REGIONAL PERFUSION OF THE BRAIN DURING NEONATAL AORTIC ARCH RECONSTRUCTION

Frank A. Pigula, MD, Ralph D. Siewers, MD, and Edwin M. Nemoto, PhD, *Pittsburgh, Pa*

Circulatory arrest is considered a prerequisite for aortic arch reconstruction in neonates. Extensive aortic reconstruction is most commonly performed in neonates undergoing the Norwood operation for hypoplastic left heart syndrome (HLHS). Given the extensive reconstruction required, circulatory arrest times approaching 60 minutes are not uncommon. We describe a technique of regional low-flow perfusion that drastically reduces circulatory arrest time during aortic arch reconstruction and present data documenting its effectiveness.

Clinical summary. A 3.4-kg newborn boy was noted to be dusky shortly after birth, with oxygen saturations of 80% to 85%. A heart murmur was noted, and echocardiographic evaluation revealed HLHS with mitral and aortic atresia and a 2-mm ascending aorta. On transfer to the neonatal intensive care unit, he required alprostadil (prostaglandin E_1), intubation, and hypoxic gas mixture to maintain systemic oxygen saturations of 75% to 85%. He was taken to the operating room on day 5 after birth.

A Norwood operation was performed with minor modifications. Arterial blood pressure was monitored by a left radial artery catheter, and arterial blood gas management used the α -stat technique. Cerebral oxygen saturation and relative cerebral blood volume were obtained with near-infrared spectroscopy (NIRS, INVOS 4100; Somanetics Corp, Troy, Mich).¹ On initiation of cardiopulmonary bypass via the patent ductus through the main pulmonary artery and the right atrial appendage, the patient was cooled to 18°C. The ductus was snared around the arterial cannula; the main pulmonary artery was transected, and the bifurcation was patched with homograft material. The innominate artery was controlled at its bifurcation and a 3.5-mm polytetrafluoroethylene* tube graft was anastomosed end to side for inflow into the anticipated modified Blalock-Taussig shunt. This graft was left long and clamped, and the descending aorta was mobilized well past the ductal insertion and the site of coarctation.

Cardiopulmonary bypass was halted; the brachiocephalic vessels were snared, and the patient was exsanguinated into the reservoir. The arterial and venous cannulas were removed,

and the atrial septectomy was performed through the atrial appendage. The left radial mean blood pressure was 0 mm Hg.

At this time, the arterial cannula (10F; Medtronic Bio-Medicus, Eden Prairie, Minn) was inserted into the shunt and tied into position after careful deairing. While the right common carotid artery was temporarily occluded to prevent air embolism, perfusion was initiated 5 mL/kg/min and was increased every 2 to 3 minutes until cerebral blood volume approached baseline, reaching a final rate of 60 mL/min (Fig 1). A small metal-tipped "bullet" sucker placed through the right atrial appendage scavenged blood returning to the heart. The remainder of the arch reconstruction was performed under regional low-flow bypass conditions, during which time the left radial arterial line measured a mean arterial blood pressure of 20 mm Hg. A bloodless operative field was maintained by the brachiocephalic vessel snares, the right atrial blood scavenger, and a small angled crossclamp on the descending thoracic aorta. This distal aortic clamp accomplishes 2 goals. By elevating the distal-most portion of the aorta to be reconstructed, visualization and access are improved, and back bleeding from the descending aorta is prevented.

On completion of the arch reconstruction, the neo-aorta and right atrial appendage were recannulated, and full bypass was resumed. The patient was weaned from cardiopulmonary bypass with the aid of a 5 μ g/kg/min dose of dopamine, stable hemodynamics, and systemic oxygen saturations of 75% to 85%. Total time between cessation and resumption of full bypass was 58 minutes. Total circulatory arrest time was 11 minutes (for atrial septectomy, decannulations, and recannulations), and total low-flow bypass time was 47 minutes. The infant recovered uneventfully and was discharged on postoperative day 13.

Comment. With the acceptance of the Norwood operation for the palliation of HLHS, the use of circulatory arrest has become commonplace in neonatal heart operations. However, the effect of circulatory arrest on the neonate brain has been shown to be damaging, and many efforts to protect and preserve the brain during this period are used.^{2,3} This technique may replace these efforts by allowing arch reconstruction to be performed under low-flow conditions. Although Asou and colleagues⁴ described a similar technique, they provided no data to support the contention that the brain was sustained. Our NIRS data demonstrate the perfusion of the brain with physiologic blood flow, based on cerebral oxygen saturation and relative blood volume data.

Although the appropriate perfusion rate and pressure for the neonatal brain under hypothermic conditions remains unknown, our data (using relative cerebral blood volume and delivered by this technique) would suggest that flow rates of 15 to 20 mL/kg/min are satisfactory. Also, cerebral blood vol-

From the Department of Cardiothoracic Surgery, Children's Hospital of Pittsburgh, University of Pittsburgh, Pittsburgh, Pa.

Received for publication Dec 1, 1998; accepted for publication Dec 9, 1998.

Address for reprints: Frank A. Pigula, MD, Cardiothoracic Surgery, Room 2820, 2nd Floor, Main Tower, Children's Hospital of Pittsburgh, Pittsburgh, PA 15213.

J Thorac Cardiovasc Surg 1999;117:1023-4

Copyright © 1999 by Mosby, Inc.

0022-5223/99 \$8.00 + 0 12/54/96404

*W. L. Gore & Associates, Inc, Newark, Del.

Fig 1. Regional cerebral oxyhemoglobin saturation (*RCrSO₂*, top line) and relative cerebral blood volume index (*RCBVI*, bottom line) during a Norwood procedure in a 3.4-kg neonate. Both oxyhemoglobin saturations and relative cerebral blood volumes approach baseline with incremental increases (40 mL, 50 mL, 60 mL) of regional low-flow perfusion of blood delivered via the anticipated modified Blalock-Taussig shunt during aortic arch reconstruction. *CER PERF*, Cerebral perfusion; *CIRC*, circulatory; *CPB*, cardiopulmonary bypass.

ume data suggest that we are not over circulating the brain, risking cerebral hyperperfusion.

A mean arterial blood pressure of 20 mm Hg in the left radial artery while the right common carotid and right subclavian artery are being perfused supports the speculation that the neonate possesses a significant network of arterial collaterals. This is apparent clinically by the low incidence of paraplegia encountered in neonatal coarctation repair. These collaterals include not only intracranial connections via the circle of Willis but also extracranial collaterals, vertebral arteries, internal thoracic arteries, and intercostal arteries. We speculate that the brain, a relatively low resistance organ, receives most of the regional perfusion. This perfusion sustains the brain during arch reconstruction, as evidenced by our NIRS data. Furthermore, significant backbleeding from the descending thoracic aorta implies that some somatic perfusion is being supplied via the collateral network. Thus our initial experience leads us to recommend this technique to

minimize circulatory arrest time during neonatal aortic arch reconstruction.

REFERENCES

1. Cho H, Nemoto EM, Yonas H, Balzer J, Sclabassi RJ. Cerebral monitoring by means of oximetry and somatosensory evoked potentials during carotid endarterectomy. *J Neurosurg* 1998;89: 533-8.
2. Newburger JW, Jonas RA, Wernovsky G, et al. A comparison of the perioperative neurologic effects of hypothermic circulatory arrest versus low flow cardiopulmonary bypass in infant heart surgery. *N Engl J Med* 1993;329:1057-64.
3. Howe R. Appendix 1: Perfusion protocols and equipment. In: Jonas RA, Elliot MJ, editors. *Cardiopulmonary bypass in neonates, infants, and young children*. 1st ed. Oxford, England: Butterworth-Heinemann; 1994. p. 297-300.
4. Asou T, Kado H, Imoto Y, et al. Selective cerebral perfusion technique during aortic arch repair in neonates. *Ann Thorac Surg* 1996;1:546-8.