

Surgical treatment of isolated coarctation of the aorta: 18 years' experience

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ABSTRACT From March 1967 to February 1985 91 patients aged from 11 months to 53 years underwent surgical treatment of isolated coarctation of the aorta. The surgical procedures in descending order of frequency, were: resection with end to end anastomosis, resection with replacement by a tube graft, patch aortoplasty, and bypass graft. Resection with end to end anastomosis was achieved mainly in younger patients. The number of patients needing other procedures increased with advancing age. Eighty six patients have been followed up (mean 10 years). There were no hospital or late deaths and none of the patients suffered from spinal cord injury. There were three recurrences of the coarctation, all in patients who had had primary reconstruction below the age of one year. The patients were divided into three groups by age: group 1, 0-5 years; group 2, 6-15 years; and group 3, over 15 years. It was found that there was no late hypertension in group 1 while hypertension persisted in 7% of group 2 and in 28% of group 3. Fifty per cent of the patients with persistent hypertension were above the age of 20 years at the time of operation and had resection with replacement by a tube graft. It is recommended that elective surgery for coarctation of the aorta should be performed at the age of 3-5 years to avoid both recurrence of stenosis and persistent hypertension.

Coarctation of the aorta was first described by Morgagni in 1760¹ but was not surgically corrected until 1945, when resection with end to end anastomosis was achieved.^{2,3} Since that time several other procedures have been described⁴⁻⁹ and surgical correction is now established as the treatment of choice. While there is general agreement about the necessity for urgent operation in coarctation with heart failure,¹⁰ or with severe upper limb hypertension, controversy still exists regarding the optimal age for treatment of the relatively symptom free patient.

This study describes the outcome in 91 patients who underwent corrective surgery for isolated coarctation of the aorta in the course of 18 years, with a mean follow up of 10 years after operation. The purpose of the study was to determine the frequency of raised systemic blood pressure after operation and to study its relationship with age at operation and the type of operation performed.

Methods

PATIENTS

From March 1967 to February 1985 91 patients were admitted under the care of one surgeon (AB) for surgical treatment of isolated coarctation of the aorta at the Shotley Bridge General and Freeman Hospitals. Ninety one patients (36 female and 55 male) underwent 93 operations; two patients each had two operations, and another, who had had primary correction at the age of 11 months at another centre, was re-operated in our unit when he was 18 years old.

The indication for operation was the presence of coarctation with or without upper limb hypertension. During 1967-74 only three patients under the age of 1 year were referred for surgery, reflecting the conservative approach of the cardiologists. Since then, opinion has changed and the emphasis has shifted towards surgery; the patients under 1 year of age were, however, referred to another surgical firm. Only two patients have been excluded from this series. One patient had a true and the other a false aneurysm of the aorta distal to the coarctation that followed bacterial endocarditis, and both these patients were treated successfully by resection with graft replacement.

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Table 1 Preoperative physical findings

Variable	Group and age (y)			Total group (n=91)
	1 0-5 (n=20)	2 6-15 (n=43)	3 >15 (n=28)	
Arm-leg blood pressure > 30 mm Hg	16	30	19	65
Systolic murmur	20	43	28	91
Decreased femoral pulses	20	43	26	89
Palpable intercostals	2	11	9	22
Posterior chest wall murmur	8	14	19	41
Hypertension	12	28	25	65

The 91 patients ranged in age from 11 months to 53 years. For the purpose of this study they were subdivided into three groups: group 1, 0-5 years (20 patients (22% of the total)); group 2, 6-15 years (43 patients (47%)); and group 3, over 15 years (28 patients (31%)). The physical findings in each group are summarised in table 1.

ASSOCIATED LESIONS

Among the associated lesions, bicuspid aortic valve was observed in 40% of the patients, patent ductus arteriosus in 8%, a small ventricular septal defect in 3%, and aneurysms of the intercostal arteries in 12%.

INVESTIGATIONS

Radiological examination of the chest and electrocardiography were performed in each patient, and 54

had cardiac catheterisation (table 2). Echo cardiography was performed in the last few patients. The systolic pressure gradient across the coarctation in each of the three groups was 20-110, 20-75, and 25-100, with means of 50, 45, and 60 mm Hg respectively (table 2).

SURGICAL TECHNIQUE

Most (80%) of the patients in groups 1 and 2 and 45% in group 3 had resection with end to end anastomosis (table 3). Among these, two patients in group 2 also had reimplantation of the left subclavian artery. The next most common operation, mainly in group 3, (41%), was resection with interposition of a tube graft, with reimplantation of the left subclavian artery in one patient. This procedure was performed in only three (7%) of the patients in group 2 and none in group 1. Patch grafts were used in 10 patients: three in group 1, five in group 2, and two in group 3. In eight patients a poor collateral circulation was observed at operation. In all these patients a temporary shunt of crimped Dacron tube was established between the left subclavian artery and the aorta beyond the coarctation to prevent spinal cord damage. After the insertion of the shunt, however, it was found that the relief of obstruction was satisfactory in three patients. Consequently the shunts in these three patients were not taken down. In another patient a similar bypass graft was used because of the noticeable adhesions in the region of the coarctation from previous mediastinitis. Thus bypass grafts were used in four patients, two each in groups 2 and 3.

Table 2 Preoperative data in the three age groups

	Group 1 (n=20)	Group 2 (n=43)	Group 3 (n=28)	Total (n=91)	(% of total)
Chest radiograph					
Rib notching	4	19	7	30	(32)
Cardiomegaly	17	25	12	54	(59)
"3 sign"*	3	8	2	13	(14)
Electrocardiogram					
LVH	6	21	13	40	(43)
RVH	4	4	1	9	(10)
LVH + RVH	7	3	1	11	(12)
Normal	3	15	13	31	(34)
Catheter					
Number studied	14	23	17	54	(59)
Pressure gradient (systolic)	20-110 (mean 50)	20-75 (mean 45)	25-100 (mean 60)		

*This refers to the appearance of the aortic shadow on the chest radiograph. LVH, left ventricular hypertrophy; RVH, right ventricular hypertrophy.

Table 3 Surgical procedures used in the three age groups

	Group 1 (n=20)	Group 2 (n=43)	Group 3 (n=28)	Total	(% of total)
Resection + EEA	17	34	13	64	(68.8) (RLSA)
Resection + graft	—	3	12	15	(16.2) (RLSA)
Patch graft	3	5	2	10	(10.7)
Bypass graft	—	2	2	4	(4.3)
Total No of operations	20	44	29	93*	(100)

*Two patients each had two operations. RLSA—reimplantation of left subclavian artery; EEA—end to end anastomosis.

In patients under 1 year of age the anastomosis was completed with interrupted sutures, in patients aged 1–10 with continuous posterior and interrupted anterior layers, and over the age of 10 with continuous sutures. In the early part of the series Merselene sutures were used and in the latter part prolene sutures. From two to six intercostal arteries were divided and the aortic cross clamp time varied from 18 to 52 minutes (average 35 minutes).

SYSTEMIC HYPERTENSION

Like Lawrie *et al.*,¹¹ we defined blood pressure as normal if it was below 140/90 mm Hg. Mild hypertension was defined as ranging from 140/90 to 160/100 mm Hg and severe hypertension as being above 160/110 mm Hg. In patients below 15 years we used the same three categories after applying the age adjusted criteria laid down by the Task Force on Blood Pressure Control in Children.¹²

FOLLOW UP

Eighty six patients have been followed up so far. This has been achieved either by seeing the patient or through correspondence. One patient emigrated and four others were lost to follow up. The follow up period ranged from six months to 18 years in group 1, from eight months to 18 years in group 2, and from one year to 16 years in group 3 (mean 10 years in each group). Resting blood pressures were recorded at each follow up attendance.

Results

EARLY OUTCOME

There were no deaths in hospital. Thirty three patients (36%)—two in group 1, 17 in group 2, and 14 in group 3—had early complications (table 4).

LATE OUTCOME

Mortality

There was no death related to the surgical procedure or to the associated lesion. One patient, however, committed suicide one year after surgery.

Neurological complications

One patient in group 3 who was hypertensive suddenly developed left sided hemiplegia eight years after surgery. He made a slow but gradual recovery and at the last follow up visit he had minimal residual symptoms.

Blood pressure response

Of the 20 patients in group 1, two were lost to follow up. The remaining 18 were normotensive at the last attendance. In group 2, 15 were normotensive, 20 had mild hypertension, and the remaining eight had severe

Table 4 Early complications after surgery

	No of patients
Paradoxical hypertension	20
Wound infection	4
Postoperative bleeding	3
Chylothorax	3
Transient leg paraesthesia	1
Abdominal pain	1
Subacute bacterial "endocarditis"	1
Total	33 (36%)

hypertension before surgery. After surgery 40 were normotensive and one was mildly and two severely hypertensive. In group 3, 25 of the 28 patients were available for follow up. Before operation five had mild and 20 severe hypertension. At the time of the review, two had mild and five severe hypertension (table 5). Thus there were 10 patients in groups 2 and 3 who were still hypertensive. Five of these 10 were over 20 at the time of surgery. In these 10 patients with persistent hypertension resection with replacement by tube graft had been performed in five cases, resection with end to end anastomosis in three, and a bypass and a patch graft each in one case.

RECURRENCE OF COARCTATION

There were three recurrences of coarctation. All of these patients were 11 months old at the time of primary correction. Two patients had initially been operated on in our unit, while the third had his first operation at another centre (hence only 93 operations were performed in our centre). At the first operation two had resection with end to end anastomosis, while the third had a resection with tube graft interposition. At reoperation (when the patients were aged 9, 14, and 18 years) the surgical procedures were patch grafts in one and tube grafts in two cases.

Discussion

Simple coarctation leads to the development of hypertension proximal to the coarcted segment. The aetiology of this hypertension remains controversial, although several mechanisms have been suggested.^{13–16}

If untreated, coarctation of the aorta decreases the life expectancy considerably. Campbell¹⁷ observed that 25% of those with untreated coarctation who survived the first two years of life died before the age of 20 years, 50% by 32, 75% by 46, and 90% by 58 years. These obvious risks led Lerberg *et al.*¹⁸ to conclude that the absolute indication for surgery is the very existence of the coarctation itself, even though the patient is symptom free.

In our series 26 of 91 (28.5%) patients were normotensive while 65 (71.5%) were hypertensive before

surgery. At the last follow up 88% were normotensive. There was thus an obvious benefit—which, however, was not uniformly spread in all three groups. All patients in group 1 were normotensive; but in group 2 three of 43 (7%) patients and in group 3 seven of 25 (28%) were hypertensive at follow up (table 5). These data suggest that the patients have a better chance of remaining normotensive when the elective operation is performed before the age of 5.

The suggested optimal time for corrective surgery of coarctation of the aorta varies widely, though recent reports suggest an earlier age.¹¹⁻¹⁹ The results of the present study indicate that all patients operated on in group 1 and 40 of 43 (93%) of the patients in group 2 had an excellent outcome in terms of hypertension (table 5). As 7% of patients in group 2, however, had persistent hypertension, a proportion similar to the 9% reported by Bergdahl and associates,²⁰ this would support our belief that operation should be considered below 5 years of age. In our older (group 3) patients, hypertension persisted in 28% of cases, compared with 37% and 46% in series reported by others.²⁰⁻²¹ This difference in the incidence of persistent hypertension is probably due to a longer follow up period in these other series. Clarkson and colleagues²² have clearly shown that the incidence of hypertension varies with the duration of the follow up and we therefore presume that more patients will become hypertensive with the passage of time.

Surgery for coarctation during the first year of life using end to end anastomosis, though advocated by some,²³ should be avoided if possible, because of the high risk of recurring stenosis and therefore recurring hypertension.²⁴ This, however, contrasts with the results of aortic reconstruction using subclavian flap angioplasty.²⁵ The incidence of persistent or recurrent pressure gradients after conventional repair of the coarctation of the aorta in infancy is around 33%.²⁶⁻²⁷ Beekman *et al*²⁸ reported a 38% incidence of reoperation in patients younger than 3 years of age compared with 1.5% in patients over 3. Moss and associates²⁹ showed angiographically that by the age of 3 the ascending aorta had already grown to 55% of its adult diameter. The risk of recurring coarctation would therefore appear to be small when it is repaired after 3 years of age. A similar recommendation has been made by others.¹⁸ In our series there were three reoperations; all the children were 11 months old at the time of primary reconstruction. No other patient had a recurrence of coarctation of sufficient severity to warrant secondary corrective surgery. Therefore to remain normotensive and to avoid restenosis the surgery for uncomplicated coarctation should be performed before the age of 5 years and preferably after

Table 5 Late response of blood pressure to operation

Group	Preoperative (n=91)			Last follow up (n=86)		
	N	M	S	N	M	S
1 (n=20)	8	6	6	18	0	0
2 (n=43)	15	20	8	40	1	2
3 (n=28)	3	5	20	18	2	5
Total No (%)	26 (29)	31 (34)	34 (37)	76 (88)	3 (4)	7 (8)

N, normotensive; M, mild hypertension; S, severe hypertension.

the age of 3.

We were able to achieve resection with end to end anastomosis in 17 of the 20 procedures (85%) performed in group 1. The proportion fell to 77% in group 2 and to 45% in group 3 (table 3). The frequency of graft interposition was significantly more frequent in group 3 patients: of the 29 patients in this group, 12 (41%) had resection with graft replacement, compared with three of 44 (7%) procedures in group 2 ($p < 0.001$). Interestingly, five of the 10 patients who were hypertensive at the last follow up had tube grafts put in after resection of the coarcted segment (table 5). Three of the remaining five patients had resection with end to end anastomosis, one had bypass graft, and one a patch graft. Later in the series patch grafting was avoided because of its reported late complications.³⁰ Evidently therefore not only does the risk of needing a prosthetic graft increase with advancing age but there is also an added risk of hypertension either persisting or developing again. A similar observation has been made by others,²²⁻³¹ which substantiates our belief that surgery for coarctation should be performed during early childhood, when a resection with end to end anastomosis can be achieved safely in most patients.

Percutaneous balloon angioplasty has been used for persistent or recurring coarctation after operation,³²⁻³³ though its role in unoperated patients has not yet been determined.³⁴ Initial reductions in aortic gradients are observed to be followed by early recurrence,³⁴⁻³⁶ and sometimes the procedure can be fatal.³⁷ From his considerable experience Lock³⁸ therefore cautions against an enthusiastic approach for balloon angioplasty as the method of first choice.

None of our patients had paraplegia after surgery though its reported incidence varies from 0.5% to 1.5%.¹⁸⁻²²⁻³⁹ We believe that if the coarctation is mild with poor collateral vessels, resulting in a severe fall in blood pressure in the distal segment after the aorta has been clamped, a temporary bypass shunt with crimped dacron tube should be used. Other methods that have been recommended in patients with a minimal collateral circulation are left atriofemoral bypass with a pump⁴⁰ and the use of a heparin bonded shunt.⁴¹

There was only one late death (a patient committed suicide one year after operation). Another patient developed left sided hemiplegia eight years after surgery, but he recovered from it gradually. Clarkson *et al*²² had 19 deaths two to 23 years after the operation, mainly due to cardiovascular diseases. Apparently therefore patients can develop fatal complications at varying times after surgery. The incidence will increase with the period of follow up, and it is thus essential that after corrective surgery for coarctation of the aorta, patients should be reviewed at regular intervals for early detection and management of complications arising either directly from the operation or from the associated lesions.

In conclusion, surgical correction of aorta in symptomless patients should preferably be performed at 3–5 years of age, so that both recurrence of stenosis and prolonged postoperative hypertension can be avoided and a resection with end to end anastomosis can be performed easily. In older patients the hypertension tends to be fixed and the frequency of prosthetic interposition with the likelihood of persisting hypertension increases. After surgery an indefinite follow up is essential.

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