Early and long-term results of reoperative total aortic root replacement with reimplantation of the coronary arteries

Ismail El-Hamamsy, MD, PhD,^{a,c} Michael Ibrahim, BA (Cantab),^c Louis-Mathieu Stevens, MD,^b Herbert Witzke, MD,^c Lucy Clark, PhD,^c and Magdi H. Yacoub, FRS^c

Background: Total root replacement with biologic valves and reimplantation of the coronaries gives good early and midterm results. There is continuing concern, however, regarding the risks and long-term results for reoperation after total replacement of the aortic root with reimplantation of the coronaries.

Methods: Between June 1981 and July 2010, a total of 84 patients underwent reoperative aortic root replacement with reimplantation of the coronaries (60 male, mean age 38 ± 15 years). All patients had undergone first-time total aortic root replacement with homografts (82 patients) or autografts (2 patients). Indication for reoperation was structural valve deterioration in 72 patients (85%) and infective endocarditis in 12 patients (15%). Mean interval between first operation and reoperation was 11.1 ± 4.7 years (range, 1 month–24.7 years). Median length of follow-up was 9.7 ± 5.6 years (range, 1 month–24.4 years).

Results: Thirty-day mortality was 2.4% ($n = 2$ patients). Both patients died postoperatively of low-output syndromes with multiorgan failure. At reoperation, 74 patients received homografts (87%), 7 patients underwent a Ross procedure (9%), and 3 received stentless porcine roots (4%). One patient required pacemaker implantation (1%). Actuarial survivals were $89\% \pm 4\%$ and $81\% \pm 5\%$ at 5 and 10 years, respectively. Nine patients underwent a successful third root replacement during follow-up. Freedom from third-time aortic root operation was $97\% \pm 3\%$ at 10 years.

Conclusions: Reoperative aortic root replacement can be performed safely with good short-term and midterm outcomes in a young patient cohort. (*J Thorac Cardiovasc Surg* 2011;142:1473-7)

The aortic root performs several sophisticated functions that can directly influence coronary blood flow, ventricular workload, and the magnitude and distribution of stress on valve cusps.¹ Optimal function of the aortic root depends on the structural integrity of its constituent parts: the valve, the annulus, the sinuses of Valsalva, and the sinotubular junction.²⁻⁴ This complexity has prompted us to perform total aortic root replacement with coronary artery reimplantation in patients with aortic valve or root disease. In addition to maintaining the structural unity of the aortic root, this approach maximizes valve effective orifice area, an important determinant of long-term prognosis, particularly in patients with poor left ventricular function.⁵⁻⁸

The technique of the first root replacement operation has become standardized particularly in relation to the placement of the coronary arteries without tension, torsion, or kinking. Furthermore, progressive dilation of the biologic root has not been observed after this operation. Although first root replacement is associated with good outcomes, with an operative mortality of approximately 1% to 5%,⁹⁻¹² there is continuing concern about the risk of reoperation in these patients in both the short and longer terms. The objectives of this study were therefore to evaluate the safety of repeat total aortic root reoperation with coronary reimplantation in patients with previous root replacement and also to assess the durability of implanted roots. Primary outcomes were operative mortality and morbidity, and secondary outcomes were late survival and freedom from third operation.

MATERIALS AND METHODS

Patient Population

From 1981 to 2010, a total of 84 patients underwent second-time reoperative total aortic root replacement after initial total aortic root replacement. All operations were performed by a single surgeon (M.H.Y.). Any patient whose first or second operation was not a total root replacement was excluded from this analysis. Data were collected prospectively and analyzed retrospectively. This study was approved by the internal review board, and individual patient consent for data analysis was waived. Patients were followed up with yearly visits to the outpatient clinic, where they were assessed clinically and echocardiographically. In addition, all living patients were contacted by telephone to rule out any sudden deterioration since the last clinic visit.

From the Department of Cardiac Surgery,^a Montreal Heart Institute, and the Centre Hospitalier de l'Université de Montréal (CHUM),^b University of Montreal, Montreal, Quebec, Canada; and the Department of Cardiothoracic Surgery,^c Royal Brompton and Harefield NHS Trust and Imperial College London, London, United Kingdom.

I.E.H. and L.M.S. were supported by Fellowship Awards from the Canadian Institutes for Health Research (CIHR). M.I. is supported by an MB-PhD Studentship from the British Heart Foundation.

Disclosures: Authors have nothing to disclose with regard to commercial support. I.E.H. and M.I. contributed equally to this article.

Received for publication Dec 15, 2010; revisions received March 15, 2011; accepted for publication April 6, 2011; available ahead of print May 11, 2011.

Address for reprints: Magdi H. Yacoub, FRS, Harefield Hospital, Hill End Rd, London, UK, UB9 6JH (E-mail: m.yacoub@imperial.ac.uk).

0022-5223/\$36.00

Copyright © 2011 by The American Association for Thoracic Surgery

doi:10.1016/j.jtcvs.2011.04.004

Operative outcomes were available for all 84 patients undergoing reoperation. Of the 84 patients, 7 were residents of foreign countries and were therefore unavailable for long-term follow-up. The preoperative characteristics of these 7 patients did not differ from those of the rest of the cohort in terms of age (39.2 ± 12.0 years vs 37.8 ± 14.9 years, $P > .99$), comorbidities and logistic EuroSCORE ($17.4\% \pm 4.2\%$ vs $14.2\% \pm 3.5\%$, $P = .7$). Thus overall completeness of follow-up was 93%, with a median length of follow-up after reoperative root implantation of 9.7 ± 5.6 years (range, 1 month–24.7 years).¹³

Operative Technique

The technique for total root replacement has been previously described.¹² Briefly, the cardiopulmonary bypass strategy is chosen according to the proximity of the aorta and the right ventricle to the sternal back wall, as indicated by imaging. If sternal opening appears risky, femoral bypass is commenced before opening the sternum to cool the patient to 30° before opening the chest. The aortic valve cusps are then completely excised, and the aortic annulus thoroughly decalcified, avoiding trauma to the coronaries. In this experience, calcification never extended into the coronary ostia. Single interrupted sutures are used for the proximal anastomosis. No foreign material is used to reinforce either anastomosis. No glue is used. The coronary anastomosis is performed with continuous 5-0 Prolene sutures (Ethicon, Inc, Somerville, NJ). Neither pericardium or polytetrafluoroethylene is used to support the anastomoses. For the Ross procedure, after reimplantation of the autograft root, a pulmonary homograft is implanted in the right ventricular outflow tract with the largest possible homograft.¹⁴ Cold antegrade blood cardioplegia through the coronaries and topical cooling with ice is our preferred technique for myocardial protection. We have not used mechanical valve Bentall operations as the preferred root substitution, for which we use biologic replacements because of their superior hemodynamics, reduced risk of thromboembolism, and lower risk of second and third operations.

Statistical Analysis

Continuous variables are expressed as mean $\pm$ SD, whereas discrete variables are expressed as numbers and percentages. Actuarial survival was estimated with the Kaplan-Meier method. All statistical analyses were performed with SAS statistical software package release 9.1 (SAS Institute Inc, Cary, NC).

RESULTS

Patient Characteristics

Patient characteristics are presented in Table 1. Mean age at time of first aortic root reoperation was 38 ± 15 years (range, 8–73 years; Figure 1). Ten patients (12%) required either urgent or emergency reoperation. Mean logistic EuroSCORE for all patients was $22\% \pm 11\%$. Apart from the previous initial root replacement, our patients had undergone a total of 34 operations before second-time root replacement, as described in Table 2. Seven patients had undergone 2 ($n = 2$) or more ($n = 5$) previous homograft insertions not involving total root replacement with reimplantation of the coronaries.

Initial aortic root replacement was performed with a homograft in 82 patients (98%) and an autograft (Ross procedure) in 2 patients (2%). The indications for reoperation were structural valvular deterioration in 72 patients (85%) and infective endocarditis in 12 patients (15%). Mean interval between first operation and reoperation was

TABLE 1. Patient characteristics (N = 84)

Height (cm, mean $\pm$ SD)	158 $\pm$ 41
Weight (kg, mean $\pm$ SD)	66 $\pm$ 24
Age (y)	38 $\pm$ 15
Logistic EuroSCORE (% , mean $\pm$ SD)	22% $\pm$ 11%
Comorbidities	
Hypertension (no.)	4 (4.9%)
Hypercholesterolemia (no.)	1 (1.2%)
Familial coronary artery disease (no.)	1 (1.2%)
Renal failure* (no.)	2 (2.4%)
Previous cerebrovascular accident (no.)	1 (1.2%)
Peripheral vascular disease (no.)	1 (1.2%)
New York Heart Association functional class III or IV (no.)	31 (38%)
Left ventricular ejection fraction <50% (no.)	7 (8%)
Previous intervention	
Homograft (no.)	82 (98%)
Ross (no.)	2 (2%)
Surgical indication	
Structural valve deterioration† (no.)	72 (85%)
Infective endocarditis (no.)	12 (15%)

*Renal failure was defined as a Cockcroft-Gault creatinine clearance of less than 50 mL/min. †Aortic insufficiency in 38 patients.

11.1 ± 4.7 years (range, 1 month–24.7 years). Median length of follow-up was 9.7 ± 5.6 years (range, 1 month–24.4 years). At reoperation, 74 patients underwent homograft root replacement (88%), 7 patients underwent a Ross procedure (8%), and 3 patients underwent placement of a stentless xenograft root (4%) with a Medtronic Freestyle prosthesis (Medtronic Inc, Minneapolis, Minn; Table 3). Concomitant procedures were required in 25

FIGURE 1. Age distribution at first reoperation.

TABLE 2. Total previous cardiac procedures

Coarctation repair	4
Repair of subaortic stenosis	2
Subaortic ring insertion	1
Aortic valvotomy	14
Mitral valve replacement	1
Ventricular septal defect repair	1
Aortic cusp extension	1
Valvotomy and ventricular septal defect repair	1
Triple homograft replacement (subcoronary implants)	2
Double homograft replacement (subcoronary implants)	5

Data represent numbers of individuals who underwent a given procedure.

patients (30%). All coronary artery bypass grafting surgeries, except 1 (below), were planned because of preexisting atherosclerotic coronary artery disease.

Operative Mortality

Thirty-day mortality was 2.4% (n = 2 patients). Surgical indication was structural valve deterioration of the homograft root in both cases. Both patients were in clinically unstable condition before surgery, with preoperative logistic EuroSCOREs of 54% and 12%. The first patient was aged 7 years at the time of reoperation and underwent a Ross procedure. She had low cardiac output syndrome despite maximal inotropic support early after surgery. She underwent heart transplantation on day 11 but died shortly thereafter of irreversible multiorgan failure. The second patient was a 26-year-old man in New York Heart Association functional class IV at reoperation. Homograft root replacement with challenging coronary reimplantation was performed. After weaning from bypass, he had severe right heart failure. A venous graft was performed to the right

TABLE 3. Operative outcomes following first aortic root reoperation (N = 84)

Operative mortality (no.)	2 (2.4%)
Reoperative intervention (no.)	
Homograft	72 (88%)
Ross	7 (8%)
Stentless root (Freestyle*)	3 (4%)
Concomitant procedures (no.)	
Coronary artery bypass grafting (all elective)	10 (12%)
Mitral valve repair or replacement	15 (18%)
Cardiopulmonary bypass time (min, mean ± SD)	141 ± 55
Crossclamp time (min, mean ± SD)	97 ± 31
Operative complications (no.)	
Bleeding†	5 (6%)
Sternal infection	2 (2.4%)
Renal failure‡	1 (1.2%)
Prolonged ventilation§	3 (3.7%)
Heart block	1 (1.2%)
Atrial fibrillation	6 (7%)

*Medtronic Inc, Minneapolis, Minn. †Defined as bleeding requiring reexploration. ‡Renal failure requiring hemofiltration. §Ventilation for longer than 24 hours.

coronary artery; however, the patient subsequently died of multiorgan failure on postoperative day 16.

Operative Morbidity

The prevalences of complications are listed in Table 3. Five patients required reexploration for bleeding (6%). One patient had renal failure requiring hemofiltration (1%) and later died (as described previously). One patient had complete heart block after surgery requiring pacemaker implantation (1%). No patients had perioperative myocardial infarction or stroke.

Late Outcomes

Survival. Actuarial survivals were 89% ± 4% and 81% ± 5% at 5 and 10 years, respectively (Figure 2). Eighteen patients died during the follow-up period. The mean interval between reoperation and death was 6.6 ± 5.1 years (range, 11 days–16.4 years). Nine deaths were cardiac related: 5 of heart failure, 1 of myocardial infarction, and 3 of sudden cardiac death. Nine deaths were not cardiac related.

Freedom from reoperation. Actuarial freedom from additional reoperation was 97% ± 3% at 10 years (Figure 3). Of the 77 patients with late follow-up, 9 patients required a second aortic root reoperation (Table 4). The mean interval between first and second aortic root reoperations was 11.4 ± 3.4 years. Eight patients underwent reoperation for homograft structural valve deterioration and 1 patient underwent reoperation after autograft root dilatation with accompanying moderate regurgitation and progressive left ventricular enlargement. All patients underwent successful stentless xenograft total root reimplantation with Medtronic Freestyle prostheses. There were no associated deaths.

Functional status. At latest follow-up, mean left ventricular end-diastolic diameter was 50.2 ± 23.6 mm and mean left ventricular ejection fraction was 68.7% ± 14.2%. Four patients were in New York Heart Association

FIGURE 2. Actuarial survival after first aortic root reoperation.

ACD

FIGURE 3. Actuarial freedom from second aortic root reoperation after first aortic root reoperation.

functional class III (3 patients) or IV (1 patient) at latest follow-up, 2 of them with severe chronic obstructive pulmonary disease. Average aortic regurgitation grade was 1.05 ± 0.03 , with only 3 patients having severe aortic regurgitation. These patients are currently awaiting surgery.

DISCUSSION

This study defines the pattern of early and midterm survival and freedom from second reoperation after reoperative aortic root surgery. The current results demonstrate that reoperative replacement of the aortic root with coronary artery reimplantation after initial aortic root replacement can be performed safely with a low operative mortality in a cohort of relatively young patients. The small number of older patients showed similarly good short-term and midterm outcomes. It is important, however, to intervene as early as possible to minimize the operative risk. This operative risk compares favorably with that of first-time aortic root operation, which ranges from 1% to 5% according to various reports.⁹⁻¹² As illustrated in this series, a critical determinant of outcomes in reoperative cases is operative timing, which determines the patient's preoperative status. Surgery on patients in

severe heart failure is associated with high perioperative morbidity and mortality. This is illustrated by the wide variability in reported mortality associated with aortic root reoperation, which ranges from 0% to 17.9%.¹⁵⁻²¹ Series involving emergency or urgent operations or patients in New York Heart Association class III or IV tend to have higher mortalities. In this series, both perioperative deaths occurred early in the series, and both were of patients who were referred late and in a clinically unstable condition. If patients are operated on in a timely fashion, operative risks can be reduced further. This is a critical point worth emphasizing to our cardiology colleagues.

Careful surgical planning and operative technique are important technical keys to the success of this operation. Preoperative imaging provides important clues regarding the proximity of the ascending aorta to the sternum. In cases where the aorta appears closely adherent to the sternum, the femoral arteries should be exposed and prepared for cannulation. In high-risk patients, femorofemoral bypass is instituted before opening the sternum. Coronary artery mobilization can be challenging in aortic root reoperations, especially with homografts because of the high calcification burden. The placement of coronary venous interposition grafts has been suggested and described in as many as 48% of cases in some series.²² In our experience, we have found that calcification almost never extends into the coronary button or arteries and that limited, careful mobilization can be performed safely.²³ It is essential, however, that the coronaries be reimplanted without torsion, tension, or kinking. Meticulous decalcification with removal of all previous suture material should be performed to facilitate this. We previously reported the insertion of a prosthetic valve within an existing aortic homograft as a bailout procedure²⁴ or for those with a noncalcified root and valvular pathology. Reoperative total root replacement has become our favored approach, however, and was used in all cases in this series.

Most reoperations in this series were for homograft aortic root degeneration, which is often associated with heavy calcification of the aortic wall or cusps.²⁵ In recent years, stentless xenograft roots have been increasingly used and have been

TABLE 4. Characteristics of patients requiring second aortic root reoperation after first aortic root reoperation

Age at reoperation (y)	Initial intervention	Reintervention	Interval between 2nd and		Indication for 3rd operation
			3rd operations (y)		
35	Homograft	Homograft	13		Endocarditis
29	Homograft	Homograft	4		SVD
32	Homograft	Homograft	8		SVD
20	Ross	Homograft	11		SVD
47	Homograft	Homograft	15		SVD
26	Homograft	Homograft	11		SVD
55	Homograft	Homograft	13		SVD
48	Homograft	Homograft	15		SVD
29	Homograft	Homograft	14		SVD

SVD, Structural valve deterioration.

shown to provide better durability than homografts.¹¹ Importantly, the degree of calcification in these xenograft roots appears to be significantly lower than in homografts,⁵ in large part because of their pretreatment with anticalcification agents such as α -amino oleic acid to mitigate aortic cusp and wall calcification. Consequently, the added technical challenge associated with the heavy calcium burden in homografts is decreased in these cases. Calcification is almost never an issue in cases of autograft root reoperations. In addition, with timely reintervention, the autograft valve can be spared²⁶; alternatively, the full root should be replaced.

Freedom from a second aortic reoperation after the first aortic root reoperation in this series was 97% at 10 years. This is all the more significant in that the vast majority of patients underwent homograft root replacement at both first and second operations. Homograft failure is thought to be due to direct and indirect immune reactions elicited by the persistence of living cells and protein remnants on the homograft cusps and wall, raising concerns about accelerated degeneration after repeated homograft implantation in presensitized hosts.^{27,28} In this limited series, homograft durability did not seem to be compromised by these considerations. Our series spans a long period (1981–2010), and the superiority of the autograft root was not established. Indeed, a recent randomized, control trial has addressed this issue.¹¹ Currently, the Ross operation is our preferred option in this age group.

This study has some limitations. Only patients undergoing reoperation were assessed for this study, which may have introduced a selection bias. In this series, however, no patient was refused reoperation because of severity of heart failure. The completeness of follow-up was 93% because a number of patients returned to their countries of origin and were subsequently unavailable for follow-up (n = 7).

In conclusion, this study supports the notion that aortic root reoperation with coronary reimplantation after an initial aortic root operation can be performed safely and with satisfactory long-term results if performed in a timely fashion. This finding supports the contention that aortic root replacement for a first-time operation should not be avoided in patients with a high likelihood of requiring reoperation. It is thought that with newer generation stentless xenografts the technical challenge of reoperation after aortic root replacement might be further decreased than with homografts because of lower rates of root calcification. Continued follow-up of these patients is required to validate the good long-term outcomes after reoperative surgery.

References

1. Yacoub MH, Kilner PJ, Birks EJ, Misfeld M. The aortic outflow and root: a tale of dynamism and crosstalk. *Ann Thorac Surg*. 1999;68(3 Suppl):S37-43.
2. Yacoub MH, Cohn LH. Novel approaches to cardiac valve repair: from structure to function: Part II. *Circulation*. 2004;109:1064-72.
3. Yacoub MH, Cohn LH. Novel approaches to cardiac valve repair: from structure to function: Part I. *Circulation*. 2004;109:942-50.
4. Lansac E, Lim HS, Shomura Y, Lim KH, Rice NT, Goetz WA, et al. Aortic root dynamics are asymmetric. *J Heart Valve Dis*. 2005;14:400-7.
5. Lim E, Ali A, Theodorou P, Sousa I, Ashrafian H, Chamageorgakis T, et al. Longitudinal study of the profile and predictors of left ventricular mass regression after stentless aortic valve replacement. *Ann Thorac Surg*. 2008;85:2026-9.
6. Ruel M, Al-Faleh H, Kulik A, Chan KL, Mesana TG, Burwash IG. Prosthesis-patient mismatch after aortic valve replacement predominantly affects patients with preexisting left ventricular dysfunction: effect on survival, freedom from heart failure, and left ventricular mass regression. *J Thorac Cardiovasc Surg*. 2006;131:1036-44.
7. Flameng W, Herregods MC, Vercauteren M, Herijgers P, Bogaerts K, Meuris B. Prosthesis-patient mismatch predicts structural valve degeneration in bioprosthetic heart valves. *Circulation*. 2010;121:2123-9.
8. Pibarot P, Dumesnil JG. The relevance of prosthesis-patient mismatch after aortic valve replacement. *Nat Clin Pract Cardiovasc Med*. 2008;5:764-5.
9. Sioris T, David TE, Ivanov J, Armstrong S, Feindel CM. Clinical outcomes after separate and composite replacement of the aortic valve and ascending aorta. *J Thorac Cardiovasc Surg*. 2004;128:260-5.
10. Zehr KJ, Orszulak TA, Mullany CJ, Matloobi A, Daly RC, Dearani JA, et al. Surgery for aneurysms of the aortic root: a 30-year experience. *Circulation*. 2004;110:1364-71.
11. El-Hamamsy I, Clark L, Stevens LM, Sarang Z, Melina G, Takkenberg JJ, et al. Late outcomes following Freestyle versus homograft aortic root replacement: results from a prospective randomized trial. *J Am Coll Cardiol*. 2010;55:368-76.
12. Lund O, Chandrasekaran V, Grocott-Mason R, Elwidaa H, Mazhar R, Khaghani A, et al. Primary aortic valve replacement with allografts over twenty-five years: valve-related and procedure-related determinants of outcome. *J Thorac Cardiovasc Surg*. 1999;117:77-91.
13. Clark TG, Altman DG, De Stavola BL. Quantification of the completeness of follow-up. *Lancet*. 2002;359:1309-10.
14. Yacoub MH, Klieverik LM, Melina G, Edwards SE, Sarathchandra P, Bogers AJ, et al. An evaluation of the Ross operation in adults. *J Heart Valve Dis*. 2006;15:531-9.
15. Szeto WY, Bavaria JE, Bowen FW, Geirsson A, Cornelius K, Hargrove WC, et al. Reoperative aortic root replacement in patients with previous aortic surgery. *Ann Thorac Surg*. 2007;84:1592-9.
16. Hahn C, Tam SK, Vlahakes GJ, Hilgenberg AD, Akins CW, Buckley MJ. Repeat aortic root replacement. *Ann Thorac Surg*. 1998;66:88-91.
17. Raanani E, David TE, Dellgren G, Armstrong S, Ivanov J, Feindel CM. Redo aortic root replacement: experience with 31 patients. *Ann Thorac Surg*. 2001;71:1460-3.
18. David TE, Feindel CM, Ivanov J, Armstrong S. Aortic root replacement in patients with previous heart surgery. *J Card Surg*. 2004;19:325-8.
19. Kirsch EW, Radu NC, Mekontso-Dessap A, Hillion ML, Loisanse D. Aortic root replacement after previous surgical intervention on the aortic valve, aortic root, or ascending aorta. *J Thorac Cardiovasc Surg*. 2006;131:601-8.
20. Joudinaud TM, Baron F, Raffoul R, Pagis B, Vergnat M, Parisot C, et al. Redo aortic root surgery for failure of an aortic homograft is a major technical challenge. *Eur J Cardiothorac Surg*. 2008;33:989-94.
21. Malvindi PG, van Putte BP, Heijmen RH, Schepens MA, Morshuis WJ. Reoperations on the aortic root: experience in 46 patients. *Ann Thorac Surg*. 2010;89:81-6.
22. Butany JW, David TE, Ojha M. Histological and morphometric analyses of early and late aortocoronary vein grafts and distal anastomoses. *Can J Cardiol*. 1998;14:671-7.
23. Khan A, Mond DJ, Kallman CE, Murata K, Rojas KA, Herman PG. Computed tomography of normal and calcified coronary arteries. *J Thorac Imaging*. 1994;9:1-7.
24. Sundt TM 3rd, Rasmi N, Wong K, Radley-Smith R, Khaghani A, Yacoub MH. Reoperative aortic valve operation after homograft root replacement: surgical options and results. *Ann Thorac Surg*. 1995;60(2 Suppl):S95-100.
25. El-Hamamsy I, Zaki M, Stevens LM, Clark LA, Rubens M, Melina G, et al. Rate of progression and functional significance of aortic root calcification after homograft versus Freestyle aortic root replacement. *Circulation*. 2009;120(11 Suppl):S269-75.
26. Luciani N, Anselmi A, de Geest R, Glieda F, Possati G. Facilitated aortic root substitution after aortic valve replacement: technique and results of the prosthesis-sparing operation. *J Thorac Cardiovasc Surg*. 2010;139:785-7.
27. Yankah AC, Wottge HU, Muller-Ruchholtz W. Prognostic importance of viability and a study of a second set allograft valve: an experimental study. *J Card Surg*. 1988;3:263-70.
28. Smith JD, Hornick PI, Rasmi N, Rose ML, Yacoub MH. Effect of HLA mismatching and antibody status on "homovital" aortic valve homograft performance. *Ann Thorac Surg*. 1998;66(6 Suppl):S212-5.