Fate of the Remaining Neo-Aortic Root After Autograft Valve Replacement With a Stented Prosthesis for the Failing Ross Procedure

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Background. Aortic root replacement (ARR) is advocated for irreparable autograft failure after the Ross procedure to avoid late aneurysm formation. However, redo ARR is complex and associated with bleeding and coronary injury risks. We examine results of autograft valve replacement (AuVR) with stented prostheses (SP) without ARR with special focus on the fate of the remaining root and need for reintervention.

Methods. Between 1994 and 2011, 50 of 510 Ross patients underwent AuVR with SP. Serial postoperative echocardiograms (n = 342) were analyzed and regression models adjusted for repeated measures were used to model longitudinal change of the remaining root and ascending aorta dimensions after AuVR.

Results. Fifty patients, median age 21 years (range 11 to 50 years) underwent AuVR with SP: mechanical (n = 38) or tissue (n = 12). Thirty patients (60%) had concomitant procedures: most commonly mitral valve surgery (n = 20) or conduit change (n = 12). There were no operative deaths and 10-year survival was 95%. Freedom from prosthesis, root, and all-cause reoperations was 97%, 98%, and 90% at 10 years, respectively. Serial echocardiography data showed that there was little but, nevertheless, progressive increase of the remaining root (EST: +0.0190 [0.0041] cm/year, p < 0.001) and ascending aorta diameters (EST: +0.0191 [0.0037] cm/year, p < 0.001). While there was small steady non-statistically significant increase in mean prosthesis gradient (estimate [EST]: +0.16 [0.09] mm Hg/ year, p = 0.08); ejection fraction remained stable with time (EST: -0.12 [0.14] %/year, p = 0.41).

Conclusions. Our results indicate that AuVR with SP without ARR for failing autografts is justified as it is associated with low mortality and reoperation risk. Preemptive complex ARR should be reserved for those with significant root dilatation at time of AuVR. Although root reinterventions are rare, patients should be followed for progressive root dilatation. Faster growth is seen in those who fail with regurgitation and dilated annulus.

Research Center in Riyadh, Saudi Arabia. Our current patient cohort was 50 of 510 patients who required AuVR with SP from 1994 to 2011. Patients were identified using the hospital surgical database. Clinical, operative, and outcome data were abstracted from medical records. Approval of this study was obtained from the Research Ethics Board at our institution and requirement for individual consent was waived for this observational study.

Operative Details
All autografts were implanted as full root; our Ross technique can be reviewed in previous publications [2, 4]. At time of AuVR, redo midline sternotomy was performed and standard cardiopulmonary bypass and myocardial protection techniques were used. After a transverse incision was made in the aorta, the AuV was examined for possibility of repair. If repair was not feasible and there was no significant dilatation of the aortic root, the AuV was replaced with SP. In that case, AuV cusps were excised, annulus was debrided, and then SP was implanted using pledgeted sutures. Overall, 38 patients received mechanical and 12 received tissue prostheses. Mechanical prostheses were CarboMedics (Austin, TX) (n = 35), ATS (Minneapolis, MN) (n = 2) and St. Jude (St. Paul, MN) (n = 1); tissue prosthesis were Carpentier-Edwards (Edwards Lifesciences LLC, Irvine, CA) (n = 6), Mosaic (Medtronic Inc, Minneapolis, MN) (n = 5), and Hancock (Medtronic) (n = 1). Median valve size was 25 mm (range 19 to 29, interquartile range IQR 23 to 25). During our study period, 5 additional patients required AuVR with homograft (n = 4) or mechanical valved conduit (n = 1).

Thirty patients (60%) required concomitant cardiac surgery at time of AuVR, including mitral valve (MV) replacement (n = 15), MV repair (n = 5), right ventricle to pulmonary artery conduit change (n = 15), tricuspid valve repair (n = 3), and other (n = 3). Immediate postoperative results were assessed in the operating room by means of transesophageal echocardiography.

Follow-Up
Patients were evaluated clinically and by means of detailed echocardiography upon discharge, 6 weeks after operation, and yearly thereafter. Late outcomes were determined from recent office visits or from direct correspondence with patients’ families. Follow-up was complete in 90% of patients. Median follow-up duration after AuVR was 8.4 years and ranged up to 17.7 years.

Echocardiography
Serial echocardiographic data were collected for last pre-AuVR, immediate post-AuVR, and all future studies during follow-up. There was a total of 342 post-AuVR studies performed. All measurements were reviewed by a single cardiologist. Neo-aortic valve annulus and root dimensions were measured in the parasternal long axis view.

Statistical Analysis
Data are presented as means with standard deviation, medians with minimum and maximum values, and frequencies as appropriate. Long-term survival and freedom from reoperation were estimated using the Kaplan-Meier method. Cox regression was used to determine independent predictors of late outcomes. Linear regression analysis, based on maximum likelihood estimates, adjusted for repeated measures with autoregressive covariance structure, was used to determine trends over time for serial echocardiographic assessments of root and ascending aorta at level of the sinotubular junction (STJ) dimensions, ejection fraction (LVEF), peak, and mean gradient across SP. These models consider every measurement within each patient, as opposed to every patient, as an “observation,” increasing available sample size from 50 to 342 observations. Correlation between observations is accounted for through a compound symmetry covariance structure. Each regression model included, in addition to specific patient identifier, covariates of interest, time since AuVR and the interaction between covariates of interest, and body surface area. All statistical analyses were performed using SAS statistical software v9.3 (SAS Institute, Cary, NC).

Results

Patient Characteristics
There were 36 male patients (72%). Median age at time of Ross was 17.2 years (range 9.0 to 42.5). Underlying cardiac patholgy was rheumatic (n = 45, 90%), congenital (n = 4, 8%), and endocarditis (n = 1, 2%). Hemodynamic aortic valve dysfunction at time of Ross was primarily regurgitation (n = 43, 86%), mixed disease (n = 5, 10%), and primarily stenosis (n = 2, 4%). Twenty patients (40%) had concomitant cardiac surgery at time of Ross including MV repair (n = 19, 38%) and ventricular septal defect closure (n = 1, 2%). Annular and STJ reinforcement were utilized at time of Ross in 6 and 1 patients, respectively. Prior to AuVR, 3 patients (6%) underwent cardiac reoperation for MV repair, conduit change, and AuVR at another institution (n = 1, each).

Median age at time of AuVR was 21.0 years (range 11.0 to 49.5) with median interval of 3.8 years (range 0.5 to 19.0) between Ross and AuVR. The mode of AuV failure was annular dilatation with cusp prolapse, tear and failure of coaptation (n = 30, 60%), inflammatory process associated with various degrees of cusp thickening, calcification, commissural fusion and subvalvar thickening (n = 16, 32%), endocarditis (n = 1, 2%), failed prosthesis placed elsewhere (n = 1, 2%), and unknown (n = 2, 4%).

Clinical Outcomes
There were no operative deaths and 5 late mortalities. Overall survival at 1 and 10 years was 98% and 95%, respectively. No variables were identified as risk factors for late mortality on multivariable analysis.

During follow-up, 5 patients (10%) required cardiac reoperations. Procedures included conduit change (n = 2), tricuspid valve repair (n = 2), repeat aortic prosthesis replacement with SP (n = 1) or composite valved conduit (n = 1), mitral prosthesis replacement (n = 1), and repair.
of aneurysmal dilatation of left ventricular outflow tract (n = 1).

Overall freedom from aortic prosthesis, root and all-cause cardiac reoperation at 10 years was 97%, 98%, and 90%, respectively. Both patients who required redo replacement had tissue prosthesis and none of the patients who had mechanical prosthesis required replacement. While there was a trend for lower freedom from all-cause cardiac reoperation in patients who received tissue prosthesis (hazard ratio: 4.5, 95% confidence interval: 0.8 to 27.6, \( p = 0.10 \)), no variables were identified as risk factors for cardiac reoperation on multivariable analysis.

**Changes in Echocardiographic Parameters During Follow-Up**

On immediate pre-AuVR echocardiograms median neo-
aortic root diameter was 35 mm (interquartile range [IQR] 33 to 38) and median ascending aorta above STJ diameter was 32 mm (IQR 30 to 35). Median peak and mean AuV gradient was 11 mm Hg (IQR 8 to 24) and 10 mm Hg (IQR 5 to 20), respectively. Median LVEF was 55% (IQR 33 to 38) and median ascending aorta above STJ diameter was 35 mm (interquartile range 0.8 to 27.6, \( p = 0.06 \)) (Fig 2). Of note, rate of root diameter increase after AuVR was not related to indexed root size at time of AuVR (EST: +0.0025 [0.0065] cm/year, \( p = 0.70 \)) (Fig 3), age at time of Ross (EST: -0.0002 (0.0008) cm/year, \( p = 0.82 \)) or AuVR (EST: -0.0002 [0.0006] cm/year, \( p = 0.70 \)), concomitant cardiac surgery at time of Ross (EST: +0.0051 [0.0061] cm/year, \( p = 0.40 \)) or AuVR (EST: +0.0069 [0.0062] cm/year, \( p = 0.26 \)), prosthesis type (EST: +0.0049 [0.0055] cm/year, \( p = 0.37 \)), or size (EST: +0.0015 [0.0013] cm/year, \( p = 0.28 \)).

Median ascending aortic diameter in all postoperative measures was 34 mm (IQR 30 to 36). There was little, but progressive, increase in ascending aorta diameter with time (EST: +0.0191 [0.0037] cm/year, \( p < 0.001 \)) (Fig 4). There was no significant difference in initial ascending aorta diameter between patients with underlying rheumatic fever and those with other pathologies (EST: 0.1787 [0.0971] cm, \( p = 0.07 \)) and diameter increase rate was not significantly faster (EST: -0.0063 [0.0039] cm/year, \( p = 0.10 \)). Patients with pre-Ross primarily regurgitation started with a larger ascending aorta than those with mixed disease (EST: +0.3831 [0.1690] cm, \( p = 0.02 \)) but diameter increase rate was not significantly faster (EST: +0.0064 [0.0041] cm/year, \( p = 0.12 \)). Patients with autograft failure due to annular dilatation started with a larger ascending aorta than those with recurrent inflammation (EST: +0.2985 [0.1597] cm, \( p = 0.06 \)) but diameter increase rate was not significantly faster (EST: +0.0077 [0.0065] cm/year, \( p = 0.24 \)) (Fig 5). Of note, rate of ascending aorta diameter increase after AuVR was not related to indexed ascending aortic size at time of AuVR (EST: -0.0106 [0.0070] cm/year, \( p = 0.13 \)) (Fig 6),

![Image 308x118 to 537x285](image1)

Fig 1. Trajectory of aortic root diameter increase after autograft valve replacement (AuVR) over time is linear, and increases over time. Circles represent individual data points (there are >1 data point per patient). Fine solid lines represent individual patient trajectories and heavy solid line is a smoothing spline that represents best-fit average trend over time. Time zero was taken to be date of AuVR.

![Image 57x128 to 286x296](image2)

Fig 2. Trajectory of aortic root diameter increase after autograft valve replacement (AuVR), stratified by the mode of autograft failure. Patients with autograft failure due to annular dilatation (dotted line) started with a larger root than those with recurrent inflammation (solid line) and showed faster increase in diameter with time.
age at time of Ross (EST: $+0.0001 \ [0.0006] \text{ cm/year}$, $p = 0.89$) or AuVR (EST: $-0.0001 \ [0.0006]$, $p = 0.91$), concomitant cardiac surgery at time of Ross (EST: $+0.0067 \ [0.0078] \text{ cm/year}$, $p = 0.39$) or AuVR (EST: $-0.0004 \ [0.0070]$, $p = 0.95$), prosthesis type (EST: $+0.0059 \ [0.0058]$, $p = 0.31$), or size (EST: $-0.0007 \ [0.0020]$, $p = 0.74$).

Median mean gradient across SP in all postoperative measures was 11 mm Hg (IQR 9 to 14). There was a nonsignificant increase in mean gradient with time (EST: $+0.16 \ [0.09] \text{ mm Hg/year}$, $p = 0.08$). Patients with pre-Ross primarily stenosis started with a higher initial mean gradient than those with primarily regurgitation or mixed disease (EST: $+3.4215 \ [1.2180] \text{ mm Hg}$, $p = 0.005$) and had faster increase in gradient with time ($+1.1275 \ [0.0877] \text{ mm Hg/year}$, $p < 0.001$). Larger prosthesis size was associated with lower initial mean gradient (EST: $-1.0998 \ [0.3500] \text{ mm Hg}$, $p = 0.002$); however, there was no difference in gradient increase with time (EST: $-0.0442 \ [0.0493] \text{ mm Hg/year}$). Mechanical prostheses started with a higher initial mean gradient (EST: $+4.2414 \ [1.5071] \text{ mm Hg}$, $p = 0.005$), however had slower increase in gradient with time (EST: $-0.6324 \ [0.2937] \text{ mm Hg/year}$, $p = 0.03$). Median LVEF in all postoperative measures was 55% (IQR 48% to 60%) and stayed stable with time (EST: $-0.12 \ [0.14] \% \text{/year}$, $p = 0.41$).
Comment

The numerous advantages of the Ross procedure such as growth potential, hemodynamic characteristics, and low thrombogenicity persuaded many surgeons to consider it the AVR of choice in children and young adults [1–4]. However, enthusiasm for Ross weakened when surgeons began to recognize its shortcomings that were not limited only to the right ventricle to pulmonary artery conduit as was anticipated earlier but rather often related to the autograft itself, with common reoperation requirements for regurgitation or aneurysm formation [5–10]. Subsequent to those discouraging results, several risk factors for autograft failure such as preoperative aortic regurgitation, dilated aortic annulus, size mismatch between the larger aortic and smaller pulmonary valves, regurgitating bicuspid aortic valve (BAV), and rheumatic fever especially in the setting of multiple valve involvement or active inflammatory phase were identified [17–21]. Subsequent to that, several surgeons adopted technical modifications aiming to reduce late autograft dilatation such as thinning of muscle rim below the valve, suturing the autograft within the native aortic annulus, shortening the autograft, enforcing the proximal and distal suture lines with Dacron felt, replacing the ascending aorta with Dacron graft, or even wrapping the autograft with a mesh or encasing it into Dacron tube in older patients who would not need autograft growth [9, 22–24]. Changes in selection criteria for Ross candidates, along with technical modifications have contributed to reduction in autograft reoperation in several contemporary studies; however, longer follow-up is needed to confirm the advantages of those modifications [9, 24].

Association between autograft dilatation and development of AVR regurgitation has been well demonstrated, more so for annular and STJ than for root sinuses dilatation [6–10]. Over the past 2 decades, surgeons have gained considerable experience with AVS for treatment of patients with aortic regurgitation and Marfan syndrome [11, 12]. The AVS application has expanded to allow successful management of neo-aortic root dilatation and AVR regurgitation. Several authors have shown encouraging mid-term results and AVS has become the current first treatment choice of failing autografts; however, longer follow-up is necessary to confirm AVS durability in the failing Ross subpopulation [11, 12]. Numerous patients in our current series might have been candidates for AVS, which has been employed most recently in few patients at our institution. Nonetheless, AuVR might still be required in some patients with failing autografts, especially in the setting of endocarditis, recurrent inflammation, or severe degeneration of the AuV cusps that is not amenable to repair.

Ross is a complex procedure and cardiac reoperations after Ross can be often more complicated [13, 14, 16]. In a recent series from the Mayo Clinic [13], a total of 144 procedures were performed in 56 patients during their first reoperation after Ross. In a similar report from our institution [16], 92 procedures were performed in 50 patients who needed cardiac reoperation after Ross performed during childhood. Redo ARR is also a complex operation that is technically demanding and associated with relatively long ischemic and cardiopulmonary bypass times. While several experienced groups have reported acceptable outcomes with redo ARR, there is a small but not negligible risk of bleeding or coronary injury [13–15]. Given the complexity of Ross reoperations and multiple simultaneous procedures that are often needed, longer ischemic and bypass times linked to the more complicated redo ARR might have special negative impact on morbidity and mortality risk. On the other hand, AuVR with SP is a simpler operation that is associated with shorter ischemic and cardiopulmonary bypass times, lower risk of bleeding or coronary injury, and good immediate valve function, especially that the neo-aortic annulus is often dilated allowing placement of a large size prosthesis. Thus, AuVR with SP might have a favorable impact on morbidity and mortality risk. Nonetheless, the concern with AuVR with SP is the fate of the remaining autograft wall that might dilate in the future, thus necessitating another complex cardiac reoperation in the future. The etiology of autograft dilatation is not well understood but has been linked to associated structural anomalies, intraoperative trauma, wall degeneration, and remodeling with increased collagen content and loss of elastin, and finally hemodynamic causes such as high systemic blood pressure and regurgitation jet effect [17–20].

One could criticize our study for having more patients with underlying rheumatic fever and fewer patients with BAV than what is usually reported in Western series. However, failure mode after Ross in rheumatic patients was similar to that seen in BAV in the majority of patients (ie, annular and aortic dilatation, cusp prolapse, and lack of coaptation), though occurring relatively earlier after Ross than in patients with BAV, which would explain the lower incidence of initial root replacement requirement in our series. The question is do autografts behave differently based on underlying cardiac etiology?

Several studies have shown that the degenerative changes seen in the aorta of patients with BAV are also present in their pulmonary trunks, and usually more severe that those seen in the pulmonary trunks of patients with tricuspid aortic valve [17]. However, more recent series [25–27] failed to demonstrate that BAV itself is risk factor for failing autografts but showed that preoperative regurgitation and annular dilatation with mismatch between aortic and pulmonary valves were the factors associated with failure rather than diagnosis of BAV itself. Therefore, although it is possible that pulmonary trunks of patients with BAV could dilate more than those taken from patients with tricuspid aortic valve, hemodynamic effects of regurgitation and high blood pressure likely have more influence on the rate of root dilatation. Consequently, it is probable that elimination of regurgitation effect with AuVR could alter the rate of later root dilatation and there is no clear evidence that the rate of autograft dilatation is different between BAV and rheumatic patients.

It is well demonstrated that pre-Ross hemodynamics and underlying pathology intimately influence the rate of autograft dilatation and subsequent failure; this explains our current findings that those patients started with
larger root diameters at time of AuVR [9, 10, 27]. In our study, we found that those patients had a trend for faster increase in remaining root and ascending aorta dimensions; however, our numbers are too small to provide any solid conclusion. Not surprisingly, patients in whom autograft mode of failure was due to annular dilatation and lack of cusp coaptation started with a larger root and ascending aorta than those in whom mode of failure was recurrent inflammation. Our current data are more convincing that mode of failure also affects the rate of dimension change in the remaining root.

Another important finding is that the rate of increase in root and ascending aorta diameters was not related to the initial indexed dimensions, evidently within our study range. At time of last echocardiographic follow-up, only 1 patient had aortic root diameter that exceeded 5 cm (5.2 cm); that patient underwent AuVR 15 years earlier and started with a root diameter of 4.6 cm, which is a clear example that the rate of dilatation after AuVR is not necessarily related to the initial diameter. Given that information, simple AuVR with SP seems a valid option in patients with root diameter less than 4 cm.

Study Limitation
The current study offers a unique opportunity to examine the fate of the remaining neo-aortic root after AuVR with SP in a large series of patients with a failing Ross procedure. The obvious limitation of the current study is the large proportion of patients with underlying rheumatic fever in whom the timing and mode of failure differ from that seen in patients with underlying congenital heart disease. Although the hemodynamic manifestation prior to Ross and the degree of aortic annular dilatation are more important factors determining the rate of root and ascending aortic dilatation than underlying pathology itself; our results should be interpreted with caution when applied to patients in the Western population with predominant congenital heart disease. While there is no current evidence that the performance of the remaining autograft would diverge based on underlying pathology after neutralization of the hemodynamic factor with AuVR and a competent SP, the obvious concern is that patients with congenital heart disease (especially those with BAV) would have faster growth of the remaining root due to preexisting degenerative changes in the autograft wall and the comparatively late failure, consequently longer exposure to regurgitation and larger root diameters at time of reoperation.

Summary
Autograft failure due to development of progressive root dilatation and regurgitation might necessitate autograft reoperation. Aortic valve sparing techniques are the current treatment of choice and allow AuV salvage in selected patients with good mid-term results. If AuVR is necessary, the choice of procedure should be individualized, taking into consideration surgical complexity, patient’s age, initial dimensions, and mode of autograft failure. Given the low incidence of root reoperation, straightforward AuVR with SP is justifiable in patients with root diameter less than 4 cm. Aortic root replacement should be reserved for patients with larger root diameters at time of AuVR, especially those with longer life expectancy and other associated risk factors for faster root growth. Although reoperations after AuVR with SP are rare, patients should be followed for progressive dilatation of remaining root and ascending aorta.

References
RESULTS

The diagnosis of inflammation was based on echocardiographic, intraoperative, and pathologic findings in the explanted valves. The typical echocardiographic findings in those patients with recurrent inflammation include leaflet thickening, subvalvular involvement, commissural fusion, and variable degrees of calcification, similar to what you would see in rheumatic or any other inflammatory process affecting the aortic valve. Those findings are confirmed again intraoperatively. The explanted valve is also sent to pathology, and in those cases there was documented inflammation, some with confirmed pathologic and serologic recurrence of rheumatic valve disease, which is strange considering that the pulmonary valve is usually rarely affected by rheumatic fever; while in other cases, nonspecific inflammatory process is identified without evidence of rheumatic fever recurrence.

As for the criteria for reoperation on the failing autografts, there are no specific guidelines for this particular group of patients. In general, we follow the same guidelines for aortic regurgitation. So reoperation is based on symptoms, exercise intolerance, presence of progressive dilatation of the left ventricle, and deterioration of systolic function. Occasionally, decision for reoperation is based on the root size rather than the degree of aortic regurgitation. However, that was rare in our series as I have shown, and the indication for reoperation in most patients was in fact aortic regurgitation.

DISCUSSION

DR TARA KARAMLOU (San Francisco, CA): Nice presentation, Dr Alsoufi. Two quick questions: One, how was the recurrence of inflammation defined and what parameters did you use to label the patient with recurrent inflammation? And the second is, you used a hard end point of reoperation or reintervention. Could you elaborate on the criteria that was the threshold for reintervention at your center? Thanks.

DR ALSOUFI: The diagnosis of inflammation was based on echocardiographic, intraoperative, and pathologic findings in the explanted valves. The typical echocardiographic findings in those patients with recurrent inflammation include leaflet thickening, subvalvular involvement, commissural fusion, and variable degrees of calcification, similar to what you would see in rheumatic or any other inflammatory process affecting the aortic valve. Those findings are confirmed again intraoperatively. The explanted valve is also sent to pathology, and in those cases there was documented inflammation, some with confirmed pathologic and serologic recurrence of rheumatic valve disease, which is strange considering that the pulmonary valve is usually rarely affected by rheumatic fever; while in other cases, nonspecific inflammatory process is identified without evidence of rheumatic fever recurrence.

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DR BRIAN KOGON (Atlanta, GA): I didn’t realize this when I read the abstract, but the average age at the Ross was 17, the average age at the reoperation was 21, and you reoperated on 10% of your patients. So it makes me wonder if the Ross operation was the right operation the first time.

DR ALSOUFI: Definitely that’s a good question and the answer is no. Obviously this study spans from the beginning of our experience with the Ross procedure in 1990 till 2011. At the beginning of our experience, the Ross procedure was being offered to children and young adults with all sorts of cardiac pathologies. It was not long before our surgeons, as well as others, discovered that it should not be offered to everybody. The biggest group that it should not be offered to is patients with rheumatic fever, especially those who start with pure regurgitation, dilated aortic anulus, size mismatch between the larger aortic valve and the smaller pulmonary valve, those with concomitant mitral valve disease requiring surgery, or those who have positive rheumatic activity at time of operation. So by changing our institution’s selection criteria and by adopting some technical modification, the risk of autograft reoperation has substantially decreased.

Interestingly, as you have pointed out, the reported autograft failure in our series with predominantly rheumatic fever patients is earlier than that reported in Western series with predominantly bicuspid aortic valve disease, and that’s demonstrating the usual fate of the Ross procedure in rheumatic patients.

DR PETER SKILLINGTON (Melbourne, Victoria, Australia): The patients who were re-done after a Ross procedure for bicuspid aortic valve disease, in these patients, were you able to preserve the pulmonary autograft in any, by doing a valve sparing root replacement?

DR ALSOUFI: Most of our failures and subsequently our reoperations were done in the 1990s and early 2000s. So that’s before the aortic valve (AV)-sparing operation became popular, especially before the role of AV-sparing has expanded to allow salvage of failing autografts. Our current management of failing autografts depends on the mode of failure. In those who fail with neo-aortic anular and root dilatation, cusp prolapse, and failure of coaptation, our current first choice is AV-sparing repair allowing preservation of the autograft valve in many cases. In retrospect, 60% of our current patient cohort could have been candidates for AV-sparing operation. However, in some patients, failure is due to cusp disease rather than root disease, and in those patients you are forced to change the valve.

So, we are currently seeing less failing autografts, and in many of the patients we can salvage those failing autografts with AV-sparing operation. The importance of our study, however, is that it shows the fate of the remaining root in large number of cases and that’s information we can use when we need to replace the autograft valve. Our findings support simple autograft valve replacement with stented prosthesis without the need of a prophylactic root surgery when the root is less than 4 cm at time of reoperation. Our findings seem to be applicable to Western population as the rate of root growth in those who fail with dilatation, while faster, remains low.