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Behavior of the Pulmonary Autograft in Systemic Circulation After the Ross Procedure

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ABSTRACT

Objective: The purpose of this study was to evaluate performance in systemic circulation following pulmonary autograft aortic root replacement by means of serial postoperative echocardiographic studies.

Methods: From November 1997 to November 1999, 30 patients (21 males, 9 females) with a mean age of 29.97 ± 12.97 years (age range 6-54 years) underwent pulmonary autograft aortic root replacement. Seven of these patients (23.33%) were less than 15 years old. Postoperative echocardiographic measurements of the neo-aortic root were performed within three months of operation, at six months, one year, and annually thereafter. Analysis of this study includes 22 patients with at least three months of follow-up.

Results: Operative mortality was 0%. Compared with preoperative values, the mean autograft annulus diameter exhibited an increase of 8.44% in the first month (1.44 ± 0.22 cm/m^2 vs. 1.55 ± 0.21 cm/m^2, p = 0.0101). An additional aortic annular dilation of 11.33% from baseline preoperative values was observed within the first year (1.41 ± 0.15 cm/m^2 preoperatively vs. 1.57 ± 0.22 cm/m^2, p = 0.0449). After the immediate postoperative period, the pulmonary autograft seemed to adapt to systemic circulation, and there were no differences in aortic annular size between 1-3 months after surgery and the 18-21 month follow-up period (1.60 ± 0.18 cm/m^2 vs. 1.60 ± 0.27 cm/m^2, n = 10). Diameter increase was not associated with the presence of aortic regurgitation. Mean neo-aortic maximal gradient was 7.85 ± 5.59 mm Hg (3-29 mm Hg). There was a significant decrease in left ventricular size three months after surgery (50.71 ± 10.20 mm preoperatively vs. 44.98 ± 7.29 mm, p = 0.0491 in aortic stenosis patients and 68.50 ± 8.39 mm vs. 59.04 ± 9.21 mm, p = 0.0017 in aortic insufficiency patients).

Conclusions: Pulmonary autograft annulus increases up to the first year after the Ross procedure but does not appear to progress beyond that time. The pulmonary autograft allows optimal hemodynamic performance without causing substantial aortic regurgitation, thereby permitting normalization of left ventricular dimensions and improvement of left ventricular function early in the postoperative period.

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INTRODUCTION

The pulmonary autograft replacement of the aortic valve was first introduced by Donald Ross [Ross 1967] in 1967 and was first performed as a root replacement technique [Chambers 1997] in 1974. Pulmonary autograft implantation as a neo-aortic root is a simple surgical technique that better maintains pulmonary valve geometry. Due to excellent short-term results, the root replacement has become the most frequently utilized technique for performing the Ross operation. Only limited mid- and long-term assessments of durability and adaptation of the pulmonary root to systemic pressures are available. However, the capacity of the pulmonary autograft to keep up a normal valve function under systemic pressure has been questioned. Although dilation of the pulmonary root in the systemic circulation has been reported by some groups, it has not been associated with neo-aortic valve insufficiency until the recently published study of David et al. [David 2000], which reported dilation of the neo-aortic root associated with failure of the autograft valve.

In this report, we review the use of the pulmonary autograft as a root replacement and the adaptation of the pulmonary autograft to systemic pressures in a series of pediatric and adult patients by means of an echocardiographic analysis of neo-aortic valve function.

MATERIALS AND METHODS

Patients

Between November 1997 and November 1999, 30 patients had a Ross operation as a root replacement at the

Reina Sofía University Hospital. Their ages were 6 to 54 years (mean age was 29.97 ± 12.29 years) at the time of the Ross procedure. Seven of these patients (23.33%) were less than 15 years old. The patients were predominantly males (21 males, 9 females). The aortic valve lesion was congenital in origin in 18 patients (60%), including one eight-year-old girl with Shone syndrome and another 15-year-old girl with Laubry syndrome, previously operated on. Two patients had subaortic stenosis and aortic valve disease. The cause of the lesion in 11 of the remaining 12 patients was rheumatic disease (36.67% of the complete group of patients). The other patient had an aortic valve endocarditis that healed with antibiotics, although severe aortic valve insufficiency persisted. Indications for aortic valve replacement included aortic stenosis (AS) in eight patients (26.67%), aortic insufficiency (AI) in 13 patients (43.33%), and mixed valvular disease with predominant stenosis in nine patients (30%).

Six patients (20%) had undergone previous open-heart surgery. Previous surgical procedures included aortic commissurotomy in two patients, resection of the subvalvular membrane and septal myomectomy in two patients, repair of aortic coarctation in the eight-year-old girl with Shone syndrome, and closure of a ventricular septal defect and Trusler's aortic valvuloplasty in the patient with Laubry disease. Five patients (16.6%) had undergone previous percutaneous procedures in the aortic valve, with one of them receiving percutaneous balloon valvuloplasty on two occasions. One pediatric patient underwent a percutaneous repair of an aortic coarctation (balloon dilation and stent implantation).

Concomitant procedures included enucleation of subvalvular stenosis in two patients, supravalvular resection in one patient, and septal myomectomy in two patients. One male patient, 29 years old, had a Ross operation with resection of an ascending aortic aneurysm and aortic annulus reduction and fixation with a Teflon felt strip. Vertical aortoplasty was required in five patients (16.6%). Eight rheumatic patients (26.7%) had additional mild mitral valve disease for which surgical repair was not required.

We have reviewed 22 of 30 patients with a follow-up of at least three months. For this study, patients were classified as to their dominant lesion with 11 having AS and 11 AI. The some of the patients (44.0%) had New York Heart Association (NYHA) functional class III or IV symptoms preoperatively.

Surgical Technique

Pulmonary autograft replacement of the aortic wall was performed using a similar root replacement operative technique in all patients, as described previously by Ross et al. [Ross 1994, Ross 1996]. The pulmonary valve was confirmed to be normal by visual inspection and then excised with a small ridge of right ventricular musculature. The aortic root was then removed and the right and left coronary arteries were mobilized with generous aortic buttons. The pulmonary autograft was implanted on the aortic position with interrupted 4/0 polypropylene stitches. To maintain hemostasis and annular stabilization, the proximal autograft suture line was reinforced in all cases with autologous pericardium. On pediatric patients, autologous pericardium was interrupted at least two times.

The ascending aorta with mild dilation was reduced in size with a vertical aortoplasty to the size of the sinotubular dimension of the pulmonary autograft. Aortic annulus reduction and fixation [Elkins 1997] with an external cuff of Teflon was employed in one additional young patient with aneurysmal dilation of the ascending aorta and preoperative aortic annulus dilation. The coronary arteries were inserted in the sinuses of the pulmonary autograft.

In all patients, the right ventricular outflow tract was reconstructed with a cryopreserved pulmonary allograft from the Heart Valve Bank of the Reina Sofía University Hospital. The policy of our group was to use the largest and youngest pulmonary homograft that could easily be inserted. Mean pulmonary homograft diameter was 26.32 ± 3.59 mm (range: 19-35 mm). Blood group compatibility was preferred.

Standard cardiopulmonary bypass techniques were routinely established through a medial sternal approach. Myocardial protection was provided by intermittent retrograde cold blood cardioplegia and topical iced saline with moderate systemic hypothermia (30-34°C). The mean aortic cross-clamp time was 124.60 ± 18.64 minutes (range 110 to 160 minutes), and the mean perfusion time was 170.64 ± 23.43 minutes (range 135 to 220 minutes).

According to our policy, all patients who underwent autograft aortic valve replacement were examined with transesophageal echocardiography (TEE) after disconnecting extracorporeal circulation.

Patient Follow-up

Preoperative evaluation included physical examination and echocardiography in all patients to assess aortic annulus size, aortic sinus size, and sinotubular dimension. Two-dimensional Doppler echocardiography was used to measure the diameters of the pulmonary and aortic annulus. The inner diameter of the annulus was measured at the hinge points of the valve leaflets in an early systolic, parasternal, long-axis view of every precordial two-dimensional echocardiogram. Ascending aortic size and pathology were confirmed by computed tomography or magnetic resonance imaging. All echocardiographic dimensions were confirmed by intraoperative measurements with Hegar dilators. All patients underwent intraoperative, post-autograft echocardiography.

Our follow-up protocol consisted of clinical examination, electrocardiography, chest radiographs, and Doppler echocardiography performed in the outpatient clinic. The clinical condition of patients was scored using the New York Heart Association classification for dyspnea. Follow–up assessment included late death, all valve–related complications according to the criteria of Edmunds et al. [Edmunds 1996], and any other complication that could not be related to the valve.

Postoperative standard transthoracic echocardiograms were obtained within three months of operation, at six months, one year, and annually thereafter. To compare the autograft annulus diameters with normal ones we used the results of Snider et al. [Snider 1984]. Pulse-wave and continuous-wave Doppler was used to measure left and right ventricular outflow tract obstruction, and color-flow mapping was used to assess autograft and homograft insufficiency. Severity of autograft and homograft regurgitation was quantified by obtaining the ratio of the jet diameter to the left and right ventricular outflow tract diameter [Willems 1997]. Autograft and homograft valve insufficiency were graded as follows: 0 (none), 1+ (trace), 2+ (mild), 3+ (moderate), and 4+ (severe).

Follow-up was 100% complete. In this study, we analyzed 22 patients with at least three months of follow-up. Median follow-up of these patients was 432 days (range 113-629 days), and total follow-up obtained was 316 patient-months.

Statistical Analysis

Data are expressed as the mean ± one standard deviation unless otherwise specified. All analyses were performed using PATS system software (Dendrite Systems, Inc., Sistemas Hospitalarios, Grupo Palex, Barcelona, Spain). Between-group differences of continuous variables were analyzed using analysis of variance methods, and χ^2 or Fisher exact methods were used to test differences between proportions. All tests were two-tailed, and $p < 0.05$ was considered to indicate statistical significance.

RESULTS

Patients

There were no operative or late deaths and only three patients required a prolonged surgical time to attain hemostasis. There were no major postoperative complications, although one patient required a re-exploration for bleeding. Five patients (16.6%) had reversible episodes of atrial fibrillation or supraventricular tachycardia. Episodes of bacterial endocarditis and valve-related thromboembolic phenomena have not been identified during the follow-up period. Just one patient was in New Heart Association class II at the most recent follow-up, and all other patients (95.4%) were in functional class I.

Serial Evaluation of Aortic Annulus

Preoperative mean pulmonary annulus diameter was slightly larger in our group of patients than mean aortic annulus diameter (23.36 ± 3.44 vs. 23.34 ± 4.77 mm). Annulus diameters were normalized (1.44 ± 0.22 cm/m^2 vs. 1.41 ± 0.36 cm/m^2) to the square root of each patient's body surface area (BSA) [Sievers 1983]. Serial echocardiographic measurements of the aortic annulus were obtained. With the pulmonary valve transposed to the aortic position, an abrupt increase in neo-aortic annular diameter was observed in the immediate postoperative period (Figure 1, ◉). By a mean follow-up period of one month, the indexed neo-aortic valve annulus had increased by 8.44% from its preoperative pulmonary valve ring diameter (1.44 ± 0.22 cm/m^2 vs. 1.55 ± 0.21 cm/m^2, $p = 0.0101$, $n = 22$).

Paired data analysis demonstrated an increase in neo-aortic annulus size by 11.33% within the first postoperative 12 months (1.41 ± 0.15 cm/m^2 preoperatively vs. 1.57 ± 0.22 cm/m^2, $p = 0.0449$, $n = 11$). At 18 months, ten patients had serial echocardiographic data, and their indexed neo-aortic annulus size increased by 13.57% from its preoperative pulmonary annulus size (1.41 ± 0.16 cm/m^2 preoperatively vs. 1.60 ± 0.27 cm/m^2, $p = 0.0580$, $n = 10$).

After this abrupt increase in neo-aortic annular diameter observed in the immediate postoperative period, the pulmonary valve seems to adapt to systemic circulation. Comparison of the indexed pulmonary annulus within one to three months after surgery with the measurement at the 12-month follow-up period reveals that the indexed neo-aortic valve annulus decreased by 1.68% (1.59 ± 0.17 cm/m^2 at one month vs. 1.57 ± 0.22 cm/m^2 at 12 months, $p = 0.6260$, $n = 11$). In the 10 patients who had serial echocardiographic data within three and 18 months, the aortic annular diameter was unchanged during this period (1.60 ± 0.18 cm/m^2 vs. 1.60 ± 0.27 cm/m^2, $n = 10$). See Figure 2 (◉).

Figure 3 (◉) illustrates the evolution of aortic annulus diameter of patients who have undergone the Ross procedure measured echocardiographically early and late postoperatively, and compared to the general population. Patient aortic annular diameters were plotted against a normative database of similarly obtained aortic annulus measurements [El Habbal 1989, Kirklin 1993]. The neo-aortic annulus was enlarged in some patients who have undergone pulmonary autograft replacement of the aortic valve compared with the general population although progressive aortic regurgitation has not been documented in these patients.

Autograft Valve Function

Correct autograft valve function was checked with transesophageal echocardiography in the operating room after disconnecting extracorporeal circulation. At the transthoracic echocardiogram performed within the first three months after surgery, stable pulmonary autograft function (no or only 1+ AI) was observed in 100% of patients. Trace (1+) aortic regurgitation has been observed during the first three months after surgery in 68.18% of patients (15 patients). Postoperatively the pulmonary autograft valve seems to adapt to systemic circulation, and in the last echocardiogram six of the 15 patients (40%) showed no aortic regurgitation. Six of the nine remaining patients have maintained trace (1+) aortic regurgitation during follow-up. Autograft valve function, based on the most recent echocardiographic evaluation, showed stable function (no or only 1+ AI) in 19 patients. There was no change in the degree of aortic valve regurgitation over time in 86.36% of patients, but autograft valve insufficien-

cy increased to 2+ at 21 months in one pediatric patient. Autograft reoperation was required in two patients 13 and 14 months postoperatively for severe autograft valve insufficiency requiring autograft valve replacement. Histopathological analysis of an explanted pulmonary tissue valve in one of these patients showed myxomatous degeneration. In the other patient, a mismatch between native aortic annulus and pulmonary autograft annulus diameter (32 mm vs. 26 mm) could be the cause of the pulmonary autograft dysfunction. Aortic insufficiency was the preoperative indication for surgery in these two patients, but a relationship between preoperative aortic insufficiency and pulmonary autograft dysfunction has not been observed in our series of patients ($p = 0.3329$).

The pulmonary autograft has shown excellent hemodynamics. The mean tract gradient of postoperative peak left ventricular outflow at 21 months was 7.85 ± 5.59 mm Hg (range 3-29 mm Hg). The neo-aortic valve gradient has remained constant during follow-up. The mean value of the neo-aortic valve gradient was 4.06 ± 3.17 mm Hg (range 1-16 mm Hg) at 21 months after operation.

Left Ventricular Dimensions

In the AS group, the preoperative left ventricular end-diastolic internal dimension (LVEDD) value was 50.71 ± 10.20 mm, which decreased to 44.98 ± 7.29 mm ($p = 0.0491$) in the first month after operation. There was also a decrease in LVEDD from preoperative values in patients with preoperative AI (68.50 ± 8.39 mm preoperative vs. 59.04 ± 9.21 mm at one month, $p = 0.0017$, $n = 11$). Assessment of LVEDD in the six patients of this group with data at 12 months demonstrates further reduction in chamber size over time (67.66 ± 10.27 mm preoperative vs. 57.05 ± 12.76 mm at 12 months, $p = 0.0229$, $n = 6$).

Homograft Valve Function

The mean Doppler gradient across the pulmonary artery homograft obtained from the echocardiogram at 18 months was 13.59 ± 9.44 mm Hg. Homograft valve function was considered excellent except in two pediatric patients who developed considerable obstruction beyond the first year. Homograft valve failure after reconstruction of the right ventricular outflow tract has been associated with obstruction of the conduit distal to the pulmonary valve. One of the two pediatric patients developed accelerated homograft valve dysfunction, with a mean gradient > 50 mm Hg and required palliative percutaneous balloon dilation and stent implantation. The mean gradient across this homograft was reduced to 12 mm Hg. The other patient is asymptomatic at this time and is being followed closely.

DISCUSSION

The introduction of the pulmonary autograft replacement of the aortic valve by Ross in 1967 and the subsequent event-free survival for over 20 years led to the increasing use of this surgical procedure. However, the long-term fate of the pulmonary root in the systemic circulation is unknown. Experience with the Ross operation is limited, with only 20 patients who have undergone root replacement of the aortic valve having been followed up for more than 20 years. At present, 18 of these patients continue to function and are being followed [Chambers 1997]. To date, the patients who have had an arterial switch for transposition of the great vessels have experienced a low incidence of neo-aortic valve dysfunction, and late complications requiring replacement of the pulmonary root due to dilation have not been reported.

The pulmonary autograft is a viable valve substitute that is durable in most patients. Long-term success with the use of pulmonary autograft tissue in children is predicated on the adequate growth of that to accommodate somatic growth of the patient. The greatest advantage to the use of a pulmonary autograft is its ability to increase in diameter over time. Growth of autologous pulmonary tissue in the systemic circulation has been previously described in patients with d-transposition of the great arteries who have undergone the arterial switch procedure [Arensman 1985, Hourihan 1993]. Studies have also suggested neo-aortic root growth in patients who have undergone pulmonary autograft replacement of their aortic valves [Elkins 1994]. Follow-up of our short series of pediatric patients confirmed an adequate pulmonary autograft function and normal growth patterns. However, Elkins et al. [Elkins 1992, Elkins 1994] reported a greater increase in the diameter of root replacement pulmonary autografts than in the diameter of autografts placed using the intra-aortic cylinder technique, suggesting enlargement resulting from both growth and dilation, even though there was only one incidence of associated insufficiency.

We agree with other authors [Elkins 1992, Kouchoukos 1994] that the main concern with the use of the pulmonary autograft in the aortic position is the potential for dilation of the wall of the pulmonary artery and the subsequent development of valvular incompetence of the neo-aortic valve. Dimension and function of the pulmonary autograft in the aortic position are mainly influenced by exposure of the graft to systemic pressure. Sievers et al. [Sievers 1993] observed in their patients an initial increase in diameter of the autograft after release of the cross-clamp, and they did not observe a significant change in dimension of the autograft between the two postoperative studies.

Functional mild central aortic regurgitation is frequently observed immediately after the operation and is attributed to increased hemodynamic stress [Matalon 1971]. Fourteen of 17 patients in the study of Stelzer [Stelzer 1998] and Elkins [Elkins 1994] and five of eight patients in the series of Sievers et al. [Sievers 1993] had minimal or moderate aortic regurgitation on hospital discharge. Interestingly, these researchers found that, at the second investigation, primary aortic insufficiency grade 1+ had disappeared in some of these patients. Some kind of adaptation of the pulmonary autograft to systemic pressure appears to take place with time in certain cases, because the increased diastolic pressure load as the major factor in the development of functional insufficiency was still present later

[Matalon 1971]. These findings are essentially similar to that observed in our patients.

Gorczynski et al. [Gorczynski 1996] demonstrated with biomechanical measurements that pulmonary valve leaflets had a 2.6 times greater tensile strength than aortic valve leaflets, and stated that pulmonary cusps are able to withstand the abrupt onset of systemic pressures. Sievers and associates [Sievers 1993] did not observe pulmonary leaflet disruption up to a diastolic pressure load of 200 mm Hg.

Bellhouse [Bellhouse 1973] stated the importance of normal geometry of sinotubular union to prevent aortic regurgitation. Elevated diastolic pressures may change design parameters [Thubrikar 1981], increasing root diameter, and at critical pressures the leaflet coaptation area may decrease, leading to functional insufficiency [Matalon 1971, Caguioa 1992]. If progressive dilation of the pulmonary wall occurs, it should produce progressive aortic regurgitation. Tantengco et al. [Tantengco 1999] also observed enlargement of the aortic root during the first postoperative year, but the enlargement stabilized without progression in dilation beyond the first year.

Interestingly, these results coincide with the findings from serial echocardiograms of our series of patients. Elkins et al. [Elkins 1996] reported five such cases in 206 patients requiring reoperation at five years (2.4%). Oury et al. [Oury 1999] did not perform any reoperations for progressive aortic regurgitation at a maximum follow-up of more than eight years. Recently, David et al. [David 2000] reported echocardiographic evidence of an increase of more than 20% of the sinotubular diameter in 36% of their patients. Only five patients (4.2%) showed moderate regurgitation and did not require reoperation. An echocardiographic study by Hokken et al. [Hokken 1997] found an autograft annulus dilation rate of 19% in 36 cases followed for a maximum of six years, but no progression in regurgitation was detected. Interestingly, 59% of the cases of dilation in the Hokken study had occurred within 10 days after operation and the remaining cases occurred only during the first year. In both the David and Hokken series, no particular proximal suture line protection or reinforcement was used.

An important consideration is the maximum tolerance that should be accepted between the difference in diameter of the pulmonary and aortic annulus. Initially, it was thought that the pulmonary annulus would adapt to a substantially larger aortic annulus, but it is now believed that a maximum difference of 3 to 5 mm should be considered. Although the pulmonary wall might be capable of remodeling or compensating under stress with a minimal to moderate size mismatch, as suggested by Nagy et al. [Nagy 1999], it is likely that under certain pathological conditions, this ability might be impaired. Elkins et al. [Elkins 1994] recommend reduction by encircling annuloplasty in cases of significant disparity.

Another consideration is the protection against dilation of the autograft by some type of external wrapping. Ross has always insisted on the need to anchor the pulmonary annulus within the aortic annulus, thus ensuring at least aortic wall support for the pulmonary autograft. We not only ensure subanular insertion of pulmonary autograft but also protect the proximal anastomosis with a strip of either autologous pericardium or Teflon placed externally and incorporated in the proximal anastomosis. The strip of Teflon or pericardium is incorporated in the individual ties, thereby achieving staged aortic annuloplasty. Other forms of external fixation have been used by others groups, including wrapping the autograft with resorbable mesh [Moritz 1993] or glutaraldehyde-fixed bovine pericardium [Pacifico 1994] in order to prevent pulmonary autograft dilation.

Some authors have referred to the importance of sinotubular diameter in long-term postoperative valve function. Oury et al. [Oury 1999] use an external wrap of either autologous pericardium or Teflon to re-establish the sinotubular junction. This external wrap re-establishes the sinotubular junction at a size comparable to or 10% smaller than the neo-aortic annulus. The use of this external support has completely eliminated this area as a site for early postoperative bleeding and could have significant implications in terms of late dilation reported in other series.

Recently, particular concern has been expressed about the use of a Ross root replacement in patients with bicuspid aortic valve disease [David 2000]. David et al. had 30% of 82 patients followed up to seven years with a sinus of Valsalva 40 mm or larger after root replacement with a pulmonary autograft. It has been suggested that these patients may have a genetic defect that involves the aortic and pulmonary artery wall, which may lead to significant long-term complications if the pulmonary root is used as a valve conduit to replace the aortic wall. However, Elkins et al. [Elkins 1999] were unable to show any association of late autograft valve dysfunction or increased incidence of pulmonary root dilation in patients with bicuspid or unicuspid aortic valve disease. Dilation of the pulmonary autograft root when it is placed in the systemic circulation should not be a surprise, and one need not look for a histological abnormality in the pulmonary artery wall to explain this finding. Hourihan et al. [Hourihan 1993] showed dilation of the neo-aortic root in patients having an arterial switch procedure to correct transposition of the great arteries. Sequential echocardiograms in the two-stage correction of transposition of the great arteries have shown no evidence of progressive dilation, although there may be a slight progression initially until the pulmonary root thickens and becomes very stable, stiffer, and stronger than a normal aortic root.

Although it is of concern that the pulmonary autograft root replacement does not maintain similar dimensions to the known dimensions of the normal aortic root, and it does not appear to undergo significant remodeling of the pulmonary arterial wall [Schoof 1998], its clinical effectiveness has been excellent. The decrease in left ventricular dimensions and the normalization of left ventricular mass index strongly suggest resolution of left ventricular dilation and hypertrophy that has been maintained over the 21 months of follow-up.

The high rate of early survival, limited operative complications, excellent postoperative autograft valve func-

tion, and normalization of left ventricular function have encouraged us to continue using this technique. Correlation between an increase in the autograft annulus diameter and the severity of aortic regurgitation could not be found. Long-term follow-up and continued careful evaluation with at least annual echocardiography is therefore necessary to come to any conclusions about the effect of the increased pulmonary autograft diameter.

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REVIEW AND COMMENTARY

1. Editorial Board Member NC124 writes

The study described in this article has very good results and follow-up. It would be very interesting to compare these results with reconstruction of the aortic root utilizing simple aortic homografts. Apparently the results are similar, even long range, which is why some groups are changing the Ross procedure for homograft utilization.

Authors' Response by Juan José Legarra, PhD

I agree that reconstruction of the aortic root with aortic homografts has good results. We have a series of patients (55-70 years old) with aortic homografts, and the hemodynamic and clinical results are encouraging. However, we believe that the growth potential and viability of the pulmonary autograft allows aortic valve replacement in children and patients younger than 55 years old. We do not think that homografts and autografts will have similar long-term results in young patients.

2. Editorial Board Member TL41 writes

This is a prospective evaluation of a successful series that is relevant to concerns in some quarters about the outcome of a currently fashionable operation. The study is limited, however, both by its small numbers and the short average follow-up of just over one year. The 10 cases followed beyond 18 months probably do not give enough power to support the conclusion. For example, in Figure 1 (◎), the P value of 0.58 for the over-18-months comparison could reflect either lack of power or lack of true difference. More seriously, the absence of the two reoperated patients from the over-18-months group may have induced survivorship bias in the observations on the remaining non-reoperated ones.

It might be possible to gain power in the timed comparisons by reporting the results of paired observations of the individual patients, in effect using each patient as his or her own control.

Authors' Response by Juan José Legarra, PhD

I agree that the number of patients in our series is too small to strongly support any conclusion. This paper reflects our thoughts about the Ross procedure. We are now updating patient follow-up and will share the results with Heart Surgery Forum in the near future.