Selective Cerebral Perfusion Technique During Aortic Arch Repair in Neonates

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We describe selective cerebral perfusion techniques for repair of the aortic arch in neonates. These techniques may help protect the brain from ischemic injury caused by a cessation of cerebral perfusion for aortic arch reconstruction in patients with hypoplastic left heart syndrome or interrupted aortic arch.

(Ann Thorac Surg 1996;61:1546–8)

Although hypothermic circulatory arrest has been a widely used procedure for the surgical repair of arch anomalies in neonates and infants, it has been suggested that this procedure sometimes produces neurologic injury [1]. Because the long-term outcomes of cerebral function such as intellectual function and development after hypothermic circulatory arrest still remain to be determined [2], it seems worthwhile to protect the brain from ischemic injury as much as possible in neonatal open heart operations. We herein present some selective cerebral perfusion techniques in which the cerebral blood flow can be better maintained during the reconstruction of the aortic arch in the Norwood operation for neonates with hypoplastic left heart syndrome.

Techniques

Technique 1

Cardiopulmonary bypass is commenced by inserting an arterial cannula into the main pulmonary artery and snaring both pulmonary arteries. A right atrial cannula is used for venous drainage. During cooling a 4-mm polytetrafluoroethylene graft is anastomosed to the innominate artery and then is connected to the arterial infusion circuit of cardiopulmonary bypass with a Y-shaped connector (Fig 1). When the patient reaches a rectal temperature of 22°C the arterial cannula to the main pulmonary artery is clamped and removed. The innominate artery just proximal to the graft is then also clamped to direct perfusion to the brain. The brain is perfused at the rate of 50 $mL \cdot kg^{-1} \cdot min^{-1}$ through the polytetrafluoroethylene graft. The arterial pressure is monitored in the left temporal artery. After arch reconstruction with an equine pericardial roll, the roll is clamped at its proximal end with both the innominate artery and the descending aorta unclamped. The perfusion rate returns to 150 $mL \cdot kg^{-1} \cdot min^{-1}$ to perfuse the upper and the lower part of the body via the graft of the innominate artery. The pericardial roll is anastomosed to the proximal end of the main pulmonary artery conjoined with the ascending aorta to create a systemic outflow tract. After the atrial septal defect is enlarged, another arterial cannula is then inserted into the pericardial roll to perfuse the whole body while the cannula inserted into the polytetrafluoroethylene graft is removed. Finally, the graft is trimmed and anastomosed to the pulmonary artery as a systemic–pulmonary arterial shunt.

Technique 2

Another source of cerebral perfusion during aortic arch reconstruction in neonates is a specially designed thin-walled, metal-tipped arterial cannula (Japan Medical Supply Co, Ltd, Hiroshima, Japan) (Fig 2). Its external diameter is 2.1 mm and its internal diameter is 1.7 mm. A water test showed that it could deliver water at the rate of 500 mL/min with a pressure loss of less than 100 mm Hg. The line pressure in the circuit has never exceeded 300 mm Hg in any case at a maximum flow rate of 458 ± 61 mL/min when this cannula was used for systemic perfusion in 36 neonates and infants less than 3 kg of body weight in our institute. It is inserted into the innominate artery to perfuse the brain during aortic arch reconstruction in cases where the ascending aorta is large enough to be used as a systemic–pulmonary arterial shunt (Fig 3). Because it is flexible and light, it does not cause any excessive tension on the innominate artery, which thus facilitates perfusion of the brain and arch reconstruction. Using this method aortic arch reconstruction can be accomplished without any cessation of the blood supply to both the brain and the myocardium by clamping the aortic arch just distal to the innominate artery. After cardioplegic arrest the ascending aorta is then amputated 1 cm above the aortic commissure. The proximal end of the main pulmonary artery is conjoined with the proximal end of the ascending aorta and is anastomosed to the pericardial roll the same as in technique 1. Finally, the distal end of the ascending aorta is anastomosed to the pulmonary artery to create a systemic–pulmonary shunt.

Accepted for publication Dec 16, 1995.

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0003-4975/96/$15.00
PII S0003-4975(96)00020-3

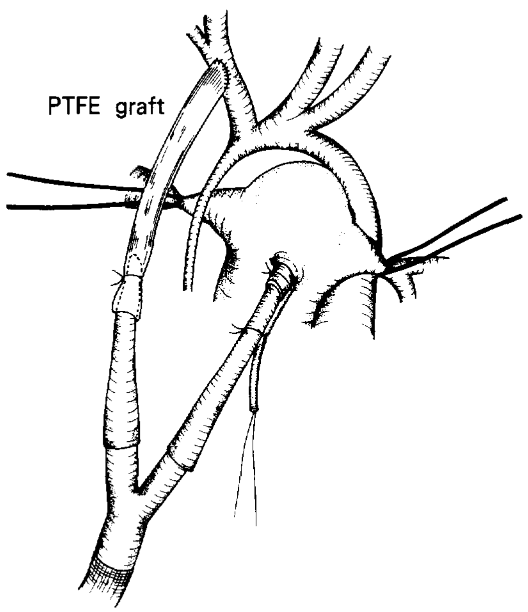

Fig 1. A polytetrafluoroethylene (PTFE) graft is anastomosed to the innominate artery and the brain is perfused through it.

Comment

Postoperative cerebral damage has been one of the major concerns in neonates and infants who have required hypothermic circulatory arrest for operation. We have developed two selective cerebral perfusion techniques to repair the aortic arch in patients with hypoplastic left heart syndrome without interfering with the cerebral blood flow. We used two different ways to perfuse the brain through the innominate artery during arch repair. First, a polytetrafluoroethylene tube graft was used, which served as a systemic–pulmonary shunt after weaning from the bypass. Second, we inserted a specially designed thin-walled, metal-tipped aortic cannula, which we have routinely used for systemic perfusion in open heart operations for patients who weigh less than 3.0 kg. We consider that the selective cerebral perfusion techniques presented herein may protect the brain from ischemic injury caused by cessation of cerebral perfusion in neonates with hypoplastic left heart syndrome. These techniques may also be useful for repairing the interrupted aortic arch [3]. We have applied the present technique in 8 neonates with hypoplastic left heart syndrome, with 5 survivors, and in 6 with interrupted aortic arch with no mortality.

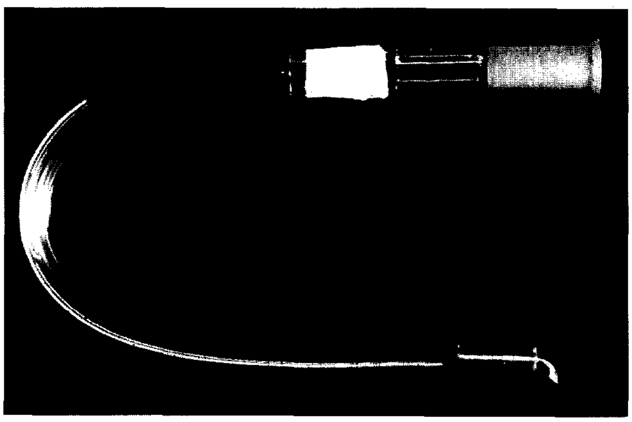

Fig 2. Specially designed thin-walled arterial cannula. Its external diameter is 2.1 mm and its internal diameter is 1.7 mm. It is flexible and light so as not to cause any excessive tension on the innominate artery.

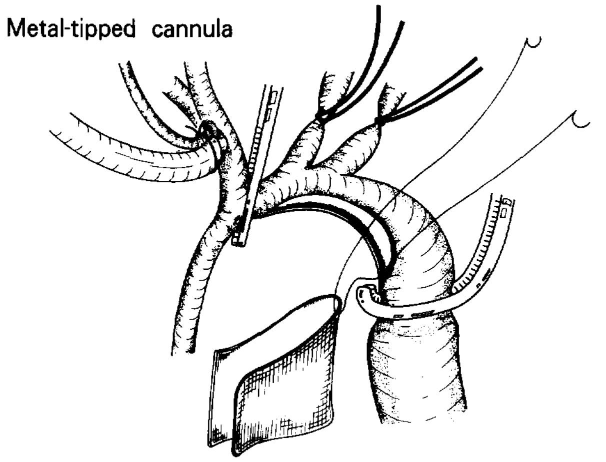

Fig 3. A thin-walled, metal-tipped arterial cannula is inserted into the innominate artery for cerebral perfusion. With a clamp placed on the aortic arch just distal to the innominate artery, both the brain and the myocardium are perfused during the reconstruction of the aortic arch.

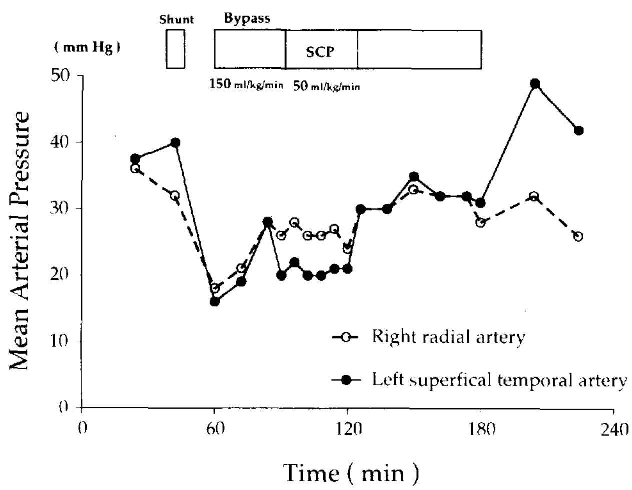

Fig 4. Mean arterial pressures were monitored on the right radial artery and the left superficial temporal artery during Norwood operation in a patient with hypoplastic left heart syndrome. The gradient between the pressures was only 8 mm Hg during selective cerebral perfusion. On the other hand, a significant difference in arterial pressure between them was found while clamping the innominate artery to anastomose the graft and after weaning from bypass. Especially, they were widely separated after commencement of the aortopulmonary shunt flow. (SCP = selective cerebral perfusion.)

The appropriate perfusion rate for the brain in the neonate during selective cerebral perfusion is still controversial. As shown in Figure 4, we measured arterial pressures of the right radial artery and the left superficial temporal artery during Norwood operation (technique 1) in a patient with hypoplastic left heart syndrome. During selective cerebral perfusion at the flow rate of 50 $mL \cdot kg^{-1} \cdot min^{-1}$ the right radial arterial pressure was around 28 mm Hg and the left temporal pressure was 20 mm Hg, with a pressure difference of only 8 mm Hg between them. This may show the existence of reasonable communication between the right and left hemispheres of the brain via the circle of Willis. The right radial arterial pressure during selective cerebral perfusion was even lower than that just before and after selective cerebral perfusion. Consequently, the flow rate (50 $mL \cdot kg^{-1} \cdot min^{-1}$) that we have selected during selective cerebral perfusion in the neonate may not be excessive, although it is much higher than that used in the adult. In the neonate the brain represents about one-seventh to one-tenth of the body weight, whereas it represents one-fiftieth of the total body weight of the adult [4]. Because of the remarkable difference in the ratio of the brain to the total body weight between the neonate and the adult, the optimal cerebral flow rate during selective cerebral perfusion in the neonate must differ from and could be much higher than that of the adult.

A remarkable difference between right radial and left superficial temporal arterial pressures was found after weaning from bypass as shown in Figure 4. Accordingly, arterial pressure measurement of the ipsilateral side of aortopulmonary shunt should not be reliable as an index of systemic perfusion after coming off bypass because of the pressure gradient in the innominate artery between the graft and the aorta attributable to the increase in blood flow of the innominate artery. Therefore, in the present technique we monitored the cerebral arterial pressure contralateral to the perfusion site.

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