tolerated better by the young and anxiety states are unusual at this age. We believe, too, that a relatively serious operation of election should be carried out before the individual has acquired responsibilities and dependants.

Summary

Fifty-two cases of aortic coarctation have been studied.

A review of the literature and of our 12 unoperated cases emphasizes the poor prognosis in the untreated case.

Forty patients were submitted to operation.

Symptoms and physical and radiological signs have been evaluated before and after operation.

A surprisingly high incidence of unexpected local complications was encountered at operation, owing possibly to the preponderance of adults.

Three deaths occurred in the surgical series.

Satisfactory clinical results were obtained in the surviving patients, who have been followed up for from three months to eight years.

The brachial blood pressures have been reduced in all cases.

The factors influencing the post-operative blood-pressure levels have been discussed.

The indications for operation have been evaluated.

We are grateful to the many physicians who have so kindly referred cases to us, and especially to Dr. Paul Wood and Dr. Terence East for allowing us to quote patients who have been under their care before and after operation; to Dr. Wallace Bridgen, who most kindly allowed us to reproduce the pre-operative angiogram of Case 13; and to Professor J. McMichael, who gave valuable advice and criticism. We are also indebted to Mr. L. L. Bromley for permission to quote his operative findings in three patients. Finally, we must record our indebtedness to Sisters Anderson, Bowtle, and Prior for their invaluable and unstinted work in the wards and theatre.

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SURGICAL TREATMENT OF CHILDREN WITH COARCTATION OF THE AORTA

BY

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Each advance in cardiovascular surgery increases the need for careful selection of patients suitable for operation. It is particularly difficult to come to a correct decision about cases of aortic coarctation because the disorder is compatible with a long and active life. Moreover, operation is not without risk, it does not always relieve hypertension, and even when the result seems at first to be successful an aneurysm may form at the line of anastomosis.

The difficulty is aggravated because when coarctation is first diagnosed it is usually impossible to predict the course of the disease, and, although undoubtedly some patients may be destined to attain a ripe old age, others will die before their due time. Sometimes death is sudden and without warning when the aorta or some smaller artery, such as one of those at the base of the brain, bursts under the strain; at other times death comes slowly when the heart fails or superimposed subacute bacterial infection proves resistant to treatment.

It might be possible to get a better idea of the likely outcome for the individual if the natural course of the untreated condition could be studied in a sufficiently large group of patients. But this again presents a problem, for during life the disorder must sometimes elude discovery, and after death, unless this occurs in hospital or is reported to the coroner, the body is unlikely to be examined by a pathologist. Probably many people with aortic coarctation die at home and are certified as having had hypertensive heart disease, myocardial infarction, or apoplexy. We recognize that these factors must make figures inaccurate and may lead to false conclusions. Nevertheless the selection of patients for operation will depend on criteria determined by experience, and we therefore record our experience of coarctation at the Birmingham Children's Hospital between July, 1950, and July, 1955.

Mortality

During these five years 30 infants (16 girls, 14 boys) died more or less directly as a result of coarctation, 17 within a week of birth, 8 within a month, and 5 within six months. Cases grossly complicated by associated defects have been excluded from this series. There was no record of a death from coarctation in an older child up to the age of 14, but we know of two deaths amongst adolescents with the disease. In this same period we saw at the hospital 22 children (14 boys, 8 girls) with coarctation, 21 of whom still survive.

It is impossible not to be impressed by the proportion of deaths occurring in infancy, especially in the first month. Fig. 1 (left-hand open column and solid columns marked A) shows that more than a third of Blackford's (1928) series of 323 cases of coarctation died in infancy. Most of these early deaths are associated with the infantile type of coarctation, but this is by no means invariable, and in our series one of the infants who died and two of the babies who have been operated on had the adult type of disease. Further, the infantile type of coarctation does not necessarily cause early death: four of the older children had a long narrow segment of aorta proximal to the origin of the ductus

arteriosus, and in three of these the ductus remained patent. Moreover, it is quite possible to operate successfully in these cases. For these reasons we shall not regard our patients as belonging to two entirely different anatomical groups.

There are reports of three large series of cases in which coarctation was found at necropsy. Blackford (1928) includes both the infantile and the adult varieties in his review :

of material make it difficult to compare the three series. However, if infant deaths are excluded from Blackford's series it can be assumed that almost all the remainder are examples of the adult type of coarctation. In Fig. 1 deaths in each decade are recorded as a percentage of all cases in the particular series—A, B, or C. Deaths occurring in infancy are represented in the single open column on the left of the figure. The remaining five triple columns form a pattern which gives an impression of the outlook for older individuals with coarctation.

If columns A and B are compared with columns C the figure shows that the prognosis has improved since antibiotics reduced the mortality of endocarditis and pneumonia. Nevertheless the general trend remains much the same now as it was in 1928. If a child with coarctation survives the perils of the first 12 months he is unlikely to die before he is 10, but he has a poor (1:3) chance of reaching his forties; indeed, he cannot lightly dismiss the possibility of dying before the age of 20. The figure does not show that only about 25% of these patients succumb to incidental illnesses, of which the most important is pneumonia, a condition to which these patients seem to be particularly susceptible. For most of the remaining 75% death, no matter when it comes, is likely to be the result, directly or indirectly, of hypertension.

Diagnosis

Uncomplicated hypertension is usually regarded as a disease without symptoms, and it is not surprising that children with coarctation should be unaware of a handicap. Yet parents are unanimous about the change wrought by successful operation. This may be because a patient who has gone through a serious operation does not like to admit that he has failed to benefit, or it may be that symptoms are recognized only after they have disappeared. Five children spoke of relief from headache, and this had been severe enough to prevent one athletic boy from playing rugby. Eight children found that they were not so easily exhausted, and this increase of energy was readily measured in two children who before operation had been regarded as lazy because they so easily gave up trying, but afterwards were able to compete successfully with an unaffected twin. In three children chest pain disappeared. The presenting symptom in 7 of the 22 children was pulmonary, and 14 had had repeated attacks of really severe bronchitis or pneumonia.

The diagnosis was seldom in doubt. A small, absent, or delayed femoral pulse was the most valuable sign of coarctation; there was great difficulty in recording the leg pressure by auscultation. The collateral circulation was

less obvious in children, and rib notching, though once doubtfully present in an infant, could not usually be recognized with certainty until about the age of 6. Murmurs could always be heard, and it was this which first brought nine of the children under observation. Most commonly, murmurs were systolic and loudest high in the chest; sometimes an aortic diastolic murmur could be heard. Murmurs could often be heard close to the spine, and no fewer than six children had systolic and mid-diastolic murmurs at the apex of the heart. These apical murmurs tended to persist after operation, and, as most of the children were too young to have acquired mitral stenosis, the sign may have been evidence of associated endocardial fibrosis of the mitral valve. There was no recognizable enlargement of the left atrium. All showed arterial pulsation in the suprasternal area.

Electrocardiographic findings varied considerably. Minor degrees of left ventricular preponderance were seen, but more usually were absent, and one child of 10, with an adult type of coarctation, had right ventricular preponderance. Several children had an increased pulmonary artery pressure, possibly secondary to bronchitis.

X-ray screening often provided confirmatory evidence of coarctation, but without doubt angiocardiography provided the most valuable information. In children good results are obtained from both intravenous and retrograde aortic injections, making it possible to study not only the position and nature of the coarctation but also the anatomy of the aortic branches and the collateral circulation, as well of the ductus arteriosus if it is patent.

From the technical point of view only one case was unsuitable for operation—a 6-year-old boy whose coarctation lay between the innominate and left common carotid arteries. The infantile type of coarctation was not considered unsuitable.

Surgical Considerations

In the period under review most of our experience was with older patients, and the chance to operate on 11 children under the age of 14 provided an opportunity to contrast the technical problems in the two groups. The resection of an adult type of coarctation in children is a far simpler problem than it is in adults; the collateral circulation is less formidable, so that entry into the thorax is easier; the exposure is better because of the ease of rib-spreading and the more elastic nature of young tissue generally. The aortic wall is free of sclerosis, and troublesome berry aneurysms have not yet formed on the intercostal vessels; we have seen these aneurysms in patients as young as 15. Once the coarcted area has been excised there is rarely difficulty in approximating the proximal and distal ends of the aorta prior to suturing. Except in one instance the ease of surgery has been notable.

Type of Anastomosis

Undoubtedly the best operation is an end-to-end anastomosis following an adequate resection of the coarcted area, so that a really wide channel exists, approaching or equalling the calibre of a normal aorta. The technique of the operation has been notably simplified by the invention by Dr. Potts of a multi-toothed, narrow-bladed aortic clamp. Had these clamps been available it is probable that one of the two subclavian aortic anastomoses mentioned below would not have been substituted for an end-to-end anastomosis. In all the patients the lower segment was wider in calibre than the upper segment—the post-stenotic dilatation so well described by Holman. To overcome this disparity in size the upper segment was cut obliquely so that its lumen approximated in calibre to that of the lower one.

Subclavian aortic anastomosis had to be used in two patients; but, clearly, the operation should be regarded only as a substitute for the better end-to-end anastomosis.

In the first case, after a long and difficult dissection and end-to-end anastomosis, the lower aortic segment developed a linear tear an inch (2.5 cm.) in length. This was repaired, but further severe bleeding from the anastomosis required

a rapid suture of both ends. The boy's condition became critical and the operation was abandoned. Three weeks after this disaster the blood pressure was 240/170 and he complained of intractable headache; the chest was reopened and a large subclavian artery was divided, turned down, and anastomosed end-to-end to the lower aortic segment. Recovery was rapid, and five years later he was well, with a normal blood pressure.

In the second case the stenosed area reached so high up to the arch that only an aortic graft or a subclavian aortic anastomosis would have been possible. Grafts were not available at that time and the subclavian artery was therefore used: the result has been perfect.

It may be said here that, though aortic homografts may be essential in adults, their use in children may not be without future danger, because of the risk of calcification and failure to grow with the child.

When there was a persistent ductus arteriosus in addition to aortic coarctation it proved possible to excise the coarctation, to close the ductus opening into the pulmonary artery, and to obtain a good end-to-end aortic anastomosis (Fig. 2).

FIG. 2.—Coarctation and persistent ductus arteriosus. The tapes are round the aorta above and below the ductus. The aorta shows post-stenotic dilatation.

In assessing the results there can be little doubt that the bigger the calibre of the anastomosis the quicker and more outstanding is the effect on the blood pressure in the upper and lower limbs.

Results of Operation

Whilst eight children have benefited from operation, one infant died, another improved only temporarily, and an older boy has deteriorated after operation.

The published figures and our experience agree that if a baby with coarctation develops symptoms of heart failure before the age of 6 months and fails to respond rapidly to treatment he is unlikely to survive more than a few weeks. In view of this we decided to operate on two infants, one of whom died shortly afterwards.

A male infant aged 2 weeks was admitted to hospital with convulsions and found to have pneumonia with coarctation and congestive heart failure. Blood pressure: arms, 150/90; legs, 0. An enlarged heart, a loud systolic murmur, large pulmonary arteries, and congested lungs suggested associated septal defect. The diagnosis was confirmed by venous angiogram and retrograde aortogram. Oedema, hepatic enlargement, and tachycardia persisted after treatment of pneumonia. The condition deteriorated. *Operation:* Age 7 weeks; adult type of coarctation resected and end-to-end anastomosis performed. Ductus arteriosus found to be closed. Post-operative respiratory failure with pulmonary oedema, attacks of cyanosis, and convulsions. Death occurred during attack of vomiting 36 hours after opera-

tion. *Necropsy:* Heart large (56 g.); hypertrophy of both ventricles, small ventricular septal defect, dilated pulmonary artery. Aortic anastomosis satisfactory. Trachea and main bronchi contained vomitus.

The second infant also developed symptoms of heart failure.

A baby girl aged 7 months was admitted with bronchitis and with deformities suggestive of Turner's syndrome. Blood pressure: arms, 160/90; legs, 0. Heart enlarged. Faint basal systolic murmur. Coarctation of the aorta of adult type confirmed

FIG. 3.—Aortogram showing post-operative stricture formation.

by angiography. *Operation:* Age 9 months; because of increasing oedema and hepatic enlargement. Resection and end-to-end anastomosis. Resected segment showed pin-hole opening and post-stenotic dilatation. Post-operatively, arterial pulse felt at groin, but blood pressure did not fall. In next few weeks femoral pulse gradually faded and disappeared. Retrograde aortography two months after resection showed that stenosis had recurred (Fig. 3). Blood pressure in arm five months after operation, 200/120 (dotted lines, Fig. 4).

The third failure has now been satisfactorily explained; it was due to failure in abolishing satisfactorily the aortic stenosis.

A boy aged 10 years. Coarctation of the adult type. Delayed femoral pulse. Blood pressure: arms, 165/100; legs, 140/110. No history of nephritis. Blood urea 80.6 mg. per 100 ml.; renal function—slightly impaired ability to concentrate (1020) and dilute (1004). Urine: no albumin or casts. As blood pressure was rising it was suggested that operative treatment might be followed by at least a partial improvement. *Operation:* Resection of adult type coarctation; end-to-end anastomosis. Post-operative condition satisfactory with good femoral pulse, but no influence on blood pressure. Follow-up: Blood urea fell to normal, but arm blood pressure rose steadily to 190/128 (dashed lines, Fig. 4).

The renal condition did not appear to be responsible for this failure because, in spite of the pre-operative findings, blood urea and urine became normal. The collateral circulation was well developed, and the femoral pulse was easily felt, though delayed, both before and after operation. An angiogram showed that there was some narrowing of the aorta at the operation site, and direct brachial and femoral artery blood-pressure readings show that the hypertension is confined to the upper part of the body. This boy has been operated upon again using a human graft.

FIG. 4.—Blood-pressure records before operation and at time of discharge from hospital after operation.

The remaining eight children improved. This was demonstrated by the comments of the parents. Increase in exercise tolerance was pronounced, and one child climbed Snowden within a year of operation, a feat which she could not previously have attempted. Her greater capacity for exertion was due in part to easier breathing, but more to a greater power in her legs. As her mother put it, "Her legs are twice the size." Four children noticed that their feet were no longer cold, and three of them were relieved of cramps.

The most readily measurable criterion is the effect on blood pressure. Before operation the 11 children showed only slight fluctuations in blood pressure, and 11 controls (identical except that they had not been treated surgically) have shown a slight increase of pressure during the period of observation. The effect of resection is shown in Fig. 4, where immediate pre-operative pressure is compared with the post-operative pressure. The two cases treated by subclavian aortic anastomosis showed improvement in every way comparable to that from an end-to-end aortic junction.

In successful cases the blood pressure not only fell immediately but continued to fall for some weeks after operation. This can be demonstrated by comparing the blood pressure at the time of discharge with that recorded when the patients were last seen (Fig. 5). The finding encourages the hope that improvement may be permanent in most of these children.

FIG. 5. — Blood-pressure records at time of discharge from hospital and when last seen.

section and a good anastomosis. It is difficult to avoid the impression that some inherent quality of the infant's aortic tissue played a part in the recurrence. In the older child stenosis was less severe and developed less rapidly.

The cause of the hypertension in coarctation remains a matter of controversy. When circumstances made it necessary to occlude the descending aorta for several days in a child who had well-developed collateral channels, the blood pressure in the arms rose from 145/110 to 240/170. It fell again immediately after a successful operation ten days later. The blood pressure remained high in both patients who developed post-operative stenosis. These observations suggest that a purely mechanical factor plays a considerable part in the hypertension, but the progressive, less spectacular, fall of blood pressure which follows the immediate improvement points to a gradual reduction of vascular tone, and perhaps may be due to a falling concentration of pressor substances in the circulating blood.

Impressions

Coarctation seems to be potentially a dangerous disease, and for any individual patient it is difficult to predict the future. When a baby with coarctation has symptoms of heart failure, and when this failure shows no response to medical treatment, he is unlikely to survive more than a few months unless treated surgically: the only post-operative death in this series occurred in an infant previously in heart failure. During the rest of the first decade a child with coarctation appears to be comparatively safe, but the hazard

to life seems to increase greatly after puberty. Operation has seemed to us to be easier and safer in children than in adult subjects, and has usually been followed by a fall of blood pressure which has been progressive over a period of several weeks. Stricture formation may follow operative treatment; it is likely to have more serious consequences in infancy, and on present evidence, therefore, we feel that the best age for operating on cases of coarctation is the second half of the first decade. Earlier operation may be essential when there have been symptoms of heart failure or of subarachnoid haemorrhage.

Summary

Evidence is presented to show the prognosis of coarctation of the aorta. If a baby has coarctation and symptoms of heart failure, and if the failure is slow to respond to medical treatment, death is probable within the course of a few months unless treated surgically.

During a period of five years at the Children's Hospital, Birmingham, 30 infants died from coarctation within six months of birth. During the rest of the first decade a child with coarctation appears to be comparatively safe, but the hazard to life increases again at puberty and the chances of reaching the age of 40 are poor. Operation has proved easier and safer in children than in adult subjects, and has usually been followed by a fall of blood pressure which has been progressive for a period of several weeks. Stricture formation may follow operative treatment: two examples of this are given. We believe that the second half of the first decade is the best time to operate on cases of coarctation.

We thank our colleagues for referring patients to us, Dr. H. S. Baar for post-mortem reports, and Dr. Roy Astley for his constant help.

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OUTBREAK OF FOOD-POISONING FROM BREAD MADE OF CHEMICALLY CONTAMINATED FLOUR

BY

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The outbreak of food-poisoning here reported upon is characterized by two factors: the widespread nature of the inquiry, and the unusual nature of the contaminant. The extensive inquiry was necessary in that, contamination during transport being suspected, it was essential to establish the full facts in order to prevent recurrence. The unusual nature of the contaminant, endrin, is indicated by the fact that no previous record has been found of endrin-poisoning since the insecticide became generally available in March, 1954. It is of interest, therefore, to report on the means by which the contaminant was identified and to provide clinical details of endrin poisoning.

Description and Location of Area.—The Rural District of Pontardawe is situated in Glamorgan some seven