

# The Ross Procedure as the Surgical Treatment of Active Aortic Valve Endocarditis

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**Background and aim of the study:** The authors' experience is reported of aortic valve replacement (AVR) using the pulmonary autograft in patients with active aortic valve endocarditis, including an urgent Ross procedure in infants with the acute condition. **Methods:** Nine patients aged between 8 months and 38 years, with a diagnosis of aortic valve endocarditis, have undergone AVR using the Ross procedure at the authors' institution since October 1997. The diagnosis was established by clinical and echocardiographic findings. Indications for surgery were severe aortic insufficiency and congestive heart failure in all patients, with the addition of thromboembolic events (n = 3), persistent hyperpyrexia (n = 3) and vegetations (n = 5). Four infants with no history of congenital cardiac malformation underwent urgent surgery because of acute bacterial endocarditis and rapid hemodynamic deterioration. Blood cultures were positive for *Streptococcus pneumoniae* in three patients, and *Kingella kingi* and *Staphylococcus aureus* in one patient each. Four patients were culture-negative. All patients were treated with intra-

The Ross procedure has gained increased popularity in the treatment of children and young adults who require aortic valve replacement (AVR). Its advantages include growth potential, expected long-term durability of the pulmonary autograft in the aortic position, and freedom from the need for anticoagulation therapy (1).

As experience with the Ross procedure increased, the indications were expanded to high-risk patients, such as children with myocardial dysfunction, and

venous antibiotics for four to six weeks postoperatively.

**Results:** There were no perioperative or late deaths, and no recurrent endocarditis at the implanted valves. Echocardiographic evaluation at discharge showed trivial to mild aortic insufficiency, with no stenosis at the left ventricular outflow tract. Similar findings were found across the right ventricular outflow tract. At follow up (range: 4 months to 5.5 years), none of the patients showed progression of aortic valve insufficiency or developed stenosis; three had mild and moderate homograft stenosis (Doppler gradient 20-40 mmHg), and all children had moderate homograft insufficiency.

**Conclusion:** The Ross procedure is an excellent therapeutic option for active aortic valve endocarditis in young patients, and demonstrates low morbidity and mortality. Early surgery may be indicated in patients with acute aortic valve endocarditis because of the rapidly progressive nature of this disease.

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also to young patients with complex obstruction of the left ventricular outflow tract (LVOT) in whom the Ross procedure is combined with the Konno aortoventriculoplasty. A few reports have also described use of the Ross procedure in children with aortic valve endocarditis (2-5).

Aortic valve endocarditis occurs rarely in children and young adults. Subacute endocarditis may lead to progressive aortic insufficiency requiring AVR. The acute form of this disease may cause a rapid destructive process, leading in turn to congestive heart failure and death, despite appropriate antibiotic treatment. In such cases, surgical treatment includes radical debridement of all infected tissue followed by aortic root replacement with either a composite graft, a homograft, or the Ross procedure (6-9).

The use of the Ross procedure has been suggested also in young patients with active endocarditis (10-13).

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In addition to the qualities of the homograft, the living autograft was expected to provide growth potential, better durability, and greater resistance to recurrent infection, which would not change over time. Yet, it is not clear if seriously ill patients with acute endocarditis will tolerate this complex procedure, and what would be the risk of pulmonary autograft infection when using the Ross procedure for active endocarditis. Herein, the present authors' experience is reported with AVR using the pulmonary autograft in patients with active aortic valve endocarditis, including an urgent Ross procedure performed in infants with the condition in its acute form.

## Clinical material and methods

### Patients

Between October 1997 and December 2002, nine patients with a diagnosis of active bacterial endocarditis affecting the aortic valve underwent AVR with a pulmonary autograft (Ross procedure) at the Schneider Children's Medical Center of Israel. The patients (four males, five females) had a median age of 13 years (mean  $14.5 \pm 13.8$  years; range: 8 months to 38 years), and four were aged less than two years.

A diagnosis of endocarditis was based on clinical findings, symptoms, two-dimensional echocardiography and blood cultures, and confirmed by the operative findings.

Five patients were reported to be in good health prior to hospital admission, and were reported not to have any heart murmur or cardiac anomaly. In addition, four patients had known cardiac disease prior to admission (three with rheumatic heart disease, one with a subaortic membrane with a fibromuscular left ventricular tunnel obstruction). The latter patient underwent anterior aortoventriculoplasty (Konno) in addition to the Ross procedure.

Indications for surgery were severe aortic insufficiency and congestive heart failure in all patients, with the addition of thromboembolic events ( $n = 3$ ), persistent hyperpyrexia ( $n = 3$ ) and vegetations ( $n = 5$ ). Four infants with no history of congenital cardiac malformation underwent urgent surgery because of acute bacterial endocarditis and rapid hemodynamic deterioration.

Blood cultures were positive for *Streptococcus pneumoniae* in three patients, and *Kingella kingi* and *Staphylococcus aureus* in one patient each. Four patients were culture-negative. All patients were treated with intravenous antibiotics for up to six weeks after surgery.

The initial diagnoses were made using two-dimensional echocardiography. None of the patients underwent diagnostic cardiac catheterization, and all were

assessed with intraoperative transesophageal echocardiography.

### Surgical approach

Using the basic operative technique and echocardiography methodology described previously (14), the operative technique included standard cardiopulmonary bypass (CPB) with moderate hypothermia, and multidose antegrade and retrograde blood cardioplegia. The aortic valve was inspected; special attention was directed to complete debridement of all infected and necrotic tissue. The pulmonary trunk was then opened distally through a transverse incision. The pulmonary wall and valve was inspected, and none was seen to be involved in the septic process. If normal, the tissue was explanted as a pulmonary autograft. The pulmonary autograft was implanted using a continuous suture technique, with the right ventricular outflow tract (RVOT) reconstruction being performed using a cryopreserved pulmonary homograft, the sizes of which ranged from 14 to 29 mm (median 23 mm).

The mean CPB time was  $190 \pm 27$  min (range: 149 to 243 min), and the mean aortic cross-clamp time  $157 \pm 20$  min (range: 128 to 193 min). The surgical findings are presented in Table I.

## Results

There were no perioperative deaths. The median hospital stay was 9 days (range: 7 to 37 days). There was no recurrent endocarditis at the implanted valves. Three patients presented with acute endocarditis and brain infarcts, but each showed complete recovery of neurological symptoms within 20 months after surgery. No new postoperative neurological impairments were seen to develop postoperatively. All patients were administered antibiotic therapy for between four and six weeks after surgery. Echocardiographic evaluation at discharge from hospital showed the presence of trivial to mild aortic insufficiency, with no stenosis

Table I: Surgical and pathological findings in patients.

Pathology/finding	No. of patients
Distortion with or without tear of aortic valve cusps	9
Vegetation	5
Annular abscess (septal, aorticomitral continuity)	2
Invasion of aortic free wall	1
Unicuspid valve with 7-8 mm opening, severe subaortic tunnel-type obstruction	1

at the LVOT. Similar findings were found across the RVOT.

The mean follow up was  $3.8 \pm 1.6$  years (range: 8 months to 6.5 years). There were no late deaths, and no recurrent endocarditis. At the latest clinical follow up examination, all patients were in NYHA functional class I. No repeat operations for either autograft or homograft failure were necessary, and no other valve-related complications were identified. The most recent echocardiographic findings are summarized in Table II.

## Discussion

Among the small group of patients in the present study, active aortic valve endocarditis presented either as an acute destructive bacterial endocarditis of a normal aortic valve, or as a subacute endocarditis of a previously abnormal aortic valve. These types of infection are rarely be eradicated medically, and consequently surgery frequently becomes a necessity. The two major problems which arise in such situations are first, what is the best valve to be used at surgery, and second, what is the best timing for performing the surgery?

Aortic valve replacement in the young population (age range from infants to young adults) has changed during the past decade from surgery with a relatively high intraoperative risk (15-17) to one which carries a risk approaching that encountered in adults (18-20). Currently available options for AVR include a mechanical valve, a bioprosthetic valve, an aortic homograft, and the Ross procedure.

Due to the early calcification and valve dysfunction associated with bioprosthetic valves, mechanical valves are now used in most centers - especially when aortic valve endocarditis is limited to the valve leaflets. The difficulty is that this option requires lifelong anticoagulation, demonstrates enhanced development of bacterial endocarditis (21), displays suboptimal hemodynamic performance (especially in small valve sizes)

(21,22), and is also hindered by the fact that mechanical prosthetic valves are not available in the very small sizes required for infants and children.

The option of an aortic homograft for aortic root replacement shows a good hemodynamic profile with a low incidence of thromboembolism and endocarditis, and does not require the postoperative use of anticoagulants. However, valve degeneration leading to early reoperation occurs more often in children than in older patients (23,24).

The pulmonary autograft (Ross operation) provides a vital, normal semilunar valve which can grow with the patient (4,25), has long-term durability, has a low incidence of thromboembolism and endocarditis, and does not require anticoagulation. Moreover, the autograft appears to be endocarditis-resistant both in the short and long term (3,5,13) when compared with mechanical valves and homografts (7,27). The viability of the autograft should make it resistant to early endocarditis and, if normal morphology and hemodynamics are maintained, the risk of recurrent endocarditis remains low. It therefore appears that, at present, the Ross procedure offers the best solution available for children requiring AVR. The primary reasoning for using the Ross operation in endocarditis is the same in both young adults and children.

One major key to the success of surgical treatment for endocarditis is the complete removal of all bacteria-harboring and non-vital tissue. This is more safely and effectively accomplished by the removal of both pulmonary and aortic roots. Moreover, total exposure of the infected area prevents the possibility of leaving closed-off cavities behind. Applying the same logic, if the pulmonary artery wall or valve appears to be infected, then the Ross procedure should not be carried out. In the presence of an active acute infection there is a theoretical risk of infecting uninvolved tissue such as the autograft. This did not occur in any of the present patients, including those young children who presented for surgical treatment during active sepsis.

Recent reports have shown that the Ross operation can be performed successfully in patients with aortic valve endocarditis, even in those who are severely ill and have serious preoperative complications (10-13).

All of the present patients met one or more of the well-defined indications for operation in aortic valve endocarditis (26), including progression of aortic insufficiency due to destruction of the valve, development of congestive heart failure with hemodynamic compromise, persistent sepsis despite antibiotic treatment, systemic embolization, large mobile vegetations, or aortic root abscesses. Today, it is believed that such patients should be operated on early in the disease process because of its highly destructive nature. The aortic root tends to become rapidly involved, and this

Table II: Follow-up echocardiographic findings among patients.

Valve/lesion	Doppler findings	No. of patients
Aortic stenosis		0
Aortic insufficiency	Trivial	8
	Mild	1
Pulmonary stenosis	None	3
	Mild (<30 mmHg)	4
	Moderate (40 mmHg)	2
Pulmonary insufficiency	Mild	5
	Moderate	4
Mitral stenosis	Mild	1
Mitral insufficiency	Mild	1

makes the operation much more complex. Moreover, when large mobile vegetations present, systemic embolization is simply a matter of time. Close observation with repeated echocardiographic follow up should identify high-risk patients such as those with vegetations and those who develop aortic root abscess.

In the presence of active infection and sepsis, some surgeons favor a simpler operation. In this respect, some concerns have been expressed regarding the Ross procedure, since it is more difficult to perform and also more time-consuming than the homograft AVR. In addition, it may also potentially convert a single-valve disease into a double-valve disease and, in the past - according to the Ross registry - it was associated with a higher perioperative mortality and morbidity when compared with other options of AVR (28). However, the present authors, in full agreement with others (29-31), believe that the advantages of the Ross procedure outweigh its disadvantages, especially in children and young adults. It has been shown (9,12,13) that even in patients with endocarditis, ongoing sepsis and hemodynamic instability, the infection can be effectively eradicated by a combination of complete surgical removal of the infected tissue and appropriate antibiotics. Indeed, sepsis should not be considered a contraindication to the Ross procedure.

*In conclusion*, the Ross procedure can be safely performed in children and young adults with bacterial endocarditis, even during the acute, active phase, and provide good medium-term results. The complexity of managing aortic root endocarditis may limit the use of the procedure by surgeons who have performed a large number of these procedures with low morbidity and mortality. Nonetheless, the ultimate value of the Ross procedure in young patients with endocarditis will be determined by its long-term results.

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