Indications for the Brock operation in current treatment of tetralogy of Fallot

H. R. MATTHEWS and R. H. R. BELSEY

Department of Thoracic Surgery, Frenchay Hospital, Bristol

It is now generally accepted that a certain proportion of children with severe tetralogy of Fallot are anatomically unsuitable for one-stage total correction of the anomaly. The choice of the best preliminary operation for these is still in some doubt, however. Following Brock's original hypothesis that relief of the outflow obstruction will encourage enlargement of the main pulmonary artery and annulus (and therefore favour subsequent successful total correction) we have preferred this procedure in all cases not suitable for immediate total correction. In a consecutive series of 36 cases the results have been found to be very acceptable and to compare favourably with those obtained with anastomotic procedures such as the Blalock or Waterston shunt. The operation has been accomplished with an 11% mortality, and in 72% of cases cyanosis has been abolished under conditions of normal exercise. Sixteen cases have subsequently come to total correction with a 25% mortality and a 75% 'cure' rate. In the light of this experience we find that closed pulmonary valvotomy with or without infundibular resection has a definite and valuable place in the current treatment of Fallot's tetralogy. General and specific indications for its use are presented.

One of the biggest problems remaining in the surgical treatment of Fallot's tetralogy concerns the management of right ventricular outflow obstruction in patients with severe hypoplasia of the pulmonary artery and annulus. Current experimental techniques, such as the use of a homograft containing a valve cusp for patching the pulmonary annulus (Asano and Eguchi, 1970), represent essentially an admission of the poor results obtained with one-stage correction in these cases. Palliative anastomotic procedures (Blalock and Taussig, 1945; Potts, Smith, and Gibson, 1946; Waterston, 1962) bypass the problem but do nothing to rectify it. Brock, however, pioneered a method of closed transventricular pulmonary valvotomy (Brock, 1948), with the later addition of closed infundibular resection (Brock and Campbell, 1950), which attacks the outflow obstruction directly and constitutes a true partial correction of the deformity. Impressed with the logic of this method we have preferred it as the initial palliative operation in all cases of severe Fallot's tetralogy not suitable for immediate one-stage total correction, and the purpose of this communication is to present our experience with this procedure and to indicate that the results obtained both before and after total correction compare very favourably with those obtained after anastomotic procedures.

MATERIAL

From 1952 to the present time we have treated 36 patients with severe Fallot's tetralogy by the Brock operation, one patient having had the operation twice. Eighteen patients were male and 18 female. Ages at operation ranged from 3 months to 25 years. Nineteen patients were under the age of 6 years, one having had a previous Blalock shunt. Of the remaining 17 older patients, nine had had previous Blalock shunts (bilaterally in two) but were still not considered ready for total correction.

Of the whole group, only five were operated on before the introduction of total correction to Bristol in 1961, so that all the remaining 31 cases represent the more severe examples of the deformity, considered electively unsuitable for immediate one-stage total correction. The average follow-up period to the date of total correction or the present time was five years (range 6 months to 18 years). Only one patient was lost to follow-up.

With regard to the nature of the outflow obstruction in the right ventricle, 18 patients had predominantly valve stenosis and required pulmonary valvotomy alone. In two of these the valve orifice on probing was of less than 2:0 mm diameter, and this we would describe as a 'pin-hole' valve. Fifteen
patients had a mixed type of outflow obstruction and required infundibular resection with the Brock punch combined with pulmonary valvotomy; three of these had a 'pin-hole' valve. The remaining three patients had a pure infundibular obstruction and required infundibular resection alone.

RESULT OF PALLIATION

The results are presented in Table I. Four patients (11%) died in the postoperative period, that is, without being discharged from hospital. One death in a patient aged 2 years 10 months was due to multiple stenoses in the peripheral pulmonary arteries which prevented any improvement in pulmonary blood flow despite relief of the proximal outflow obstruction. Two deaths were due to technical errors, one resulting from damage to an aortic valve cusp with severe aortic regurgitation and the other resulting from excessive postoperative haemorrhage with tamponade; the remaining death was due to an unexplained cardiac arrest seven hours after operation.

Symptomatic results in the 32 survivors have been divided into four groups (Table I). An excellent result indicated that the patient became free of cyanosis under conditions of full normal effort tolerance. A good result indicated a greatly improved effort tolerance but was associated with occasional cyanosis on vigorous exertion. A poor result represents those with persistent cyanosis but some improvement in effort tolerance or frequency of cyanotic attacks. The final group represents those receiving insignificant or no benefit.

Seventy-two per cent of the whole group (80% of survivors) had a good or excellent symptomatic result; 13% had an unsatisfactory result. The results were essentially the same in 10 patients who had previously had a Blalock shunt as in those without. Long-term complications were seen in only one patient who had clinical evidence of mild pulmonary incompetence.

Two other features of the results are of particular relevance: first, the complete absence of any late deaths in the 32 survivors. Bacterial endocarditis, embolic or thrombotic episodes, and heart failure were not seen. Secondly, recurrence of symptoms or clinical deterioration occurred in only four patients. The general pattern was one of a progressive improvement in symptoms with time. This is in contrast to shunt procedures when many patients show increasing deterioration with time, due to disproportion between the shunt size and the increasing circulatory requirements of the individual, or even actual thrombosis of the shunt. It does, however, correspond with what would be expected if Brock's hypothesis is correct, that increased flow through the natural channel will encourage progressive enlargement of the pulmonary artery and annulus.

Objective evidence to support this is available from a study of 13 patients in this series who had angiograms before and after the Brock procedure that were adequate for purposes of comparison. (Cases with Blalock shunt were not included unless a further angiogram had been performed after the shunt and before the Brock operation.)

ANGIOGRAPHIC RESULTS

Of the 13 patients 10 showed marked improvement in the right ventricular outflow tract obstruction, as judged by the increased size of the pulmonary root relative to the size of the aorta (thereby eliminating changes due to growth alone) or by increased pulmonary blood flow and diminished shunting to the aorta. In only three patients was there no significant angiographic improvement and two of these had a correspondingly poor clinical result. Examples from four representative cases are shown in Figures 1 to 8.

CASE SUMMARIES

Figure 1 shows the typical features of Fallot's tetralogy in a boy aged 1 year 9 months prior to a Brock procedure. The pulmonary artery and root are poorly developed (being one-third aortic diameter) and pulmonary blood flow is severely diminished. We think that total correction at this age and in this situation carries a high risk of failure. Four years after closed pulmonary valvotomy, however, there has been very considerable growth of the pulmonary artery (Fig. 2) with greatly improved pulmonary blood flow, and right to left shunting has been abolished (confirmed by oxygen studies at catheterization). The situation is now favourable for
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FIG. 1. R.C. Anterior (a) and lateral biplane (b) angiograms prior to Brock operation.

FIG. 2. R.C. Anterior (a) and lateral (b) angiograms four years after closed pulmonary valvotomy.
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FIG. 3. D.P. Anterior (a) and lateral (b) angiograms prior to Brock operation.

FIG. 4. D.P. Anterior (a) and lateral (b) angiograms five years after closed infundibular resection and pulmonary valvotomy.
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FIG. 5. B.E. Anterior (a) and lateral (b) angiograms prior to Brock operation.

FIG. 6. B.E. Anterior (a) and lateral (b) angiograms three years after closed infundibular resection and pulmonary valvotomy.
total correction and this was performed successfully and without incident at age 6 years 5 months.

Figure 3 demonstrates a similar situation in a boy aged 2 years 4 months prior to a Brock procedure. Five years after closed infundibular resection and pulmonary valvotomy the pulmonary artery has grown markedly and almost equals the diameter of the aorta (Fig. 4). Pulmonary blood flow is much improved and right to left shunting is significantly lessened. At the age of 7 years 6 months the ventricular septal defect was patched and a mild residual pulmonary valve stenosis was relieved successfully and without difficulty.

Figure 5 demonstrates Fallot's tetralogy complicated by hypoplasia of the left pulmonary artery and a supravalvar stenosis of the main pulmonary artery in a girl aged 5 years. These factors would present additional hazards if an anastomotic procedure were contemplated. By the age of 8 years, after closed infundibular resection and pulmonary valvotomy, there has been considerable increase in the diameter of the pulmonary artery, particularly at the site of the supravalvar stenosis (Fig. 6), and total correction has now been accomplished successfully and without difficulty.

Figure 7 shows a predominantly infundibular stenosis, best shown in the anterior view, in a boy aged 1 year 7 months. By the age of 4 years 6 months, after infundibular resection, the pulmonary outflow obstruction is much less and pulmonary blood flow is correspondingly improved (Fig. 8). Total correction was performed at the age of 5 years with a wholly satisfactory result.
RESULTS OF TOTAL CORRECTION

Of the 32 survivors of the Brock procedure 16 have since come to total correction, at intervals ranging from 1 year 7 months to 8 years 6 months (average 4 years 9 months). Four patients who had total corrections died without leaving hospital—one from heart block, two from 'low output' syndrome, and one from brain damage two months after recurrent ventricular tachycardia and fibrillation. This gives an overall mortality of 25%. The remaining 12 patients are all completely well and symptom-free with an average follow-up of 2 years 6 months. The only detectable abnormalities clinically are that two patients show evidence of mild pulmonary regurgitation on auscultation.

Of the other patients who have not come to total correction, the majority are either still too young or are on the waiting list for cardiac catheterization prior to open-heart surgery.

DISCUSSION AND CONCLUSIONS

One-stage total correction is obviously the best operation for tetralogy of Fallot, if it is feasible. However, in those patients in whom a preliminary palliative operation is unavoidable, the question which should concern us nowadays is not which procedure offers the best immediate relief of symptoms but which one gives the best preparation for subsequent total correction. Relief of the pulmonary outflow obstruction by the Brock procedure represents a true 'partial' correction and tends to restore the patient towards normality. Brock's original concept was that the increased flow through the natural channel would encourage significant growth of the pulmonary artery and root. This, in turn, would mean that fewer patients would come to total correction with serious outflow obstruction—which increases the possibility of right ventricular failure when the septal defect is closed, or necessitates division of the pulmonary annulus with consequent severe pulmonary regurgitation. We consider that the angiographic evidence from this series indicates that gratifying growth of the pulmonary artery does indeed occur after this procedure.

Anastomotic procedures, on the other hand, although providing satisfactory relief of symptoms, merely 'buy time' in terms of improved health and growth while in fact adding a further anatomical abnormality to the already existing ones.

In Table II a comparison is made between our results in this series and recently reported results after other procedures, both in respect of the success of the palliative procedure and subsequent total correction. If early and late deaths are added together, as they should be, anastomotic procedures carry a mortality ranging from 36% (Tuassig, 1969) to 29% (Cole, Muster, Fixeler, and Paul, 1971) and 21% (Bernhard, Jones, Friedberg, and Litwin, 1971). Our mortality has been 11%.

The figures after total correction indicate a mortality between 41% (Goldman, Mustard, and Trusler, 1968) and 50% (Borgeskov, Poulsen, and Rygg, 1971) for total correction in patients who have received a Blalock shunt. For the Pott's operation we have not been able to find any data, although the operation was introduced in 1946, and figures for the Waterston procedure are not yet available. With the Brock operation we have had a 25% mortality at total correction. One other figure is of particular relevance: if an attempt is made to treat these unsuitable cases by one-stage correction with division and patching of the pulmonary annulus, then a mortality in the region of 50% can be expected (Goldman et al., 1968). In addition, 14 out of 15 patients who were catheterized after pulmonary outflow patching demonstrated significant pulmonary regurgitation (Hawe et al., 1970), and we do not think that this can be regarded as an entirely innocent lesion.

In the light of this angiographic and clinical evidence we think that a strong case exists for the general use of the Brock operation in the palliation of severe cases of Fallot's tetralogy. Additional advantages of the procedure are that it permits direct visual assessment of the anatomy of the heart and that it can very easily be employed as an alternative at exploration, if features are revealed which might prejudice total correction. The operation can also be repeated, if necessary, and there is no shunt to be closed at the time of total correction. We appreciate that many surgeons will be reluctant to relinquish the use of shunt procedures that have given reasonable

### Table II

<table>
<thead>
<tr>
<th>Procedure</th>
<th>% Initial Mortality (early and late)</th>
<th>% Mortality at Total Correction</th>
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<tbody>
<tr>
<td>Blalock shunt</td>
<td>36 (Tuassig, 1969)</td>
<td>41 (Goldman, 1968)</td>
</tr>
<tr>
<td>Potts shunt</td>
<td>29 (Cole, 1971)</td>
<td>50 (Borgeskov, 1971)</td>
</tr>
<tr>
<td>Waterston shunt</td>
<td>21 (Bernhard, 1971)</td>
<td>Not published</td>
</tr>
<tr>
<td>Brock operation</td>
<td>11 This series</td>
<td>25 This series</td>
</tr>
<tr>
<td>One-stage total correction with outflow gussetting</td>
<td>50 (Goldman, 1968)</td>
<td></td>
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results for many years, but even to those we would suggest that the Brock procedure is specifically indicated in certain classes of cases: (1) when Blalock or other shunts have failed and the patient is still not a good candidate for total correction; (2) where there is associated significant unilateral absence, stenosis or hypoplasia of the pulmonary vessels, when occlusion of the pulmonary artery for performance of an anastomosis may be hazardous; (3) when sternotomy has been performed with a view to total correction but unfavourable anatomy has been encountered; and (4) if satisfactory results are not being obtained with anastomotic operations.

Details of the technique currently used by the authors in the performance of the Brock procedure are available on request.

REFERENCES


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