Mid-term results of the Ross procedure

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Abstract

Methods: Fifty patients underwent a Ross operation between June 1991 and October 1996. Preoperative diagnosis was: congenital aortic valve disease (31 patients), complex left ventricular outflow tract (LVOT) obstruction (11 patients), outgrowth of a small aortic valve prosthesis (five patients) and valve endocarditis (three patients). Half of the interventions were reoperations. All operations were root replacements. A pulmonary homograft was used in 45 patients. An aorticoventriculoplasty was combined with the root replacement in the 16 patients with LVOT obstruction and a too small aortic valve prosthesis. An enlargement or reduction plasty of the ascending aorta was necessary in seven patients.

Results: The mean age was 20.9 years (range: 2.5–54 years). The mean follow up was 34.2 ± 21 months and was 94% complete. Two patients died after 8 days (low cardiac output due to myocardial fibrosis) and 17.4 months (sudden death), respectively, resulting in a survival of 95–4% at 4 years. Those two deaths occurred in the group of patients undergoing Ross procedure and aorticoventriculoplasty. Two autografts were replaced after respectively 2 days (technical failure) and 44 months (progressive root dilatation) resulting in a reoperation-free incidence of 93–6% at 4 years. Other postoperative major complications occurred in six patients. All survivors had regular echo-Doppler examination. All autografts except one had a systolic gradient below 10 mmHg at the last examination. Thirty-four autografts had no leak, ten showed grade 1–2 regurgitation. Two patients showed a higher than grade 3 regurgitation: one leak remains stable with normal left ventricular dimensions and function, one autograft was replaced by a mechanical valve. Conclusion: This experience demonstrates that the medium-term results of the Ross procedure are excellent even in complex LVOT obstructions. © 1998 Published by Elsevier Science B.V. All rights reserved

Keywords: Pulmonary autograft; Homograft; Left ventricular outflow obstruction; Aortic valve disease; Aortoventriculoplasty

I. Introduction

The replacement of a diseased aortic valve by a pulmonary autograft was introduced by Ross in 1967 [1]. At that time the surgical community was not convinced, because of the complexity of the procedure and the unknown fate of the autograft as well as the homograft, used to reconstruct the right ventricular outflow tract (RVOT). Very few were the surgeons who dared to build up a moderate-to-large experience.

Nowadays it is clear that aortic valve replacement with the classical valvular prostheses have their well known disadvantages: tissue degeneration (bioprostheses) [2], thrombo-embolic phenomena, anticoagulant-related bleeding, tissue overgrowth and encapsulation (mechanical valve prostheses). The cumulative risk of these complications is, of course, higher in younger patients.

Recent reports from Ross [1] and other authors [3–5] have shown that the fate of these autografts are at least comparable to bioprostheses and even to mechanical valves. There is also some evidence that the homograft implanted as a root replacement might show improved durability compared to the subcoronary implantation [6].

Persuaded by the superiority of the pulmonary autograft in the aortic position and impressed by its growth capacity in small children [7,8] we started with this procedure in June

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1991. This series also compromises 16 patients in which the autograft root replacement was combined with enlargement of the tunnel-like obstruction of the left ventricular outflow tract (LVOT). This concept was first described by Clarke [9] who combined a homograft root replacement of the LVOT together with a Konno-like ventriculoplasty [10], the so called extended aortic root replacement (EARR).

We applied this broadened concept using a pulmonary autograft in a correction of a 10-year-old girl with tunnel subaortic stenosis in June 1991 [11]. This was, to the best of our knowledge, the first report of a Ross–Konno operation in the literature. The mid-term results of the 16 patients with EARR using a pulmonary autograft, included in this series, were recently reported [12].

2. Methods

2.1. Study population

Fifty patients (33 males and 17 females) underwent replacement of the aortic valve by a pulmonary autograft (Ross procedure) between June 1991 and October 1996. The mean age at operation was 20.9 years (range 2.5–54 years). The mean follow-up was 34.2 ± 21 months and was 94% complete.

The indication for the Ross procedure was congenital aortic valve disease (31 patients), subvalvular with or without valvular (tunnel) aortic stenosis (11 patients), an outgrown aortic valve prosthesis (five patients) and bacterial valve endocarditis (three patients).

2.2. Operative technique

Myocardial protection was achieved by antegrade crytalloid cardioplegia and topical cooling throughout the aortic cross-clamp time. The myocardial septal temperature was closely monitored and was not allowed to exceed 15°C.

Fifty percent of the procedures were reoperations. All valve replacements, except the first two were root replacements. A septal patch enlargement of left ventricular outflow tract was associated to this root replacement in 11 patients with tunnel subvalvular aortic stenosis and in five patients with an outgrown aortic valve prosthesis. The right ventricular outflow tract was reconstructed with an aortic (five patients) or a pulmonary homograft (45 patients).

The operative technique, with special emphasis to septal enlargement, was reported previously [13]. After February 1995 all adult-sized patients underwent annular reinforcement of the autograft annulus with a strip of autologous pericardium. Special attention was also given to match the diameters of the ascending aorta and the autograft at the site of the sino-tubular ridge by reduction (three patients) or enlargement plasty (four patients) of the distal ascending aorta.

2.3. Postoperative follow-up

No anticoagulant therapy was given either early or late during follow-op. All patients were followed at the outpatient clinic or by the referring cardiologist every 6 months for the first year and yearly thereafter. Assessment included: NYHA functional class, ECG, chest X-ray and transthoracic 2D Doppler echocardiogram.

3. Results

3.1. Survival

One patient died 8 days after EARR for a too small aortic valve prosthesis with a gradient of 120 mmHg across the left ventricular outflow tract. He developed low cardiac output because of excessive myocardial stunning secondary to massive left ventricular hypertrophy and myocardial fibrosis. Ventricular function did not improve despite a left ventricular assist device. Heart transplantation was successfully performed at day 7, unfortunately he showed a flat EEG because of massive air embolus.

One other patient, also after EARR, remained in right heart failure after operation and died 17.4 months later because of ventricular arrhythmia. The actuarial survival at 4 years was 95 ± 4% (Fig. 1).

3.2. Non-lethal complications

Five patients experienced a major non-lethal complication after EARR. One patient developed a massive right ventricular infarction secondary to kinking of a right coronary artery (RCA) arising from the left main coronary artery. He underwent heart transplantation after been bridged with a right ventricular assist device. Two patients underwent pacemaker implantation because of permanent
surgical atrioventricular block. One patient had a very difficult postoperative cause because of right ventricular dysfunction and tricuspid incompetence caused by transection of a large septal artery. This septal artery was deliberately divided in order to be able to enlarge a very severe tunnel LVOT. She was eventually discharged and underwent tricuspid valve replacement 3 years later.

Two patients experienced a major non-lethal complication after ‘classical’ root replacement. One patient could not be weaned from cardiopulmonary bypass because of kinking of the RCA, which was implanted too low in the autograft root. The problem was solved by bypassing the RCA with the right internal mammary artery. One patient was readmitted 2 weeks after discharge with a manifest cardiac tamponade. Re-sternotomy revealed a partially dehiscence of the distal anastomosis of the autograft to the ascending aorta.

3.3. Autograft-related complications

One patient developed important autograft leakage because of excessive traction on one of the commissures of the autograft, which was apparently too short. The autograft was replaced by a composite conduit containing a mechanical prosthesis on the second postoperative day. One patient with a perfect competent autograft after EARR developed progressive aortic incompetence, which necessitated valve replacement with a mechanical valve after 44 months. The actuarial graft survival at 48 months was 93 ± 6% (Fig. 2).

Other possible autograft-related complications such as bacterial valve endocarditis or thrombo-embolic phenomena were not encountered in this series.

3.4. Autograft function

The effectiveness of the relief of the LVOT obstruction in patients undergoing a EARR will neither be reported nor discussed in this paper, since these data were published extensively [12].

Table 1 depicts the results obtained be echo-Doppler examination in 46 patients at the time of the last follow-up. The gradients across the autograft were extremely low and did not change during follow-up. The same applies to leakages, except in the patient with a grade 4 leakage, reported above and in whom the autograft was replaced. One patient with grade 3 leakage (on a scale of 4) will be monitored very closely since replacement might become necessary.

3.5. Homograft function

Table 1 also illustrates that the gradient across the RVOT reconstruction need closed follow-up in three patients with gradients exceeding 40 mmHg. The leaks reported here were minimal and stable during subsequent examinations.

3.6. Functional status

All but two patients were in class I NYHA at their last follow-up. One patient remained in right heart failure and eventually died suddenly 17.4 months after operation, presumably secondary to ventricular arrhythmia.

4. Discussion

The Ross procedure has become popular among surgeons despite its technical complexity [14]. Most experienced surgeons are nowadays moving away from subcoronary to root replacement. There is some evidence that the long-term results, in term of leakages, are superior after root replacement or intra-luminal cylinder implantation. This was already proved in a large series of homograft root replacements [6]. The long-term results of Ross’ experience seems also to endorse this finding [15]. The geometry of the autograft, and therefore also the coaptation of the leaflets, is better preserved. For this reason we abandoned the subcoronary implantation technique very early in our experience.
Root replacement, however, also has its pitfalls: coronary kinking after coronary implantation and the possibility of progressive root enlargement with secondary valve leakage. Two patients in this series, one with an unrecognized RCA anomaly and one patient in whom the RCA was implanted too low in the autograft root, presented kinking and important myocardial ischemia. We feel that preoperative coronaryography will help to identify not only large septal arteries but also will document the presence of rare coronary anomalies which might lead to kinking after transfer to the autograft.

Dilatation of the autograft is generally observed in all patients. However, one of our teenage patients, who had initially a perfect competent autograft, experienced progressive dilatation and autograft leakage necessitating autograft replacement. After this experience we use (and also recommend) reinforcement of the autograft annulus with autologous pericardium in adult-sized patients. This additional surgical maneuver does not prolong ischemic cross-clamping time significantly and also does achieve better hemostasis.

Myocardial protection is of paramount importance in this complex operation not only because of the long cross-clamping time but also because of the important myocardial hypertrophy and fibrosis present in most of these patients. The reconstruction of the RVOT can be done on a beating heart, to shorten this long cross-clamping time. We feel, however, that this reconstruction deserves meticulous attention, since it is the Achilles heel of the Ross operation. This is particularly important for the anastomosis between the homograft and the pulmonary artery bifurcation. The good exposure resulting from the still-transected aorta and the dry operation field are of great help in performing this anastomosis free from obstruction. The same applies to the right ventricular anastomosis in which damage to important septal coronary arteries are more easily avoided if the aorta is still cross-clamped.

The low gradients encountered at follow-up strongly endorse the use of this procedure in young and active patients. These patients are encouraged to resume their activities and should even be allowed to participate in strenuous sports. Although the reported leakages are clinically unimportant, meticulous follow-up remains mandatory because any turbulence at the free edge of the autograft might cause fibrosis and possibly progressive leakage at the long end.

The question remains whether this operation should be offered to older patients. We feel that this operation should be reserved for patients younger than 35–40 years of age. The reasons for this restriction are many: (1) older patients have a lower cumulative risk of the classical mechanical valve-related complications, (2) the autograft in older patients is more fragile and lead to a higher incidence of bleeding and (3) the insufficient availability of large pulmonary homograft does not permit a very liberal use of the Ross operation.

It has become evident that pulmonary homografts show better durability than aortic homografts for the reconstruction of the RVOT [16–18]. However, the availability of pulmonary homografts has become problematic because there is some tendency among surgeons to perform this procedure in older patients, in whom the advantages of this procedure are doubtful. There is ample proof that bioprostheses can achieve excellent results in older patients. This shortage of homografts will eventually lead to the use of short and non-oversized homografts or to the use of alternative valves or techniques. These alternatives might end up in inferior RVOT reconstructions and will eventually put the reputation of this excellent procedure at risk.

One of the most convincing advantages of pulmonary autografts are their growth capacity [7,8]. This is a strong argument to use autografts instead of homografts for the reconstructions of LVOT obstructions in infants, as there is some evidence of shorter durability of left-sided homografts in this age group [19,20], while the durability of rightsided homografts in this same age group is better [16,18].

We used this operation in combination with a septal enlargement procedure in cases of complex left ventricular tract (tunnel) obstruction where all previous attempts of correction failed. The combination of the Ross procedure with septal enlargement will of course increase the morbidity (septal infarction, complete atrioventricular block), as it was the case in this experience. The relief of tunnel subvalvular aortic stenosis is a very complex problem which cannot, in our opinion, be solved by simple procedures.

We realize that this moderate experience is rather short. Nevertheless, we feel that the pulmonary autograft procedure can be performed with acceptable mortality and morbidity, even in complex LVOT obstruction.

References