TECHNICAL PROBLEMS OF CARDIAC SURGERY IN ADULTS

RECONSTRUCTION OF THE OUTFLOW TRACT OF THE RIGHT VENTRICLE

By Donald N. Ross

Reconstructive procedures to restore the outflow tract of the right ventricle have become an accepted procedure and have been used with increasing frequency since our use of a homograft valve segment in a case of pulmonary outflow atresia in 1966. (Ross and Somerville 1966). This child is well six years later and although the homograft aortic wall has calcified slightly, the valve cusps are fully functional as demonstrated angiographically on two separate occasions. The technique has been adapted to a number of other conditions notably in the correction of truncus arteriosus (Rastelli et al 1967) and transposition with a ventricular septal defect (Rastelli et al 1969).

However, it is my belief that in the coming years, more attention will be paid to reconstructive surgery of the obstructed right ventricular outflow in cases of difficult Fallot and its variants as opposed to the present emphasis on the relief of obstruction only. This latter attitude often ignores the functional importance of the pulmonary valve on the assumption that an absent or regurgitant pulmonary valve is of no clinical importance. This view is based on animal work but the resulting volume overload of free pulmonary regurgitation over a number of years must represent an abnormal burden on the right ventricle.

Before going on to the management and reconstructive surgery on the right ventricle outflow we should review the surgical anatomy of the area.

In this communication we are dealing with the right ventricular outflow tract which in itself is a vague term. We speak loosely of the inflow and outflow "positions" of the right ventricle but these areas are not clearly demarcated from the outside.

Considered on an embryological basis, the right ventricular outflow can be looked upon as that part of the right ventricle derived from the bulbus cordis and it includes the crista supraventricularis, the ostium infundibulum when present, the infundibulum, the pulmonary valve and ring and the origin of the pulmonary artery (Fig. 1).

As far as surgical access to the outflow tract is concerned, the general tendency is to use transversely placed incisions. These serve well but they do have disadvantages particularly when dealing with a narrow or hypoplastic outflow tract. In these cases a transverse incision is restricting and cannot be extended proximally or up into the pulmonary artery (Fig. 2). Two important points have to be kept in mind, however. One is to be on the lookout for an anomalous left anterior descending artery. The other is to avoid encroaching on the inflow or sinus portion of the ventricle.

As far as surgical management is concerned, my own preference is to use limited periods of ischaemic arrest for relaxation and a dry field to assess the anatomy and close the ventricular septal defect. A beating heart is then necessary to assess the functional result and to decide whether there has been adequate relief of the obstruction.

Stenotic pulmonary valves are usually dealt with quite simply by mobilization of the commissures which are then incised with a knife (Fig. 3). However, we should not delude ourselves into believing that we preserve a functionally competent valve—in fact, stenosis is relieved at the expense of some regurgitation.

However a narrow valve ring or a subvalvar muscular sphincter which will not accept the passage of a little finger must be divided and some form of reconstructive surgery then becomes obligatory.

In the simplest cases a diamond-shaped patch of pericardium or Dacron afford adequate relief of the stenosis but where the valve ring is involved or a long patch is necessary, free pulmonary regurgitation must result.

However in cases with complete atresia of the outflow, a tubular reconstruction is necessary. We have preferred to use a segment of aorta and contained homograft valve. There have been a number of variations on this theme from a number of centres including tubular valves made of pericardium and fascia and homografts inserted in Dacron tubes (Horiuchi et al 1971) (Weldon et al 1968). The fascial tubular valve reconstructions which we used in 3 patients have all stenosed and failed and we do not recommend this technique (Ross and Somerville 1971).

In reconstructing the atretic outflow tract with a homograft, the method I use differs from that described by Rastelli (McGoon et al 1970) in that I prefer to countersink the homograft valve within the right ventricular outflow and by avoiding a protruding tubular prosthesis hope to avoid its subsequent kinking and compression within the pericardium (Figs. 4 and 5).

In cases of truncus arteriosus our experience is small but in these cases it is necessary to use a free tube running from the ventriculotomy to the mobilized pulmonary arteries. Again since the pulmonary arteries are excessively friable it is technically easier to anastomose these to a soft elastic wall of a homograft rather than to a Dacron prosthesis (Fig. 6).

I have no experience of homograft reconstruction in transposition with pulmonary stenosis and a ventricular septal defect. However, a number of successful cases have now been reported and the technique is well established (Rastelli et al 1969).

There are still more interesting prospects for basic technique and Fontain has used a homograft reconstructive method in cases of tricuspid atresia to divert the right atrial blood to the pulmonary artery. He converts the right atrium into a pumping chamber by means of additional valve in the inferior vena cava (Fontain et al 1971). (Fig. 7).

More recently I have tried to adapt this technique to the correction of single ventricle with pulmonary stenosis and common A-V valve in a terminally ill adult (Fig. 8). The technique worked well although the patient died some 12 hours later from low cardiac output. A problem in this case was that the patient had in addition transposition and atrial inversion so that the inferior vena cava was not accessible for the insertion of an additional valve. In young patients however, I believe this method of reconstruction offers the prospect of relief in some cases of true single ventricle with pulmonary stenosis and a common A-V valve.

By far the commonest use of an aortic valve reconstruction of the right ventricle has been in my series of 134 pulmonary autografts for isolated aortic valve disease (Ross, D. N. 1967) (Fig. 9). In this large series studied over a period of 5 years there has been only one failure of the valve in the right ventricular position and this was from fungus endocarditis. Their continued trouble free function at this site (Somerville et al 1972) has encouraged their wider application to other forms of right ventricular reconstruction. One puzzling feature has been an absence of visible calcification of the aortic wall in these adult patients, whereas calcification is rapid in ours and other reported series when the valve is used in children.

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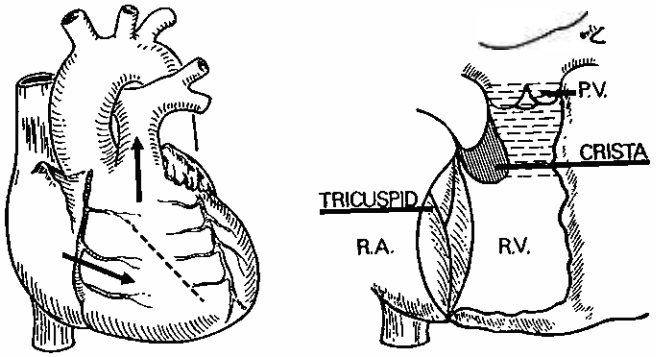

Fig. 1. The outflow tract is that point of the right ventricle distal to the crista and includes the proximal pulmonary artery and valve.

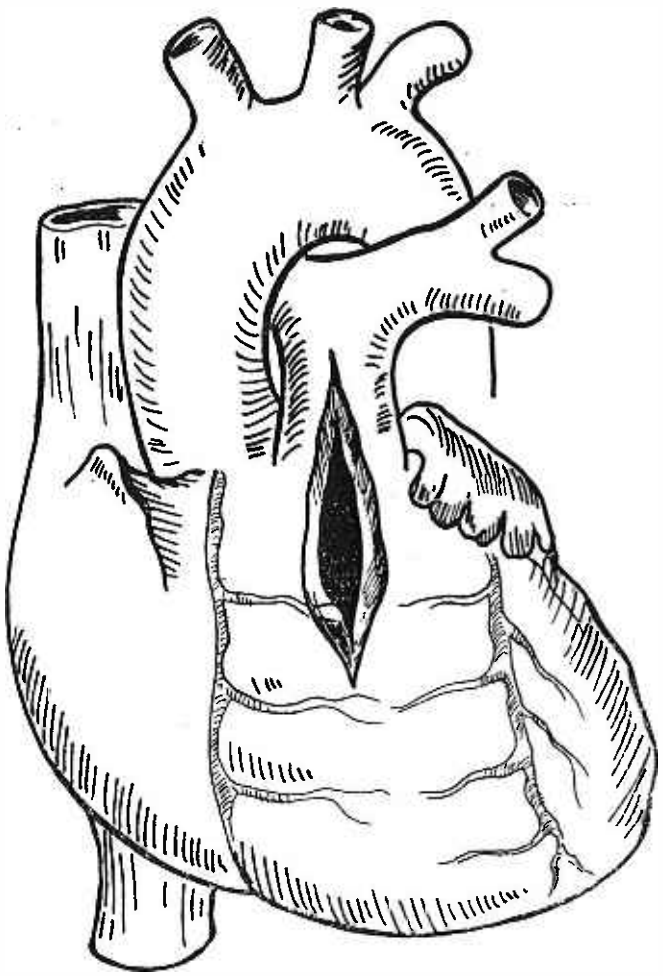

Fig. 2. Vertical incisions in cases with a hypoplastic or absent outflow allow scope for extension and allow reconstructive conduits to bed down without danger of kinking.

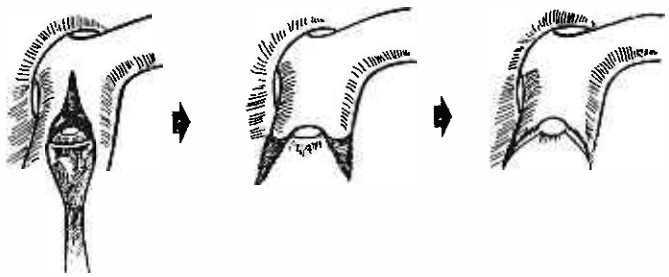

Fig. 3. Valve stenoses are again best approached through a vertical incision and the commissures are mobilised from the wall where adherent.

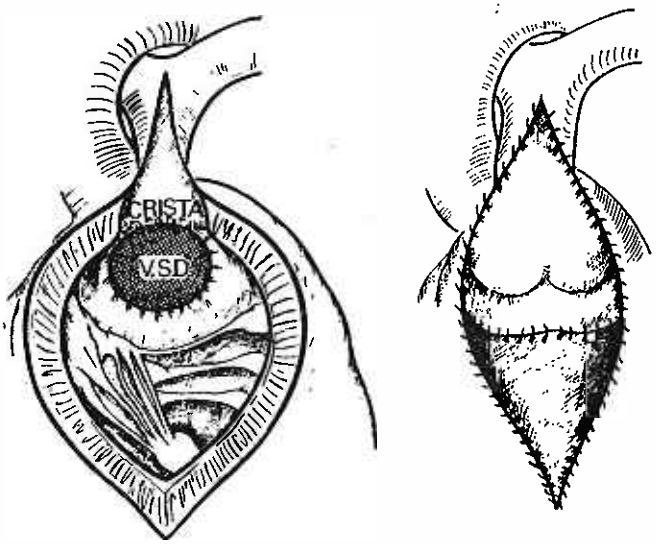

Fig. 4. After closure of the V.S.D. the graft is attached to the upper margin of the patch and laterally to the margins of the incisions in the ventricle and pulmonary artery.

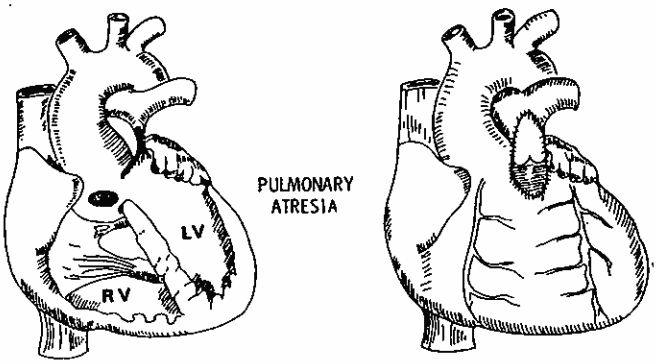

Fig. 5. The completed reconstruction. In some cases a proximal deficiency of the graft is filled in with woven Dacron graft material.

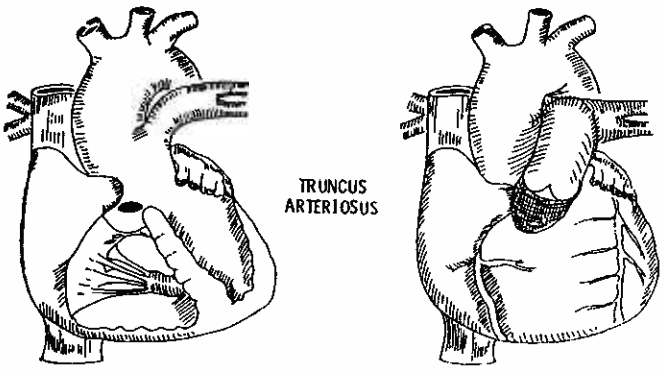

Fig. 6. Correction of truncus arteriosus after mobilization of the pulmonary arteries and V.S.D. closure.

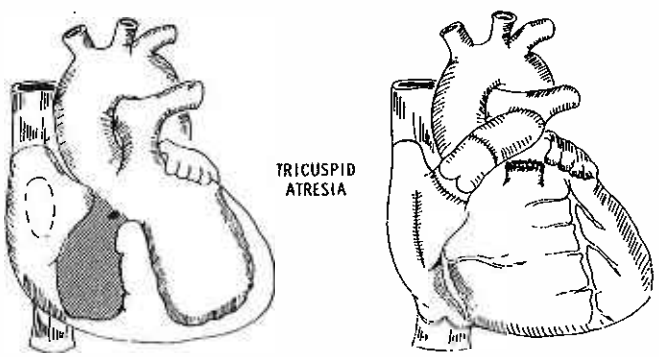

Fig. 7. Fontain's method of correcting tricuspid atresia by transferring blood from the right atrium to pulmonary artery. Note the additional valve in the inferior cava.

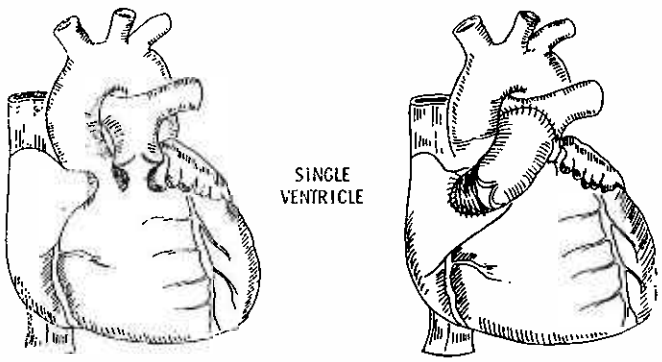

Fig. 8. In this case of single ventricle the right atrial blood has been excluded from the ventricle with a baffle and is redirected to the lungs via a homograft conduit.

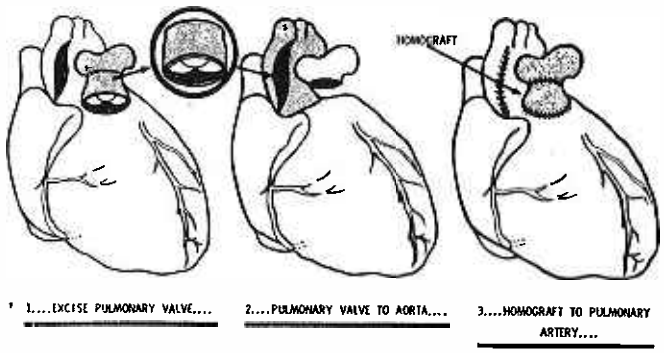

Fig. 9. Diagramatic representation of aortic homograft reconstruction of the excised pulmonary valve which has been used as a replacement for the aortic valve.

TABLE I

R. V. Reconstruction—Policy

Waterson Shunt and Tie Collaterals
Homograft Reconstruction at 1-2 Years

TABLE II

Pulmonary Atresia—Radical Correction
N.H.H. Feb. 1966 - 1970

15 Patients
2 Deaths ← { 1 Staph B.E. / 1 Anuria
No late deaths
1 - 5 Years Follow-Up—Excellent
Wall calcified in all cases at 6 months
Cusps fully functional on angiography
No evidence of stenosis at valve level.

TABLE III

Right Ventricular Reconstruction

Pulmonary Atresia, Pseudotruncus, Hypoplastic Fallot
47 Patients
15 Deaths (31%)
Previous Shunts 40

TABLE IV

Right Ventricular Reconstruction with Biological Valves

	No.	Deaths
Pulmonary Autograft	134	18
Pulmonary Atresia Group	47	15
Truncus Arteriosus	5	3
Single Ventricle	1	1
	187	37 (19%)

As far as the pulmonary atresia cases are concerned it has been our policy to create a Waterston shunt and tie systemic collateral vessels as a first step in all cases and one to two years later the reconstruction is carried out (Table 1).

In the first 15 patients there were only 2 deaths (Table II) but since that time we have tackled a number of cases with dominant systemic vascular connection to the lungs and cases of pseudotruncus. This has increased the mortality of the operation considerably as a result of persistent right ventricular hypertension (Table III) but a more radical approach to the collaterals as advocated by Kirklin (1972) may resolve the difficulty.

Of the three deaths in the truncus series one was due to continued bleeding from the friable suture live in the high pressure pulmonary arteries. The remaining two died in low output with marked pulmonary vascular changes of the Eisenmenger type emphasing the need to palliate or correct these cases within the first year of life (Table IV).

SUMMARY

Outflow reconstructive surgery with homografts have been used by me particularly after excision of the pulmonary valve for use as an aortic valve substitute but their most spectacular application has been in cases of pulmonary outflow atresia and in the correction of truncus arteriosus and transposition with a ventricular septal defect. In tricuspid atresia they have air application and there seems to be a prospect that they may be of value in some cases of complex single ventricle. In addition it is suggested that the method will gain increasing acceptance in future in the management of Fallot's tetralogy with a severely hypoplastic outflow.

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