

The Ross Operation: Initial Israeli Experience

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Abstract

Background: The need for aortic valve replacement in children and young adults poses a special problem to cardiologists and surgeons. Replacing the sick aortic valve with the patient's pulmonary valve as described by Ross has proven to be a good option in this special age group.

Objective: To review our initial experience in order to assess the short-term results.

Methods: From January 1996 to June 1999, 40 patients (age 8 months to 41 years) underwent aortic valve replacement with pulmonary autograft. Indications for surgery were congenital aortic valve disease in 30 patients, bacterial endocarditis in 5, rheumatic fever in 3, and complex left ventricular outflow tract obstruction in 3. Trans-esophageal echocardiography was performed preoperatively and post-bypass in all patients, and transthoracic echocardiography was done prior to discharge and on follow-up.

Results: There was no preoperative or late mortality. All patients remain in functional class I (New York Heart Association) and are free of complications and medication. None showed progression of autograft insufficiency or LVOT obstruction. Homograft insufficiency in the pulmonary position has progressed from mild to moderate in one patient, and three developed mild homograft stenosis.

Conclusions: The Ross procedure can be performed with good results in the young population and is considered an elegant surgical alternative to prosthetic valves and homografts.

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Replacement of a diseased aortic valve by pulmonary autograft, a procedure first described by Ross [1], has been shown to be a successful surgery both in children and adults, and to be associated with low morbidity and mortality rates [2-4]. Unlike a mechanical valve, the patient's own pulmonary valve provides a natural substitute for his malfunctioning aortic valve with good hemodynamics, minimal incidence of thromboembolism, and rare endocarditis. This option is especially attractive in the pediatric population, because the new aortic valve maintains a growth potential and may provide a long-term solution [5,6].

LVOT = left ventricular outflow tract

Table 1. Age at operation

Age	No. of patients
8 months-10 yr	7
11-20 yr	19
21-30 yr	9
31-41 yr	5

Several surgical techniques have been described for the Ross procedure. The intraluminal cylinder and root replacement are currently preferred to the subcoronary technique since they result in lower transvalvar gradients as well as less valvar regurgitation [7,8].

For all those reasons, the Ross operation has gained in popularity and is now considered to be a valuable alternative to the use of mechanical valves, xenografts and homografts for aortic valve replacement. In this report, we describe our initial experience with replacement of the aortic valve by pulmonary autograft.

Patients and Methods

Patient population

Between 1996 and 1999, 40 patients (31 male, 9 female) aged 8 months to 41 years underwent replacement of their aortic valve or root by pulmonary autograft [Table 1].

Indications for operation

Indications for surgery included congenital aortic valve disease in 29 patients, bacterial endocarditis in 5, rheumatic fever in 3, and complex LVOT obstruction in 3. Thirty-nine percent of the patients had aortic insufficiency, 18% had aortic stenosis, and 43% had stenosis and insufficiency.

Additional procedures

Eight surgical cardiac procedures had previously been performed in six patients: aortic commissurotomy in six, patent ductus arteriosus ligation in one, and repair of aortic coarctation in one. In six patients balloon valvuloplasty was carried out before the Ross operation. In three patients with subaortic tunnel narrowing, a ventriculoplasty of the left ventricular outflow (Konno procedure) was added to the procedure. In one patient presenting with severe aortic regurgitation and an aneurysm of the thoracic aorta, resection of the aortic aneurysm was done 3 months after the Ross procedure.

Operative techniques and echocardiography methodology have been described previously [9]. Briefly, the Ross procedure was carried out through a median sternotomy and on standard cardiopulmonary bypass. Initially, the pulmonary valve is inspected to ensure its normal structure and integrity. A transverse aortotomy is performed approximately 5 mm above the sino-tubular ridge followed by complete transection of the aorta. The aortic valve is then excised and the coronary ostia are cut as circular buttons. Excision of the pulmonary autograft cylinder is then carried out as described by Ross and trimmed of adventitia. The autograft is then sewn into the aortic root at the level of the aortic annulus using continuous 4-0 Polypropylene, the suture line being in the transverse plane. Punch holes are then created in the respective pulmonary autograft sinuses for anastomosis of the coronary ostia; the coronary arteries are then anastomosed using 7-0 Polypropylene. End-to-end anastomosis of the autograft to the ascending aorta is then performed using continuous 6-0 Polypropylene. The right ventricular outflow tract is reconstructed using a homograft. Preoperative and post-bypass TEE was performed in all patients. Postoperative TTE was performed prior to discharge and then on follow-up.

Right ventricular outflow tract reconstruction was performed with 39 cryopreserved pulmonary homografts, mean diameter 23.1mm (range 15–29 mm), and 1 cryopreserved aortic homograft (25 mm in diameter).

Results

Operative data

There were no perioperative or late deaths at follow-up 1–36 months (mean 12 months). Complications included bleeding in two patients, one of whom required delayed sternal closure 24 hours after surgery. Six patients developed post-pericardiotomy syndrome and were treated with aspirin and/or steroids.

Postoperative data — immediate

Evaluation on discharge showed a trivial degree of autograft insufficiency in most patients, ranging from none to mild. There was no LVOT stenosis. Similar findings were observed across the homografts at the pulmonary position.

Follow-up

Patients were followed for a mean of 12 months (range 1–36 months). There has been no late death. All patients were found to be in NYHA functional class I. None showed progression of autograft insufficiency or development of LVOT obstruction. Homograft insufficiency at the pulmonary position has progressed from mild to moderate in one patient and three developed mild homograft stenosis (Doppler gradients of 25–28 mmHg).

Discussion

Left ventricular outflow tract obstruction and aortic insufficiency in young patients pose a special dilemma to cardiologists and surgeons alike, the two major questions being how to determine the optimal time for surgery and the best aortic valve substitute to be used. The classical choice worldwide is still a mechanical prosthesis [10,11]. More recently, alternative options have evolved, namely biological valves including xenografts and homografts [12–14].

The most recent biological substitute for aortic valve replacement was described by Ross in the late 1960s [1]. In this surgery, the aortic valve is replaced by the patient's own pulmonary valve while the latter is replaced by a homograft. The superior hemodynamics of the pulmonary autograft in the aortic position, together with a virtual absence of thromboembolic complication (without the administration of anticoagulants), have been established in long-term studies by Ross and associates, who demonstrated an 85% freedom from autograft replacement at 20 years [2]. Moreover, the pulmonary autograft shows evidence of growth when in the aortic position both in an animal model [15] and in children [5,6]. On these grounds, patient-prosthesis mismatch is not expected to become a problem for the replaced aortic valve in growing children. Naturally, this is not the case for the homograft used in this surgery to replace the pulmonary valve. And indeed, re-operation following the Ross procedure has been shown necessary mostly for right-sided homograft replacement. Another advantage of the Ross operation was demonstrated in recent studies indicating that this procedure results in a more complete and rapid normalization of left ventricular function and volumes than with other aortic substitutes [16,17].

Recently, combining the Ross operation with LVOT enlargement, namely the Ross-Konno operation, was proven a feasible and highly successful solution for the relief of complex LVOT obstruction [18–21]. Children with tunnel LVOT obstruction and hypoplastic aortic annulus can benefit from aortic valve replacement, together with various techniques to enlarge the outflow tract. Three of our patients with tunnel type LVOT obstruction underwent this combined procedure successfully; all maintained their normal sinus rhythm.

Although attractive, there are some unresolved issues related to the Ross operation. Several authors [22] describe the development of aortic regurgitation during long-term follow-up, most developing without any apparent technical cause. This may reflect the inability of the autologous pulmonary valve to adapt to systemic pressure, a hypothesis that is supported by the fact that similar phenomena have been observed in up to 40% of patients following the arterial switch procedure [16]. Even if this risk is real, the hemodynamic profile of the pulmonary autograft is far better than that of any of the currently available alternatives.

The second unresolved issue is the fate of the pulmonary homograft. In this respect, the results of follow-up studies [23] on the long-term outcome of patients in whom a large

TEE = transesophageal echocardiography
TTE = transthoracic echocardiography
NYHA = New York Heart Association

variety of pulmonic valve substitutes were used are quite encouraging, with freedom from re-operation being more than 80% at 20 years. In addition, surgery for homograft replacement carries a low risk, as demonstrated by Schaff [24].

Special attention should be directed to young patients with endocarditis. In our series, we report on five patients with endocarditis. Two were young adults who presented with a history of subacute bacterial endocarditis and progressive AI. The other three were infants (aged 8–14 months) who presented with acute fulminant destructive aortic valve endocarditis on a previously healthy valve. These were otherwise healthy infants with no documented pathology in their history. All infants underwent urgent Ross operation during their acute illness. They all recovered well from surgery with no signs of re-infection on follow-up (1–20 months). All three infants were found to be in NYHA functional class I. Echocardiography during follow-up showed trivial AI, no LVOT or RVOT stenosis. For infants with acute endocarditis in need of aortic valve replacement, the Ross operation appears to provide the better solution, because in addition to its known qualities, the autograft is less susceptible to bacterial infection when compared with mechanical valves and homografts in both short- and long-term follow-up [25–29]. If normal morphology and hemodynamics are maintained, the risk of recurrent endocarditis remains low.

Lastly, our series shows that although the Ross operation is technically demanding, the learning curve of a surgeon already skilled in modern solutions for the repair of congenital heart defects can be very short, and this procedure can be safely performed in infants, children and young adults, with exceedingly low morbidity and mortality rates. The operative results, short-term clinical outcome and echocardiographic findings in our study are comparable with those of other studies [19,22,23]. Based on our experience, the Ross operation should be considered the procedure of choice in the treatment of infants with acute endocarditis. In conclusion, the Ross procedure, which is an elegant alternative to the use of prosthetic valves and homografts in the treatment of aortic valve diseases, can be performed safely in Israel with results comparable to the best tertiary care centers in the world.

References

- Ross DN. Replacement of aortic and mitral valves with pulmonary autograft. *Lancet* 1967;ii:956–8.
- Ross DN, Jackson M, Davies J. The pulmonary autograft — a permanent aortic valve. *Eur J Cardio Thorac Surg* 1992;6:113–17.
- Elkins RC. The Ross operation. *Semin Thorac Cardiovasc Surg* 1996;8:345–9.
- Kouchoukos NT, Davila-Roman VG, Spray TL, Murphy SF, Perrillo JB. Replacement of the aortic root with pulmonary autograft in children and young adults with aortic valve disease. *N Engl J Med* 1994;330:1–6.
- Schoof PH, Cromme-Dijkhuis AH, Bogers JJ. Aortic root replacement with pulmonary autograft in children. *J Thorac Cardiovasc Surg* 1994;57:367–73.
- Elkins RC, Knott-Craig CJ, Ward KE. Pulmonary autograft in children: realized growth potential. *Ann Thorac Surg* 1994;57:1387–94.
- O'Brien MF. Aortic valves implantation techniques. Should they be any different for the pulmonary autograft and the aortic homograft?. *J Heart Valve Dis* 1993;4:385–7.
- Daicoff GR, Botero LM, Quintessenza JA. Allograft replacement of the aortic valve versus the miniroot and valve. *Ann Thorac Surg* 1993;55:855–9.
- Rubay JE, Sluysmans T. The pulmonary autograft. *Semin Thorac Cardiovasc Surg* 1996;8:362–8.
- Baudet EM, Puel V, McBride JT. Long term results of valve replacement with the St-Jude medical prosthesis. *J Thorac Cardiovasc Surg* 1995;109:858–70.
- Laske A, Jenni R, Maloigne M, Bertel O, Turina M. Pressure gradients across bileaflet aortic valve by direct measurement and echocardiography. *Ann Thorac Surg* 1996;10:1097–106.
- Jaffe WM, Coverdale HA, Roche AHG, Whilock RML, Barratt-Boyes BG. Rest and exercise hemodynamics of 20–23mm allograft, Medtronic intact (porcine) and St-Jude medical valves in aortic position. *J Thorac Cardiovasc Surg* 1990;100:167–74.
- Sanders SP, Levy RJ, Freed MD. Use of Hancock porcine xenograft in children and adolescents. *Am J Cardiol* 1980;46:429–38.
- Clarke DR, Campbell DN, Hayward AR, Bishop DA. Degeneration of aortic allografts in young recipients. *J Thorac Cardiovasc Surg* 1993;105:934–42.
- Schoof PH, Hazekamp MG, Van Wermeskerken GK. Disproportionate enlargement of the pulmonary autograft in the aortic position in the growing pig. *J Thorac Cardiovasc Surg* 1998;115:1264–72.
- Jenkins KJ, Hanley FL, Colan SD, Mayer JE, Castaneda AR, Wernovsky G. Function of the anatomic pulmonary valve in the systemic circulation. *Circulation* 1991;84:173–9.
- Hasegawa J, Kitamura S, Taniguchi S. Comparative rest and exercise hemodynamics of allograft and prosthetic valves in aortic position. *Ann Thorac Surg* 1997;64:1753–6.
- Konno S, Imai Y, Nakajima M, Tatsuno K. A new method of aortic valve replacement in congenital aortic stenosis associated with hypoplasia of the aortic valve ring. *J Thorac Cardiovasc Surg* 1975;70:900–17.
- Daenen WJ. Repair of complex left ventricle outflow tract obstruction with a pulmonary autograft. *J Heart Valve Dis* 1995;4:364–7.
- Starnes VA, Battista Luciani G, Welles WJ, Allen RA, Lewis AB. Aortic root replacement with the pulmonary autograft in children with complex left heart obstruction. *Ann Thorac Surg* 1996;62:442–9.
- Reddy VM, Rajasinghe HA, Teitel DF, Haas GS, Hanley FL. Aortoventriculoplasty with the pulmonary autograft: the “Ross-Konno” procedure. *J Thorac Cardiovasc Surg* 1996;111:158–67.
- Rubay JE, Buche M, ElKhoury GA, Vanoverschelde JL, Sluysmans T, Marchandise B, Schoevaertds JC, Dion RA. The Ross operation: mid term results. *Ann Thorac Surg* 1999;67:1355–8.
- Chambers JC, Somerville J, Stone S, Ross DN. Pulmonary autograft procedure for aortic valve disease. Long term results for the pioneer series. *Circulation* 1997;96:2206–14.
- Schaff HV, DiDonato RM, Danielson GK. Reoperation for obstructed pulmonary ventricle-pulmonary artery conduits: early and late results. *J Thorac Cardiovasc Surg* 1984;88:334–43.
- Joyce F, Tingleff J, Aagaard J, Petterson G. The Ross operation in the treatment of native and prosthetic valve endocarditis. *J Heart Valve Dis* 1994;3:371–6.
- Oswalt JT. Management of aortic infective endocarditis by autograft valve replacement. *J Heart Valve Dis* 1994;3:377–9.
- Elkins RC, Knott-Craig CJ, Randolph JD, Razook JR, Ward KE, Overholt ED, Lane MM. Medium term follow up of pulmonary autograft replacement of aortic valve in children. *Eur J Cardiovasc Surg* 1994;8:379–83.
- Haydock D, Barrrt-boyes B, Macedo T, Kirklin JW, Blackston E. Aortic valve replacement for active infectious endocarditis in 108 patients. *J Thorac Cardiovasc Surg* 1992;103:130–9.
- McGiffin DC, Galbraith AJ, MacLachlan GJ, Stower RE, Wong ML, Stafford EJ, Gardner MAH, Phioner PG, O'Brien MF. Aortic valve infection. Risk factors for death and recurrent endocarditis after aortic valve replacement. *J Thorac Cardiovasc Surg* 1992;104:511–20.

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RVOT = right ventricular outflow tract