min). There was no circulatory arrest at any time.

3. Discussion

Surgery on the aortic arch has traditionally involved the use of DHCA. DHCA may be associated with adverse neurological outcomes [1] and in recent years surgeons have focused on decreasing the morbidity associated with aortic surgery and DHCA. A number of centers, including ours, have concentrated efforts to eliminate exposure of the neonate to circulatory arrest during complex reconstruction of the aortic arch. A variety of techniques have been described over the last 5 years.

Asou et al. [2] described a technique of selective cerebral perfusion during aortic arch repair in neonates. They perfused the innominate artery through an arterial cannula attached to the distal end of a modified Blalock–Taussig shunt (MBTS) while performing the Norwood operation in patients with hypoplastic left heart syndrome. Ishino et al. [5] used a similar technique to repair coarctation with ventricular septal defect. Pigula et al. [6] used a similar technique to repair coarctation with ventricular septal defect.
technique of regional low-flow perfusion during reconstruction of the aortic arch. They found that a flow of 20 ml/kg per min was adequate in restoring cerebral blood volume and oxygen saturation at 18°C. Our low-flow perfusion rates of 0.4–0.8 l/min per m² correspond to flows of 19–77 (mean 45) ml/kg per min, suggesting that cerebral perfusion is maintained by the current technique. McElhinney et al. [3] maintained continuous upper body perfusion during a modified Damus–Kaye–Stansel procedure by cannulating the innominate artery rather than perfusing via a MBTS. Imoto et al. [4] have used combined cannulation of the open proximal end of the MBTS and descending aorta through a sternotomy approach to perfuse both upper and lower body during aortic reconstruction. Tchervenkov et al. [7] have recently described a technique of continuous low-flow perfusion avoiding both direct shunt and arch vessel cannulation during the Norwood operation. It involves retrograde perfusion into the innominate artery via the pulmonary artery confluence and fully-constructed MBTS.

Using the current technique, we found early in our experience that a clamp on the descending aorta was necessary to prevent flooding of the field during arch reconstruction. Similarly, snares were necessary on the left carotid and subclavian arteries to prevent perfusing while perfusing via the innominate. These observations suggested significant collateral flow to both the lower body and the left upper body and head when low-flow perfusion was conducted in this fashion. Pigula et al. [8] have recently provided quantitative evidence supporting our subjective findings by demonstrating that regional low-flow perfusion via the innominate artery is capable of providing subdiaphragmatic circulatory support during neonatal aortic arch surgery.

Single-stage reconstruction of the aortic arch with biventricular repair of complex intracardiac defects can be accomplished consistently without the use of circulatory arrest or direct cannulation of the arch vessels. Our experience to date has not revealed any adverse neurological outcomes or deaths. Further long-term follow-up will be needed to assess in detail whether techniques for avoiding circulatory arrest are indeed associated with improved neurological outcomes.

References