Use of the pulmonary autograft for mitral replacement: short- and medium-term experience

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Abstract

Objectives: In an effort to find a suitable mitral substitute for our young rheumatic patients who cannot follow a proper anticoagulation regimen for life, we resorted to an old concept reported by one of the authors (D.N.R.) in 1967. This report summarizes our experience with the Ross-mitral operation to date. Methods: Between 19 June 1997 and 27 June 2000, 43 patients with rheumatic valve disease underwent the Ross-mitral operation. Two patients were excluded because of graft stenosis detected at the end of the procedure for which the autograft had to be sacrificed. Of the remaining 41 patients 29 were female, and the age range was 12–57 years (median 39 years). The autograft was incorporated within a Dacron tubing, with a pericardial collar attached to its proximal end. The conduit was sutured distally to the excised mitral annulus; the pericardium was attached proximally to the atrial wall in 36 patients, and was used simply to cover the Dacron tubing in five patients. The pulmonary artery was replaced with a pulmonary or aortic homograft, or with a pulmonary xenograft. Results: There were two hospital fatalities from a cerebrovascular accident and a lung injury, and two postoperative myocardial infarctions. There were five late deaths, two due to bacterial endocarditis, one due to excessive bleeding at reoperation for a paravalvular leak, and two not related to the procedure. A phenomenon of ‘autograft stenosis’ occurred intraoperatively in four recent consecutive patients that probably resulted from our use, for the first time, of softer Dacron tubing material. This was repaired in two of the four patients. Echocardiography confirmed excellent functioning of all 34 autografts of surviving patients up to 36 months postoperatively (mean follow-up 18.2 months). Two patients remain in functional Class III status, one due to left heart failure following myocardial infarction, and the other due to recurrent tricuspid insufficiency. Conclusions: We believe that the mitral pulmonary autograft is a worthwhile alternative to mechanical prostheses in developing countries. © 2001 Elsevier Science B.V. All rights reserved.

Keywords: Mitral replacement; Pulmonary autograft; Tissue valves

1. Introduction

In an earlier report [1] we advocated the revival of the original Ross operation for replacing the mitral valve with a pulmonary autograft [2]. This report summarizes our cumulative experience since we started our first case in June 1997, and sheds more light on indications and technique.

2. Patients and methods

Between 19 June 1997 and 27 June 2000 a total of 43 patients with unrepairable rheumatic mitral valve disease were subjected to the Ross-mitral operation. In two patients the autografts had to be sacrificed at the conclusion of the procedure and were replaced with mechanical prostheses, because of graft stenosis discovered at intraoperative transesophageal echocardiography (TEE). These two patients were excluded from this review.

Of the remaining 41 patients, 12 were male and 29 were female. Their ages ranged between 12 and 57 years (median 39 years). Twelve patients were classified preoperatively as NYHA II, 28 were classified as NYHA III and one was classified as NYHA IV. Twenty-one patients had predominant mitral stenosis with minimal or no regurgitation, five patients had pure mitral regurgitation and 15 patients had a combined lesion. Significant tricuspid regurgitation (>2/4) was present in 14 patients, and mild aortic regurgitation (<1.5/4) was present in 18 patients. Twenty-two patients were in sinus rhythm and 19 were in atrial fibrillation. Table 1 summarizes the preoperative echographic/Doppler
findings. Eleven patients underwent cardiac catheterization to rule out the presence of coronary artery disease.

Criteria for exclusion were significant aortic disease, severe pulmonary hypertension (systolic pulmonary artery pressure of >80 mmHg), an earlier cardiac operation, pericarditis discovered at operation and a poor ventricular performance (ejection fraction less than 30%).

The surgical technique was described in detail in our earlier report [1]. The operation starts with the excision of an 8 £ 8 cm pericardial patch, in the center of which a 2.5 cm hole is created. After the institution of cardiopulmonary bypass, a standard left atriotomy is made when the left atrium is sufficiently large (ten patients). Otherwise a Dubost transverse transseptal incision (29 patients), or a Guiraudon superior transseptal incision (two patients) is used. When the mitral valve was heavily calcified or obviously beyond repair, the decision was quickly made to proceed with the operation. When it was deemed possible to reconstruct the valve, however, every effort was made to save it. A little over half of the patients originally planned for the Ross-mitral operation ended up with a reconstructive procedure instead. In 11 patients mitral repair was attempted but was unsuccessful. In the last eight cases a special attempt at conserving the anterior as well as the posterior subvalvular apparatus was made, using techniques similar to those described by Sintek et al. [3].

The pulmonary autograft is excised as in the standard Ross operation [2] and handed to the co-surgeon. The right ventricular outflow in this series was reconstructed with a pulmonary homograft in 25 patients, with a pulmonary xenograft in 13 patients, and with an aortic homograft in three patients. Tricuspid annuloplasty (De Vega) was carried out in 14 patients.

The co-surgeon, in the meantime, prepares the autograft and inserts it within a 2.5 cm long crimped Dacron conduit. The conduit used was 30 mm in diameter in all patients but two, in whom a 35 mm conduit was used because the pulmonary artery was exceptionally large.

Three equidistant temporary sutures are applied to attach the proximal end of the autograft to the Dacron conduit. Similar stay sutures are then used to attach the distal end of the autograft to the tubing, followed by a running stitch (Fig. 1). The hole in the pericardial patch is then attached to the proximal end of the autograft and Dacron conduit with three temporary sutures in between the original three and the pericardial patch inverted into the autograft lumen. A running stitch is now used to incorporate pericardial tissue, valve edge and Dacron conduit, in that order. When the pericardium is everted, covering the suture line, its smooth surface should be uppermost. By the time the right ventricular outflow is reconstructed, the Dacron stented autograft with pericardial collar is usually ready and its commissural end is then sutured to the mitral annulus (Fig. 2). The final step is to trim the pericardial free edge and suture it to the adjacent atrial wall, including the inlet to the left atrial appendage, thus covering all foreign material (Fig. 3). At the end of the procedure an intraoperative transesophageal echocardiogram is obtained to evaluate the outcome.

The aortic cross-clamp time decreased as we gained more experience. In the 41 patient series it ranged between 96 and 275 min (median 127 min). In an attempt to decrease the operative time we implanted the autograft/Dacron conduit without a pericardial collar attachment to the left atrial wall in five of the last eight patients. Pericardium was used instead simply to cover the Dacron and suture material. We have not encountered any major difficulty stemming from leaving the proximal end of the conduit thus ‘unsupported’, but we plan to use this method more often before

Table 1
Mitral replacement with pulmonary autograft preoperative echo/Doppler data*

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
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</thead>
<tbody>
<tr>
<td>LA (cm)</td>
<td>3.5–8.8</td>
</tr>
<tr>
<td>MVA (cm²)</td>
<td>0.6–4.2</td>
</tr>
<tr>
<td>Calcification of leaflets</td>
<td>15</td>
</tr>
<tr>
<td>ESD (cm)</td>
<td>2.7–5.8</td>
</tr>
<tr>
<td>EDD (cm)</td>
<td>4.1–7.8</td>
</tr>
<tr>
<td>EF (%)</td>
<td>38–72</td>
</tr>
<tr>
<td>FS (%)</td>
<td>23–41</td>
</tr>
<tr>
<td>Estimated PA systolic pressure (mmHg)</td>
<td>30–80 50 ± 11.8</td>
</tr>
</tbody>
</table>

* LA, left atrium; MVA, mitral valve area; ESD, end-systolic diameter; EDD, end-diastolic diameter; EF, ejection fraction; FS, fractional shortening; PA, pulmonary artery.

Fig. 1. The distal end of the autograft is sutured to the Dacron tubing with a running stitch.
recommending it as the procedure of choice. We have also come to use bovine pericardium to cover the defect created by removing the pericardial patch ever since we encountered difficulty reexploring one patient.

Since our third case, who was the only patient to develop a cerebrovascular accident, all patients have been placed on a 3 month course of anticoagulation postoperatively. Those who continued to have atrial fibrillation after the operation were prescribed submaximal anticoagulation (target International Normalized Ratio (INR) of 2.0) indefinitely.

3. Results

Intraoperative TEE, obtained at the conclusion of the procedure before discontinuing cardiopulmonary bypass, revealed an acceptable mitral valve area and no appreciable mitral gradient in all original 43 patients. In four consecutive patients (starting with patient no. 33), however, a phenomenon of ‘graft stenosis’ was observed as cardiopulmonary bypass was being discontinued. The cause was found to be our use, for the first time, of a softer variety of Dacron tubing material, coupled, probably, with our customary retention of the mural (posterior) subvalvular apparatus. A detailed account of these four patients was reported elsewhere [4]. In two of these patients the situation could be corrected, but in the other two the autograft/Dacron conduits had to be replaced with mechanical prostheses. This complication did not recur once we returned to using a more resilient form of Dacron (Cooley low porosity woven polyester tube graft; Meadox Medicals Inc.).

In the 41 patients included in this report the mitral area at the conclusion of operation, as measured by intraoperative TEE, ranged between 2.1 and 3.9 cm$^2$ (mean $2.7 \pm 0.38$ cm$^2$), and the mean mitral gradient was calculated at between 2.4 and 6 mmHg. No mitral regurgitation was detected in 34 patients, and a trace to a mild degree of insufficiency was observed in seven patients. One complication detected at intraoperative TEE was a flail pericardial collar, observed in two patients, that necessitated going back on cardiopulmonary bypass for correction.

The intensive care unit (ICU) stay for the 41 patients ranged between 2 and 10 days (median 3 days). Mechanical ventilation was used for 3–152 h (median 9 h). All patients required inotropic agents (dobutamine, dopamine and/or adrenalin) for a total of 3–192 h (median 43 h), and nitroglycerin was used in 14 patients.

Two patients developed myocardial infarction. One (septal) followed placing sutures in the area of proximal homograft anastomosis to control postoperative bleeding, and the other (anterior) occurred on the first postoperative day in the ICU for no apparent reason. Both required temporary circulatory assistance with intraaortic balloon pumping. Two patients were taken from the ICU back to the operating room to control bleeding, and one patient was taken back to repair a flail pericardial collar (the third patient with such a complication). Three patients developed temporary atrioventricular dissociation, and five patients with atrial fibrillation reverted to sinus rhythm postoperatively. Two patients developed severe signs of post-pericardiotomy syndrome, one of whom had to be reexplored for cardiac tamponade. There was only one wound infection in the 41 patient series.

Two patients died in the hospital, both in the ICU (for a
hospital mortality of 4.9%). One developed a major cerebrovascular accident on the third postoperative day from which he succumbed 10 days later. He was one of our earlier patients, and it is possible that the cause had to do with an inappropriately secured pericardial collar. The second was the youngest patient in the series (12-year-old girl) who developed acute respiratory distress syndrome and could not be weaned off the respirator until her death 8 days postoperatively. Echocardiography confirmed excellent function of the autograft in both patients throughout their ICU stay.

Follow-up was complete (for a total follow-up period of 746 months, with a mean of 18.2 months). Late mortality occurred in a total of five patients, two of whom died of causes probably not related to the procedure. One patient was readmitted to the hospital with staphylococcus endocarditis 2 months after discharge. His autograft was replaced with a mechanical prosthesis, but he succumbed to recurrent endocarditis. The cause of endocarditis in this patient could be traced back to contaminated equipment in the operating room. A second patient was readmitted 1 month postoperatively with clinical endocarditis (the causative agent could not be established). She died of multiple organ failure before her planned reoperation. A third patient was readmitted with a paravalvular leak 6 months after discharge. Subclinical endocarditis was suspected as the cause, since her autograft was functioning well prior to her readmission. Reoperation proved extremely difficult because of dense adhesions to the sternum, and the patient died from excessive uncontrollable bleeding that occurred when the pulmonary xenograft was inadvertently lacerated. Two patients died outside our hospital from causes apparently unrelated to the procedure, one from septic shock due to a severe urinary tract infection 2 months following discharge, and another from severe gastroenteritis leading to bradycardia and cardiac arrest 6 months after discharge. In both patients the autograft was functioning perfectly well when last examined.

There were two poor results. One patient (Class III) continues to have left output failure secondary to intraoperative myocardial infarction. Another patient (also Class III) is suffering from right heart failure secondary to recurrent tricuspid regurgitation after his complimentary De Vega tricuspid annuloplasty.

All the other 32 patients are asymptomatic (Class I–II). Twenty-one are in sinus rhythm. Echocardiography at the last check-up (within the last 3 months) revealed a mitral valve area ranging between 1.9 and 3.9 cm², with a mean of 2.75 ± 0.45 cm², and a mitral gradient of 2.4–10 mmHg (mean 4.9 ± 2.1 mmHg). Mitral regurgitation was nil in 21 patients, trace in seven patients, mild in three patients and moderate in one patient. The pulmonary artery systolic pressure ranged between 16 and 41 mmHg with a mean of 29.8 ± 4.2 mmHg, and the pulmonary artery gradient ranged between 0 and 30 mmHg with a mean of 9.8 ± 4.9 mmHg. Nineteen patients are now not on anticoagulants, with 13 patients either taking their temporary 3 months course or receiving submaximal anticoagulation (INR 2.0) for lone atrial fibrillation.

4. Discussion

We are convinced that a choice other than the standard mechanical prosthesis is needed to replace the rheumatic mitral valve in developing and emergent societies, where strict life-long anticoagulation is quite impractical [5]. The pulmonary autograft promises to be a good alternative, even though more follow-up is needed to prove its validity. Our experience to date encourages us to continue applying this procedure in selected cases.

The most suitable candidates for the Ross-mitral operation seem to be those patients younger than 50 years (since older patients tend to have co-morbid conditions, are less likely to tolerate a long procedure and have a less than ideal pulmonary valve structure), and those with isolated mitral disease, a sinus rhythm and a large left atrium (greater than 5 cm in diameter). The absence of severe pulmonary hypertension that, in our hands, is not compatible with a long cardiopulmonary bypass, and the negation of a previous cardiac operation with its attendant pericardial adhesions can be added to the conditions favoring a good outcome. Because no special maneuvers are required to preserve mitral-left ventricular continuity in cases of pure mitral regurgitation, the operation is simpler in this situation (where the valve can be retained) than in cases of mitral stenosis.

Although the operative technique has been more or less standardized following our first few cases, we continue to try and find ways to improve it. Our experience with autograft stenosis led us to seek the assistance of leading manufacturers of vascular prostheses to produce Dacron tubings at least as firm as the old-fashioned ones. Until we have a new product, we will continue using what we can find of the old material, or autoclaving woven non-treated tubings of the new variety.

Our recent attempt to omit the step of suturing pericardium to the adjacent atrial wall was directed at shortening the operation, as well as avoiding the mishaps that were associated with pericardial collars in some patients. Further experience with the new modification will tell if it is preferable to the ‘top-hat’ alternative. If stabilizing the proximal end of the conduit proves unnecessary, one may wonder if covering the Dacron material with pericardium is at all needed. We continue to use Dacron to close septal defects and widen outflow tracts without having to resort to anticoagulation. Since the step of covering the autograft conduit with pericardium does not, in itself, prolong the aortic crossclamp time, however, we will continue to use it as an extra precautionary measure against the all-important complication of thromboembolism.

An improvement in technique that we thought of applying
in children, and tried in the laboratory but have not yet utilized in our patients (since none except one was of pediatric age), is slitting the Dacron tubing open before the last stitches are taken on the autograft conduit proximally and distally. This would theoretically allow for enlargement of the mitral annulus with the growth of the child, a benefit that we had mistakenly thought belonged only to the aortic-pulmonary autograft.

While our hospital mortality was within an acceptable range, our late mortality was unfortunately high. This, however, was not due to the operation per se. At least two of our late deaths were due to endocarditis that probably originated in the operating room. Due to a faulty ventilation system and occasional breaks in aseptic technique we have been plagued by recurring episodes of serious nosocomial infection in our unit, of which these two patients were apparent victims. We have recently launched an aggressive program to deal with all possible sources of hospital infection which we hope will ameliorate this problem. We had to rely on histories obtained by telephone to explain the two deaths that occurred outside our hospital. It is possible that there was another source of infection beside the urinary tract that precipitated the one patient’s septic shock. It is also possible that digitalis intoxication was (at least partly) to blame for the other patient’s excessive vomiting and bradycardia. Whatever the reasons, we feel comfortably certain that the autograft itself could not be incriminated.

To get the full benefit from this operation we believe it should be coupled, in atrial fibrillation patients, with one of the recently advertised procedures developed to abort this arrhythmia [6–8]. We are presently working on choosing the method best suited for our purposes. Ideally this method should be as brief, effective and affordable as possible.

As with the classical Ross operation, the late outcome in our patients will be tempered by the fate of the right ventricular outflow-pulmonary artery graft. Although the pulmonary homograft remains the best available substitute at present, recent developments in this area promise a variety of more readily available alternatives [9] that will add further applicability and attractiveness to our operation. Of course, full endorsement of this novel approach to mitral replacement will have to wait until long-term results are available.

References


Appendix A. Conference discussion

Dr Cotrufo (Naples, Italy): In 1995 we published in the Journal of the Texas Heart Institute the implantation of a pulmonary homograft in the mitral position and the special indication was the multiple recurrence of prosthetic endocarditis. We used a technique similar to the one you described but without the employment of a Dacron tube. All the pulmonary trunk up to the bifurcation was prepared reflecting its wall in a double layer and suturing it on a free flap of autologous pericardium. The objective of preventing the fourth recurrence of endocarditis was reached, but the homograft had to be replaced one year later with a new prosthesis because of severe mitral regurgitation. So I wonder how you could observe after 59 months of follow-up such a high incidence of mitral competence.

Dr Kabbani: I am sorry, I didn’t read your paper. As I understand from you, you didn’t use a tube to stabilize the pliable homograft. So probably this is one reason why you were getting the regurgitation. Here, we have a stent, which is the reason why we don’t have regurgitation.

By the way, Yacoub and Ross performed a lot of mitral replacements with aortic and pulmonary homografts in the early 1970s.