Selective cerebral perfusion with aortic cannulation and short-term hypothermic circulatory arrest in aortic arch reconstruction

R Turkoz, B Saritas, E Ozker, C Vuran, U Yoruker, S Balci, D Altun and A Turkoz

Perfusion published online 17 July 2013
DOI: 10.1177/0267659113496581

The online version of this article can be found at:
http://prf.sagepub.com/content/early/2013/07/17/0267659113496581

Published by:
SAGE
http://www.sagepublications.com

Additional services and information for Perfusion can be found at:

Email Alerts: http://prf.sagepub.com/cgi/alerts
Subscriptions: http://prf.sagepub.com/subscriptions
Reprints: http://www.sagepub.com/journalsReprints.nav
Permissions: http://www.sagepub.com/journalsPermissions.nav

>> OnlineFirst Version of Record - Jul 17, 2013

What is This?
Selective cerebral perfusion with aortic cannulation and short-term hypothermic circulatory arrest in aortic arch reconstruction

R Turkoz, B Saritas, E Ozker, C Vuran, U Yoruker, S Balci, D Altun and A Turkoz

Abstract
Background: The deep hypothermic circulatory arrest (DHCA) technique has been used in aortic arch and isthmus hypoplasia for many years. However, with the demonstration of the deleterious effects of prolonged DHCA, selective cerebral perfusion (SCP) has started to be used in aortic arch repair. For SCP, perfusion via the innominate artery route is generally preferred (either direct innominate artery cannulation or re-routing of the cannula in the aorta is used). Herein, we describe our technique and the result of arch reconstruction in combination with selective cerebral and myocardial perfusion (SCMP) and short-term total circulatory arrest (TCA) (5-10 min) through ascending aortic cannulation.

Methods: Thirty-seven cases with aortic arch and isthmus hypoplasia accompanying cardiac defects were operated on with SCMP and short TCA in Baskent University Istanbul Research and Training Hospital between January 2007 and Sep 2012. There were 17 cases with ventricular septal defect (VSD)-coarctation with aortic arch hypoplasia (CoAAH), 4 cases of transposition of the great arteries-VSD-CoAAH, 4 cases of Taussing Bing Anomaly-CoAAH, 2 cases complete atroventricular canal defect-CoAAH, 3 cases single ventricle-CoAAH, 3 cases of type A interruption-VSD, 2 subvalvular aortic stenosis-CoAAH and 2 cases of isolated CoAAH. The aorta was cannulated in the middle of the ascending aorta in all cases. The cross-clamp was applied to the aortic arch distal to either the innominate artery or the left carotid artery. In addition, a side-biting clamp was applied to the descending aorta. The aorta between these two clamps was reconstructed with gluteraldehyde-treated autogeneous pericardium, using SCMP. The proximal arch and distal ascending aorta reconstructions were carried out under short TCA.

Results: The mean age of the patients was 2.5±2 months. The mean cardiopulmonary bypass and cross-clamp times were 144±58 and 43±27 minutes, respectively. The mean SCMP and descending aorta ischemia times were 22.6±4.8 and 27±6.3 minutes, respectively. Mean TCA time was 7.6±2.1 minutes (min: 4, max 10 min). The mean in-hospital stay time was 8.6±1.9 days. None of the cases operated with this technique had neurological defects. The mortality rate was 2.7% (1 patient).

Conclusion: SCMP with aortic cannulation and short TCA (under 10 minutes) in aortic reconstruction is safe and practical in this high-risk patient group.

Keywords
selective cerebral perfusion; hypothermic circulatory arrest; aortic arch; reconstruction; myocardial perfusion

Introduction
Traditionally, deep hypothermic circulatory arrest (DHCA) has been used until recently as the standard intraoperative technique to perform aortic arch reconstruction in neonates and infants. Recent clinical evidence has demonstrated that neurodevelopmental outcomes are adversely affected if the duration of circulatory arrest exceeds 41 minutes. Selective cerebral perfusion (SCP) first described by Asou and colleagues in...
Perfusion 0(0)

1996 as an alternative to DHCA, has recently started to be used as a perfusion method that could prevent the negative effects of DHCA in neonatal and infant arch reconstruction.² SCP is now used by surgeons with much greater frequency than it was 10 years ago.³ Most of the neonates and infants requiring aortic arch reconstruction have simple or complex intracardiac defects. Simple, safe, fast and effective arterial cannulation is advantageous in arch reconstruction accompanied by complex intracardiac repair. In this article, we describe our technique and the results of arch reconstruction in combination with selective cerebral and myocardial perfusion (SCMP) and short-term total circulatory arrest (TCA) (5-10 min) through ascending aortic cannulation.

**Materials and Methods**

Thirty-seven cases with aortic arch and isthmus hypoplasia accompanying other cardiac defects were operated on with SCMP and short TCA in Baskent University Istanbul Research and Training Hospital between January 2007 and Sep 2012. There were 17 cases with VSD-coarctation with aortic arch hypoplasia (CoAAH), 4 transposition of the great arteries-VSD-CoAAH, 4 Taussing Bing Anomaly-CoAAH, 2 complete atrioventricular canal defect-CoAAH, 3 single ventricle-CoAAH, 3 type A interruption-VSD, 2 subvalvular aortic stenosis-CoAAH and 2 isolated CoAAH. The technique was not used in patients who had hypoplastic left heart syndrome. Table 1 shows the demographic data and the patients’ aortic sizes.

**Regional Oxygen Saturation Monitoring:** Regional oxygen saturation was monitored with a FORE-SIGHT Cerebral Oximeter (CAS Medical Systems, Branford, CT, USA), which affords dual-site monitoring with a pediatric disposable sensor. The sensors were positioned bilaterally on the patient’s lower forehead and covered by an opaque plastic patch in order to prevent ambient light affecting the measurements. The data were collected and automatically converted to numerical values to be stored in an Excel spreadsheet from the onset of preoperative anesthesia induction to the end of the operation. An absolute value of 50% serves as an indication of potential hypoxic injury and warrants intervention.⁴

**Surgical Technique:** After a median sternotomy and harvesting of a piece of the pericardium, the proximal arcus aorta is dissected. The aorta is cannulated in the middle and right lateral side of the ascending aorta in all cases (Figure 1). Cardiopulmonary bypass (CPB) is instituted and the duc tus arteriosus is divided and sutured. During cooling to 24°C, the distal arch, its vessels and the upper descending aorta are mobilized as far distally as possible. The upper aortic intercostal arteries are usually clipped and divided. The cross-clamp is applied to the aortic arch distal to either the innominate artery or the left carotid artery. In addition, a small side-biting clamp (Castaneda clamp) is applied to the descending aorta. At 24°C, SCMP is initiated at a rate of 30-40 ml/kg/min, while the right radial artery pressure is measured to ensure adequate flow (between 30-45 mmHg). The undersurface of the aortic arch is incised, beginning at the divided ductus arteriosus, to the proximal aortic clamp. All ductal tissue is excised from the undersurface of the aortic arch. A distal descending aortic incision is extended 2 cm distally into the descending aorta. The aorta between these two clamps is reconstructed with gluteraldehyde-treated (30 min) autogeneous pericardium during SCMP. If augmentation involving the ascending aorta is required (proximal of the cross-clamp), short TCA is used after moving the clamp from the aortic arch to the proximal ascending aorta. The incision of the aortic arch is then extended proximally into the hypoplastic ascending aorta (approximately 2 cm) and the anastomosis is completed in a short time (less than 10 min). Following aortic reconstruction and de-airing, full-flow CPB is reinstated. A cross-clamp is applied to the ascending aorta and cardioplegia is applied for intracardiac repair. Myocardial protection is obtained by the infusion of cardioplegia.

| Table 1. Patients Demographics. |
|-------------------|------------------|
| Age (month)       | 2.5±2            |
| Weight (kg)       | 4±1.3            |
| Gender (male/female) | 22/15      |
| Aortic annulus, mean (mm) | 8.3±2.1    |
| Aortic annulus Z value, mean | -0.88±1.7 |

**Figure 1.** Arterial cannulas for cardiopulmonary bypass are inserted into the right side of the distal ascending aorta. Snare is placed around the proximal left subclavian and left carotid arteries. Cross-clamps are applied to the descending aorta and to the aortic arch distal to the innominate artery.
solution, using the antegrade minicardioplegia technique. Additional procedures are listed in Table 2. Ultrafiltration on bypass and modified ultrafiltration after bypass were used in all cases. Phentolamine infusion was routinely used during cardiopulmonary bypass. The described technique was used in all patients undergoing these procedures during the study period.

### Results

The demographic and aortic data for the patients are summarized in Table 1. The mean cardiopulmonary bypass and cross-clamp times were 144±58 and 43±27 minutes, respectively. The mean SCMP and descending aorta ischemia times were 22.6±4.8 and 27±6.3 minutes, respectively. Mean TCA time was 7.6±2.1 minutes. The extubation and the length of intensive care unit (ICU) stay times were 67±44 hours and 105±56 hours, respectively. The hospital length of stay time was 8.6±1.9 days.

### Discussion

Thirty-seven patients were operated on with ascending aorta cannulation by using SCP and short-term TCA. Deep hypothermia (<22°C) was avoided in all cases. All VSD-CoAAH patients without complex cardiac anomalies were extubated on the day of surgery or on the first morning following surgery. The cases who had prolonged extubation and ICU stay duration were the ones who had single ventricle physiology or complex cardiac anomalies. None of the cases operated on with this technique had neurological defects and needed cranial imaging.

Hypoplastic aortic arch has been found in 60-70% of infants undergoing coarctation repair. The management of a hypoplastic aortic arch is difficult through a left thoracotomy in patients with hypoplastic segment extending to proximal aortic arch and ascending aorta. Most of the neonates with coarctation (75-80%) also have ventricular septal defects or complex intracardiac anomalies. DHCA has been used for more than 4 decades in the surgical repair of complex cardiac diseases and aortic arch reconstruction. As an additional benefit, DHCA creates a bloodless operative field. On the other hand, DHCA has been associated with early and late neurodevelopmental morbidities. Another disadvantage of circulatory arrest is the prolongation of myocardial ischemia. Experimental studies also show that the cerebral tissue PO2 decreased to almost zero after 30 min of circulatory arrest and, after the onset of rewarming, a significant delay in normalization of cerebral tissue PO2 to baseline levels was observed. Recently, advances in multimodal brain monitoring techniques, namely, coupled electroencephalography (EEG), near-infrared spectroscopy (NIRS), visible light spectroscopy (VLS), transcranial Doppler ultrasound (TCD), as well as emboli detection and classification (EDAC) quantitation have come into clinical use in cases with limiting adverse neurological outcomes encountered during CPB and SCP.

By using the SCMP technique, CoAAH with concomitant cardiac defects can be repaired without a long duration of DHCA. It is reported that a variety of cannula positions can be used to achieve antegrade cerebral perfusion to the brain while performing aortic arch reconstruction. Usually, cannulation of the innominate...
artery, either through a polytetrafluoroethylene (PTFE) shunt or by a direct cannulation have been used in SCMP. Advancing the aortic cannula into the innominate artery is another technique of cannulation of the innominate artery, which was introduced by Tchervenkov for SCP.

PTFE graft anastomosis to the innominate artery for SCP adds additional procedural time and consumes extra energy in these cases which are already long and complex procedures. Direct cannulation of the innominate artery has been used in newborn and infant patients. However, the innominate artery sometimes may have a very small caliber. Consequently, direct cannulation of the innominate artery and managing the blood flow equally in two ways (proximally and distally) becomes technically very challenging. The method of advancing the aortic cannula into the innominate artery introduced by Tchervenkov necessitates additional manipulation of the cannula during CPB for re-routing the cannula to the innominate artery for SCP. Monitoring cerebral tissue oxygen saturation may provide real-time information about fluctuations in cerebral perfusion during operations. SCP flow rates in the studies vary from 20 to 94 ml/kg/min. In our clinical practice, 40-50 ml/kg/min flow has been used for SCP at 24-26°C. Our patient surgical records indicated that right and/or left cerebral tissue oxygen saturation levels had not fallen below 50% over a duration of 10 minutes during SCP in any of the patients. This outcome suggests to us that 40-50 ml/kg/min flow should be considered to provide an adequate level of brain protection.

Despite the theoretical advantage of SCP in providing cerebral blood flow, recent studies comparing neurodevelopmental outcomes at 1 year with DHCA versus SCP have revealed no differences. Inadequate flow SCP may actually be worse than DHCA as a longer time is required for SCP than DHCA in the same aortic arch reconstruction. To initiate DHCA, neonatal and infants are cooled to profound hypothermia before their total blood volume is emptied into the reservoir of the heart-lung machine. With the blood removed from the circulation, the surgeon can easily operate on the aortic arch in a bloodless surgical field without using aortic clamps or cannulas.

Recently, most surgeons have had a tendency to believe that deep hypothermic circulatory arrest is potentially more harmful than regional cerebral perfusion. The rate of regional cerebral perfusion use has increased more than twice that of deep hypothermic circulatory arrest in aortic arch reconstruction in the past few years.

Being a retrospective analysis, there are several limitations of this study. It covers a relatively small patient sample without a control group and so, its statistical analysis is limited. The series presented here also consists of an inhomogeneous patient selection and lacks precise neurological examination specific to neonates or infants. A thorough evaluation of the long-term effectiveness of our technique on the neurodevelopmental outcome, a prospectively randomized controlled study with precise neurological examination, is necessary. Nevertheless, our work clearly shows that SCP with aortic cannulation and short HCA is a safe method in aortic arch reconstruction and can be considered as a solid basis for future, more comprehensive studies.

In conclusion, SCMP with aortic cannulation and short HCA (under 10 minutes) for aortic reconstruction have been successfully used in 37 neonates and infants and has proven to be a safe method without neurologic complications during 34±19 months of follow-up. However, longer follow-up is required to assess the long-term outcomes of the technique.

Conflict of interest statement
The authors declare that there are no conflicts of interest.

Funding
This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

References


