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Left heart bypass in the surgery of aortic coarctation in children

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ABSTRACT Of 47 children over the age of 1 year who underwent repair of aortic coarctation during 1978–85, 22 had the operation performed with left heart bypass because the distal aortic pressure was below 50 mm Hg after the initial application of the arterial clamps. One further child had an elective left heart bypass. Satisfactory distal perfusion was achieved in all 23 patients. There were no deaths related to the use of left heart bypass but three complications occurred. One child had a mild transient hemiparesis on the ninth postoperative day and two had a pericardial effusion.

Introduction

Spinal cord injury is a major complication of surgery on the descending thoracic aorta. Three children undergoing surgery for coarctation at the Birmingham Children's Hospital before the use of left heart bypass suffered spinal cord injuries, two remaining paraplegic and one making an almost complete recovery.[1] Previous work suggested that after clamping of the aorta a mean distal aortic perfusion pressure of less than 50 mm Hg may predispose to spinal cord injury.[2] We therefore adopted the use of left heart bypass in children whose mean distal aortic pressure was less than 50 mm Hg when the aortic clamps were applied in an effort to avoid these and other reported complications.[2,3] There were no other alterations in our surgical technique or anaesthetic management to increase the distal perfusion pressure. We report the use of partial left heart bypass in 23 children undergoing surgery of the thoracic aorta by one surgeon at the Birmingham Children's Hospital.

Patients and methods

PATIENTS

From 1978 to 1985 surgery for coarctation of the aorta was carried out on 110 patients—63 infants and 47 children over 1 year of age. Of the 47 children, 22 had a mean distal perfusion pressure on trial cross clamping of below 50 mm Hg (range 25–48, mean 36 mm Hg) and therefore had left heart bypass performed. Thirteen children underwent a primary repair for coarctation (eight boys, five girls; mean age 7 years) and nine had a reoperation for recurrent coarctation (six boys, three girls; mean age 9 years). One child, with an aneurysm at the site of a coarctation previously repaired with pericardium at the age of 12 days, had an elective left heart bypass.

OPERATIVE TECHNIQUE

All patients had continuous intraoperative monitoring of arterial blood pressure in the right radial artery and in either a femoral artery or the thoracic aorta. A posterolateral thoracotomy was performed and the pleura over the mediastinum incised to display the coarctation. The aorta was mobilised above and below the coarctation to allow the application of arterial clamps. If after application of the cross clamps to the left subclavian artery and the aorta above and below the operation site the distal perfusion fell below 50 mm Hg, the clamps were removed while the bypass equipment was assembled and primed. The patient was given 3 mg/kg heparin for anticoagulation. A pursestring suture was inserted into the descending aorta (femoral artery in the first six patients), the pericardium opened, and a second pursestring suture inserted into the left atrial appendage. After division of the bypass loop the arterial cannula was inserted. The left atrial cannula was then inserted, with positive pressure kept on the lungs to prevent the introduction of air into the left side of the heart. The patient was put on partial bypass at a flow calculated to be half the normal resting cardiac output of 2·6 l/m^2 a minute. Oxygenated blood from the left atrium was drained to a reservoir and returned under pressure via a roller pump into the distal thoracic aorta or femoral artery (figure). After completion of the repair the distal aortic clamp was removed first and if haemostasis was

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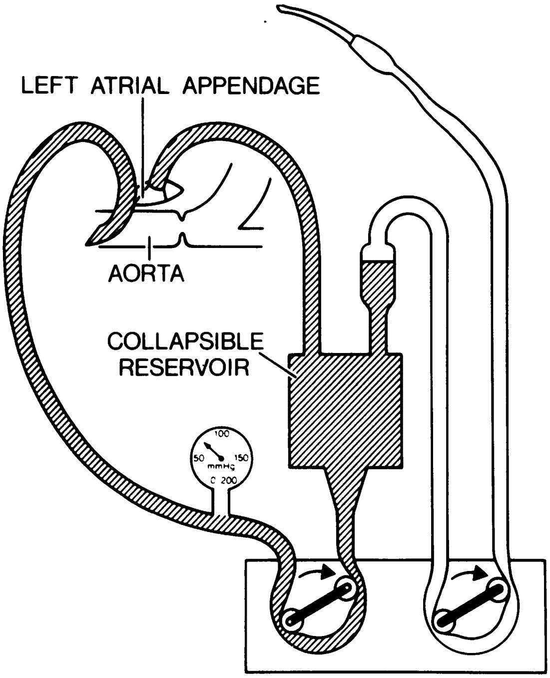

Circuit diagram for left heart bypass in the surgery of coarctation.

adequate the proximal aortic and subclavian clamps were removed. Bypass was then discontinued and the cannulas were removed, care again being taken not to introduce air into the left atrium. The heparin was reversed with protamine sulphate as calculated by Hepcon. The perfusionist had no difficulty in maintaining distal pressure (range 55–85 mm Hg, mean 68 mm Hg) and balancing the proximal blood pressure during heart bypass.

Eighteen of the repairs were carried out with preclotted Dacron patches and two with Dacron straight grafts. Two resections were performed with end to end anastomoses. The child with an aneurysm at the site of his previous coarctation had a Microvel straight graft.

Results

The mean age of the 23 children was 7 years 8 months (range 2–15 years). There were 15 boys and eight girls. Two of the girls had Turner's syndrome. Only two of the chidren had rib notching on the chest radiograph.

The total bypass time ranged from 18 to 79 minutes with a mean of 35 minutes. Haemorrhage during surgery was a problem in one child who was hypertensive before operation. He bled from his left subclavian artery at the insertion of the patch because the artery split; this was eventually dealt with by doubly ligating the artery at this point and there were no postoperative problems. Postoperatively the volumes aspirated by chest drain ranged from 60 to 455 (mean 186) ml.

There was one neurological complication. A 5 year old girl was readmitted on the ninth postoperative day with a mild left hemiparesis, which fully resolved spontaneously; she may have had a small embolus related to her left atriotomy. A 15 year old girl had a pericardial effusion (150 ml) drained postoperatively. The boy with the aneurysm also developed a small pericardial effusion, which resolved spontaneously.

Postoperative hypertension occurred in seven children and was treated briefly with labetolol. Four children required longer term treatment with atenolol or propranolol; in three of these treatment was stopped after six weeks but the fourth child was referred to a different centre for treatment of renal artery stenosis.

Since 1985 a further 15 left heart bypasses, 14 for coarctation and one for an interrupted aortic arch, have been performed. There have been no further neurological injuries and no major complications.

Discussion

The mechanism of cord injury in repair of coarctation is not proved. Recent work has shown that in the pig, which is similar to man in its spinal cord blood supply, doubly cross clamping the thoracic aorta produced a steal syndrome from the spinal artery, blood flowing to the lower body down the spinal artery at the expense of the spinal cord.[4]

Surgery on the thoracic aorta without spinal cord protection for traumatic rupture of the aorta or thoracic aneurysm is associated with cord ischaemia in up to 24% of patients.[3] The child with coarctation, however, usually develops a good collateral circulation. This acts as a protective mechanism at the time of surgery in most but not all of these children. Because of this the incidence of cord damage in surgery for aortic coarctation is in the region of 0·3–1·5%.[5-7] It is rare, although it has been reported, below the age of 1 year.[8,9] In later childhood it is more common, with a maximal incidence of 4% in the 11–16 age group.[7] It has been reported after only 15 minutes' aortic occlusion,[9] so that even with the quickest anastomotic techniques the patient may be at risk. Many series report a mean cross clamp time longer than this.[6,7,10] There is no evidence that the number of intercostal vessels ligated affects the incidence of paraplegia, perhaps because the flow in these vessels is reversed in coarctation.[6,11] Most authors believe that paraplegia is caused by ischaemic damage to the cord secondary to poor distal perfusion during the period of aortic occlusion at the time of surgery. Hyperthermia is a possible exacerbating factor, cord ischaemia becoming critical owing to the higher metabolic rate and oxygen requirement of neural tissue with low perfusion.[8] Distal perfusion pressure is usually lower when it is also necessary to clamp the left subclavian artery.[11]

The use of shunts, left heart bypass, and hypothermia have been shown to protect the spinal cord during other types of surgery on the descending aorta. The use of vasoconstricting drugs (metaraminol) has also been suggested.[11] Because the incidence of spinal cord injury is low the benefit of these techniques during surgery of aortic coarctation is still not proved. They should be used only if they can be shown to add little or no risk.

The serial recording of somatosensory evoked potentials is reported to be a relatively accurate predictor of spinal cord damage, showing early changes in spinal cord function at a stage when the damage is reversible.[10-13] Its widespread use should help to decrease the incidence of spinal cord damage. Unless, however, the surgeon is prepared to use a technique to increase distal aortic perfusion and by inference spinal cord perfusion, early evidence of damage from evoked potentials will merely encourage the surgeon to complete his anastomosis quickly or become simply a predictor of permanent damage.

Left heart bypass to protect the spinal cord in patients undergoing operations on the thoracic aorta was first described in 1957 by Cooley[14] and Gerbode.[15] They reported additional benefits from decompressing the left ventricle and minimising proximal hypertension. Moreover, because the position of the lower cross clamp in patients with coarctation is above T9, the level of the usual aortic origin of the artery of Adamkiewitz, the danger of spinal cord injury should be minimised. Anatomical variations of the artery of Adamkiewitz occur, however, and have been proposed as an important additional risk factor in patients undergoing thoracic aortic surgery,[6] and this technique may not protect against paraplegia if the origin of the artery is excluded by the positioning of the arterial clamps. The use of somatosensory evoked potentials may identify patients with left heart bypass who are at risk so that the cross clamps may be repositioned or the anastomosis fashioned more rapidly. There have been few reports of the use of left heart bypass in children.[16]

The incidence of paraplegia after reoperation is thought to be higher than after primary repair and distal cord protection may be more important in this group.[6 16] Surgery to the descending thoracic aorta not related to coarctation is rare in children, but in traumatic rupture spinal cord protection should be considered.

Experience at the Birmingham Children's Hospital has shown that left heart bypass is not without morbidity, two episodes of pericardial effusions and one episode of transient mild hemiplegia following left heart bypass in 23 children. In a child with haemorrhage from the subclavian artery, not related to the bypass, it allowed blood to be saved and retransfused, and proximal hypertension at the time of bypass was felt to be less of a problem in these children than in those who did not have bypass.

Morbidity has been reported with other temporary shunting techniques, such as haemorrhage from the left ventricle in transventricular shunts and bleeding from the proximal aortic insertion site in the aortic arch to descending aortic shunts.[17] These shunts have the advantage of being heparin lined and so not requiring full anticoagulation. Permanent shunting using a prosthetic bypass graft inserted with side biting clamps has been suggested as a technique to avoid prolonged cross clamping of the aorta, though we have no experience of the technique. It would ensure perfusion of the distal aorta throughout surgery and its use would be appropriate if no other technique were available to ensure distal perfusion in a patient found to have a low distal perfusion pressure after trial cross clamping. The long term problem of patency and the possibility that further surgery will be required if the child outgrows the graft together with increased difficulty if reoperation is necessary may limit its potential. Left heart bypass has the advantage of collecting blood from a low pressure system. A smaller distal aortic cannula can be used than with a shunt and any substantial haemorrhage is more easily dealt with because the reservoir is full of blood and a sucker can collect and recirculate any blood lost. During bypass there is a tendency for the core temperature to fall, acting as a further method of cord protection. The advantage over the use of topical hypothermia is that half of our children do not require a shunt, and theatre time can be saved by not cooling and rewarming a child unnecessarily. There also remains the slight risk of ventricular fibrillation at low temperatures.

Keen, in Bristol, reported the responses to a questionnaire sent to surgeons in Great Britain and Ireland, and found that over half now measured distal aortic pressures during surgery to the descending aorta.[5] He suggested that in the future a surgeon might be open to litigation if he failed to measure distal perfusion pressure or to monitor spinal cord function by somatosensory evoked potentials and provide distal aortic shunting or bypass for "at risk" patients. We have sympathy with this view and indeed this is our standard practice. All methods of shunting or bypass, however, have their own morbidity and the morbidity and mortality in a shunt-bypass group and an unprotected group have not been compared formally. It must therefore still be left to the individual surgeon to determine his own policy. A large multicentre trial would be required to show benefit when the reported incidence of paraplegia is 0·3–1·5%[5–7] and it could still be inconclusive.

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