Aortic and mitral valve replacement in children: is there any role for biologic and bioprosthetic substitutes?∗

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Abstract

Objective: The ideal valve substitute in children does not exist. Biologic and bioprosthetic valves do not require anticoagulation, however their use is complicated by accelerated degeneration and requirement for reoperation. We examine results following mitral (MVR) or aortic (AVR) replacement with biologic and bioprosthetic valves at our institution. Methods: Medical records of children who underwent AVR or MVR from 1986 to 2006 were reviewed. Median follow-up duration was 10.5 years. Competing-risks methodology determined time-related prevalence and associated factors for three mutually exclusive end states: death, valve reoperation, and survival without subsequent reoperation. Results: One hundred and ten children (age 15.6 ± 2.6 years, 80% females) underwent 123 valve replacements with biologic and bioprosthetic substitutes including 87 MVR and 36 AVR (13 had both). Underlying pathology was mainly rheumatic fever (91%). Thirty-nine patients (35%) had undergone a previous cardiac surgery. Most common mitral substitute was Hancock (73%) and homograft (8%); most common aortic substitute was homograft (41%) and Carpentier–Edwards (39%). Competing-risks analysis showed that 15 years after valve replacement, 16% of patients had died without subsequent reoperation, 66% underwent valve reoperations, and only 18% remained alive without further reoperation. Factors associated with increased reoperation risk included younger age at surgery (p = 0.005), AVR (p = 0.005), male gender (p = 0.02) and homograft use (p = 0.007) especially in the mitral position (p = 0.002). Fifteen-year freedom from endocarditis was 97% while freedom from bleeding and thrombo-embolic complications was 100%. Majority of patients (95%) were in NYHA functional classes I/II at last follow-up. Conclusion: While valve reoperation is inevitable following AVR and MVR with biologic and bioprosthetic substitutes; favorable results such as low valve-related morbidity rate, good long-term survival and functional status encourage their consideration as valid replacement alternatives in selected children especially females. Valve durability is higher in the mitral position and longevity of bioprosthetic valves is greater than that of homografts especially in the mitral position.

Keywords: Mitral valve replacement; Aortic valve replacement; Rheumatic fever; Homograft; Pulmonary autograft; Bioprosthetic valve

1. Introduction

Aortic and mitral valve diseases are common in children and frequently require intervention [1–3]. Congenital valve disease is the most frequent pathology in Europe and North America while rheumatic fever remains a major pathology in developing countries [1–6]. While valve repair remains the treatment of choice, replacement may be required in children in whom the valve is extensively damaged, or following repair failure.

Valve replacement in children is problematic; all options are associated with major limitations. Mechanical valves lack the growth potential, require lifetime anticoagulation that is associated with lifestyle limitations, and can lead to problems during pregnancy and major thrombo-embolic morbidity due to poor compliance with anticoagulation medications in children and teenagers [1–3,5–9]. Replacement of the aortic valve with a pulmonary autograft (Ross procedure) is widely seen by many as the procedure of choice for aortic valve replacement in children as it offers growth potential, does not require anticoagulation, and is associated with excellent survival [1,3–5,10,11]. Nonetheless, requirement for pulmonary homograft replacement, concerns about autograft dilatation and subsequent development of aneurysm and aortic regurgitation have lowered enthusiasm toward the Ross procedure lately [12,13]. Biologic (homografts) and bioprosthetic valve replacement in children are
associated with accelerated degeneration and early requirement for reoperation. In addition, size restrictions and lack of growth potential limit their application in small children [1,3,14,15].

In the current report, we describe the clinical outcome in children who had aortic and/or mitral valve replacement with biologic or bioprosthetic substitutes at our institution.

2. Patients and methods

2.1. Inclusion criteria

From 1986 to 2006, 110 consecutive children under the age of 18 years old received biologic or bioprosthetic valves for aortic (AVR) or mitral (MVR) valve replacement at the King Faisal Specialist Hospital and Research Center in Riyadh, Saudi Arabia. Those patients had 123 valve replacements including 87 MVR, 36 AVR. Thirteen patients had both AVR and MVR. Patients were identified using the hospital surgical database. Clinical, operative, and outcome data were abstracted from their 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.

2.2. Follow-up

Late outcomes were determined from recent office visits at King Faisal Specialist Hospital and Research Center or from direct correspondence with patients’ families. Median follow-up duration was 10.5 years and ranged up to 22.2 years. Follow-up was complete in 94% of patients and was partial in the remaining patients who had relocated outside Saudi Arabia.

2.3. Statistical analysis

Data are presented as means with standard deviation, medians with minimum and maximum and frequencies as appropriate. Time-dependent outcomes (death and reoperation) after valve replacement were parametrically modeled. Parametric probability estimates for time-dependent outcomes used models based on multiple, overlapping, phases of risk (available for use with the SAS system at http://www.clevelandclinic.org/heartcenter/hazard). The HAZARD procedure uses maximum likelihood estimates to resolve risk distribution of time to event in up to three phases of risk (early, constant and late). Competing risk analysis was performed to model the probability over time of each of three mutually exclusive endpoints: valve reoperation, death without second replacement, or alive and free from second replacement. Effects of covariates on the probability of outcomes in competing risk models were sought in univariable models and are reported as parameter estimates with standard error and hazard ratio with 95% confidence interval. The effect of both patient-specific variable and valve-specific variable was estimated, models for valve-specific factors are adjusted for repeated measures on some patients through a compound symmetry covariance structure. Clinical relevance of identified covariates on likelihood of selected outcomes was established through stratification analysis. All statistical analyses were performed using SAS statistical software v9.1 (The SAS Institute, Cary, NC).

3. Results

3.1. Patient characteristics

During the study period, 110 patients (22 males) received 123 biologic and bioprosthetic valves in the mitral (n = 87) or aortic (n = 36) position with 13 patients receiving both. Mean age at index operation was 15.6 ± 2.6 years. The underlying pathology was rheumatic valve disease in 101 patients (91%), congenital valve anomaly in 3 patients, endocarditis in 3 patients, and connective tissue disease in 3 patients.

Before index operation, 39 patients (35%) had undergone prior cardiac operations to address the valvular and/or other cardiac lesions. The most common mitral substitute was Hancock (73%) and homograft (8%); the most common aortic substitute was homograft (41%) and Carpentier–Edwards (39%). A complete list of the valves utilized in our patients is shown in Table 1.

3.2. Competing risk analysis for death or subsequent prosthesis replacement after initial MVR

Following the 123 initial valve replacements, 48 patients had subsequent valve reoperation and 10 patients died without a further valve reoperation. In addition, there were three additional late mortalities in patients in whom the biologic/bioprosthetic valves had been replaced with a mechanical (n = 2) or bioprosthetic (n = 1) valve. Median valve survival was 7.4 years in the aortic position and 13.1 years in the mitral position.

The hazard function for time-related transition to a valve reoperation was characterized by the absence of an early phase of risk and by the presence of a constant and a late hazard phase (Fig. 1). The hazard function for time-related transition to death without a second valve reoperation was characterized by a constant hazard phase only indicating a low but stable risk of attrition over time (Fig. 2).

The competing risks for the two events showed that at 4 years after surgery, nearly 10% of patients have died and 10% required a valve reoperation. After 4 years, the risk of death remains low, but the risk of reoperation increases significantly. At 10 years following initial valve replacement, approximately 15% of patients have died, 40% underwent further valve reoperation and 45% are alive and free from

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Types of prosthesis utilized in the series.</th>
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<tbody>
<tr>
<td></td>
<td>All</td>
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<tr>
<td>Prosthesis type (n = 123)</td>
<td></td>
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<tr>
<td>Hancock</td>
<td>68 (55%)</td>
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<tr>
<td>Carpentier–Edwards</td>
<td>17 (14%)</td>
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<tr>
<td>St John stentless (Quatro)</td>
<td>7 (6%)</td>
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<tr>
<td>Homograft</td>
<td>22 (18%)</td>
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<tr>
<td>Ionescu-Shiley</td>
<td>3 (2%)</td>
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<tr>
<td>Medtronic mosaic</td>
<td>6 (5%)</td>
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<tr>
<td>Prosthesis size</td>
<td>22.7 ± 2.0</td>
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reoperation. At 16 years following initial valve replacement, less than 20% are alive without reoperation while more than 65% underwent further valve reoperation (Fig. 3).

Significant factors for constant phase mortality were younger age at surgery (hazard ratio (HR) and 95% confidence interval: 1.2 per year (1.0—1.4), \( p = 0.05 \)), etiology other than rheumatic (HR: 3.9 (1.1—14.7), \( p = 0.04 \)) and the use of homograft in either positions (HR: 5.4 (1.8—16.6), \( p = 0.003 \)) (Table 2).

Significant risk factors for valve reoperation in the late phase included: male gender (HR: 2.5 (1.2—5.4), \( p = 0.02 \)), younger age at operation (HR: 1.2 per year (1.1—1.4), \( p = 0.005 \)), AVR (HR: 2.5 (1.3—4.7), \( p = 0.005 \)), and the use of homografts in the mitral position (HR: 4.0 (1.6—9.6), \( p = 0.002 \)). No risk factors were found for the constant phase (Table 2).

The higher risk of reoperation for AVR versus MVR is shown in Fig. 4. Similarly, the increased risk of reoperation associated with biologic versus bioprosthetic valves is depicted in Fig. 5. Finally, the effect of patient age at time of operation on the risk of future valve reoperation is illustrated in Fig. 6.

### 3.3. Causes of death and modes of prosthesis failure

There were 13 mortalities in our series. Those include two early deaths following initial valve replacement: one patient following emergency aortic and mitral valve replacement for severe endocarditis associated with root abscess, and another patient with rheumatic aortic valve disease in whom a mechanical valve was implanted but developed intraoperative coronary ischemia due to coronary orifice obstruction by the mechanical prosthesis which was removed and replaced by a homograft. He required postoperative mechanical support and died from failure of cardiac recovery.

In addition, there were 11 late deaths: 1 non-cardiac and 10 cardiac: sudden death (\( n = 2 \)), sudden death in patients in whom the valves had been replaced by mechanical prostheses (\( n = 2 \)), congestive heart failure (\( n = 2 \)), acute severe mitral stenosis prior to reoperation (\( n = 1 \)), following valve reoperation (\( n = 1 \)), and unknown etiology to us (\( n = 2 \)).

Forty-eight patients required valve reoperation including 15 aortic and 36 mitral valve reoperations. The mode of failure was different between the aortic and mitral valves. Indications for aortic valve reoperation included degenerative calcification and stenosis of the prosthesis (\( n = 8 \)), degenerative tear of the cusp and regurgitation (\( n = 4 \)), and endocarditis (\( n = 3 \)). Indications for mitral valve reoperation included prosthesis degeneration with torn cusps and regurgitation (\( n = 23 \)), calcification and stenosis (\( n = 4 \)), mixed disease (\( n = 5 \)), endocarditis (\( n = 1 \)), and during other cardiac reoperation with evidence of early prosthesis degeneration (\( n = 3 \)).

### 3.4. Late complications and functional status

Valve-related complications were infrequent; there were no reported hemorrhagic, thrombo-embolic or valve thrombosis episodes. Fifteen-year freedom from endocarditis was...
97%. The majority of survivors (95%) were in New York Heart Association (NYHA) functional classes I/II.

4. Discussion

Valve repair is the treatment of choice in mitral/aortic valve dysfunction. However, replacement may still be required in a subset of children for whom the valve cannot be repaired. Optimal prosthesis choice in children would be one that is readily available in different sizes, associated with excellent hemodynamic profile, has growth potential to match patient’s somatic enlargement, associated with minimal hemorrhagic and thrombo-embolic complications not requiring anticoagulation, and finally associated with excellent valve longevity and low incidence of structural valve deterioration. No such choice is currently available to the surgeons; all alternatives are associated with major limitations.

Our study reports a single institution’s experience with AVR and MVR using biologic/bioprosthetic substitutes in 110 children under 18 years old. Competing-risks analysis was chosen because these patients were simultaneously at risk for two mutually exclusive events: death and valve reoperation. Conventional time-related analyses consider individual events such as death or reoperation either in isolation or as a combined end point. Though useful, they do not address the question of how often an event may occur in the absence of other events for which a patient is at simultaneous risk. Although no direct comparison was made in this existing study with other valve options in children; our discussion will focus on the findings of this current series in comparison to other contemporaneous series from the literature examining outcomes of other different valve replacement options in children. We will attempt in light of those results to define the potential role that bioprosthetic and biologic valves may play in children.

4.1. Options for aortic valve replacement

Aortic valve replacement options include mechanical valves, Ross procedure, homografts and bioprosthetic valves. The Ross procedure is considered by many surgeons the ideal replacement option in children. It is associated with excellent hemodynamics, offers the growth potential and does not require long-term anticoagulation [1,3–5,10,11]. Several series in the literature detailed excellent survival and freedom from aortic valve reoperation. We reported the outcomes of 136 children who underwent the Ross procedure from 1990 to 2000. Survival was 94% at 10 years and freedom from all adverse events was 93% at 10 years.
years [4]. Similarly, Tekkenberg et al. reported survival of 93\% and freedom from valve-related reoperation of 86\% at 12 years [10]. Starnes et al. reported outcomes in 111 patients (median age 15.7 years) following the Ross procedure with equally excellent survival 94\% at 5 years and freedom from autograft replacement of 91\% at 5 years. Importantly, there was evidence of autograft growth that followed the expected increase in pulmonary annulus diameter [11].

On the other hand, in a recent study by Pasquale et al., serial echocardiograms were obtained following the Ross procedure in a mainly pediatric population. Freedom from neo-aortic root intervention was 88\% at 6 years, freedom from moderate neo-aortic regurgitation was 60\%, and freedom from neo-aortic root size z-score more than 4 was only 3\% [12]. Those results highlighted concerns that the neo-aortic root size increases significantly and out of proportion to somatic growth and that neo-aortic valve regurgitation was progressive [12,13].

Mechanical valves in children are associated with increased frequency of complications including morbidity related to long-term anticoagulation, deterioration of ventricular function due to the development of patient-prosthesis mismatch as the child outgrows the initial valve and the need for subsequent prosthetic replacement [1,3,5,7]. There have been few contemporary series of AVR with mechanical prostheses in children that can be used for comparison with our current series. Alexiou et al. reported outcomes in 56 children who received mechanical AVR. At 20 years, survival was 85\%, freedom from reoperation was 86\%, freedom from thrombo-embolism was 93\% and freedom from valve-related events was 86\% [7]. We have recently compared outcomes in 346 children who received AVR including 215 Ross procedure and 131 bileaflet mechanical prostheses. Propensity adjusted comparison of outcomes was performed. Competing-risk analysis showed that 16 years after AVR, 20\% of patients had died without subsequent AVR, 25\% underwent second AVR, and 55\% remained alive without further reoperation. After propensity adjustment, mechanical valves were associated with early phase mortality and constant late attrition. Operative mortality was lower for the Ross procedure (2.3\%) compared to mechanical AVR (6.1\%). Younger children receiving smaller mechanical prostheses were at highest risk of death. Operative mortality for patients under 5 years old in our study was 50\% for mechanical valves compared to less than 4\% for Ross. Most importantly, survival was stable for Ross procedure with no late mortality compared to 19 additional cardiac-related deaths in the mechanical group. Many of those deaths were sudden in nature highlighting the delicate problem of compliance with anticoagulation regimen and its implication on patients’ lifestyle that is especially difficult to control in children and young adults [5]. While Ross procedure offered survival advantage to our patients, it was associated with higher reoperation rate. Karamlou et al. reported outcomes following AVR in 160 children including 94 mechanical valves, 31 Ross procedure, 30 homografts and 30 bioprosthetic valves. Non-autograft use was a significant risk factor for death while implantation of a homograft or a bioprosthesis valve were significant risk factors for valve reoperation [1]. Another study from Indiana reported outcomes following AVR in 147 children including 47 mechanical valves, 81 Ross procedure, 8 homografts and 11 bioprosthetic valves. Again, survival was significantly higher in patients who underwent the Ross procedure and freedom from reoperation was lowest for patients who received a bioprosthetic valve [3].

In our current series, the observed survival following AVR with bioprosthetic valves and homografts was lower than that reported for the Ross procedure but higher than that reported for mechanical valves. While the risk of endocarditis seems to be equal for all valve types, there were no bleeding or thrombo-embolic complications in the current series, similar to the Ross procedure but much lower than that following mechanical AVR. Finally, freedom from valve reoperation in our series was much lower than that of mechanical valves and Ross procedure.

Based on our analysis of the current outcomes and the available literature, it seems that the Ross procedure offers survival advantage over mechanical valves and to a lesser degree over other valve options. This survival advantage is evident in all age groups; however it is most prominent in younger patients who would require a smaller prosthesis. In small children, Ross procedure seems to be the superior procedure. In small children in whom a pulmonary autograft cannot be utilized, homografts are indicated as bioprosthetic valves are not available in small sizes and mechanical valves are associated with significant increase inoperative mortality in this subgroup of little children. In adolescents, mechanical and bioprosthetic valves are valid options although their results are inferior to that of the Ross procedure. Bioprosthetic valves are associated with a very high risk for reoperation and small risk of late death, while mechanical valves are associated with a higher likelihood of late attrition, lower risk of reoperation and important thrombo-embolic and bleeding morbidity. The role of bioprosthetic valves for AVR seems to be limited to patients in whom the Ross procedure cannot be offered and in whom anticoagulation is not recommended such as in females at childbearing age or in patients with poor compliance with anticoagulation protocols. The operative risk for aortic valve reoperation has decreased in the current era, which may make this option preferable in that selected group of patients.
4.2. Options for mitral valve replacement

Surgical alternatives for MVR in children are narrower; replacement options are limited mainly to mechanical and bioprosthetic valves [2,6,8,9,14,15]. Although we have utilized homografts for MVR in seven patients using the top hat technique, outcomes have been poor and valve survival has been very short. Kabbani et al. have reported results of the Ross II operation utilizing pulmonary autografts mounted in a Dacron tube for MVR with encouraging results. However there is very little experience with this procedure from other institutions [16].

Two older series reported high reoperation rate following MVR with a bioprosthesis in children. Antunes reported 135 patients <20 years of age. At the time of the study, there was an overall incidence of 80 patients with structural failure, 64 who had replacement, 11 who died without replacement, and 5 who were awaiting replacement [14]. Odell et al. reported a series of 195 patients <15 years of age, using porcine and bovine pericardial valves in the mitral position. At 4 years, valve survival without calcification was less than 20%. Our more contemporary results were not very dissimilar with regards to reoperation requirement [15]. A modern study by Kojori et al. reported 104 children who underwent at least one MVR and their findings were comparable to ours. In their series, the use of Ionescu-Shiley and other bioprostheses was a significant risk factor for reoperation [2].

MVR is especially challenging in young children due to the small size of the native valve annulus, atrium, and ventricle. Several reports have identified that placement of a large prosthesis in children with small mitral annulus is associated with high risk for operative mortality due to complications related to leaflet entrapment, development of left ventricular outflow tract obstruction, tricuspid valve obstruction and conduction block [2,6,9,17,18]. Replacement in this age group has a high operative mortality ranging from 10% to 36%, in addition to significant morbidity. Caldarone et al. noted that geometric disparity based on calculations of prosthetic valve size to patient body weight impacted on operative mortality [9]. We have also examined outcomes of MVR in 79 children <8 years of age; mortality was 30% for those <2 years old and 6% for those >2 years [6]. Similar to Caldarone, valve oversizing was a significant risk factor for operative mortality. Therefore, as bioprosthetic valves are not available in small sizes, mechanical valves are the main replacement option in young children in whom a small prosthesis is required. On the other hand, bioprosthetic valves may be recommended in selected group of older patients such as in females in childbearing age and those with poor compliance with anticoagulation. While reoperation seems to be inevitable, it is associated with low mortality risk in the current era.

In our current series, valve longevity was significantly higher in the mitral position compared to the aortic position, which is different from other reports in adult patients. The mode of prosthesis failure was also different; most aortic valve reoperations were due to the development of stenosis secondary to calcification or patient prosthesis mismatch while most mitral valve reoperations were due to the development of regurgitation secondary to cusp prolapse or tear.

Those findings may explain the disparity between our study and other series in adult patients. Indications for aortic valve replacements were not limited to the development of structural valve degeneration but also to failure of the prosthesis to enlarge to match the somatic growth of the children. Patients who had AVR in our series either required small homografts in younger children or relatively small bioprosthetic valves in older children. Therefore, those patients were at higher risk of development of stenosis and subsequently required aortic valve reoperation. On the other hand, as smaller prostheses are not available for mitral valve replacement, their use was limited to older children and young adolescents. Subsequently, the mitral prostheses that were utilized in our series were of a relative appropriate size and therefore reoperation was largely due to the development of structural valve degeneration.

Finally, many of our female patients had successful and uncomplicated pregnancies. Pregnancy was not found to be a risk factor in our series for accelerated structural valve degeneration although our study is not powered to examine the effect of pregnancy on accelerated valve degeneration.

5. Conclusions

The use of homografts and bioprosthetic valves for aortic or mitral valve replacement in children is associated with rapid structural degeneration and eminent reoperation requirement. While valve reoperation is inevitable, the lack of other optimal valve substitutes, the favorable results such as low valve-related morbidity rate, good long-term survival and functional status encourage their consideration as valid replacement alternatives in selected children; especially females and patients with poor compliance with anticoagulation medications.

References


Appendix A. Conference discussion

Dr D. Barron (Birmingham, United Kingdom): I think it’s a very important study. It’s an area which perhaps has been forgotten in the past, and I think it reflects our attitudes using bioprosthetic valves in the adult field where they’ve attracted more attention recently. This is very timely, I think, looking how it behaves in children, and it raises some important questions.

I think there are limitations to this study. I think you’re operating on a slightly different population to what we’ve seen in some European centers, a lot of rheumatic disease. And although you’re talking about children, your mean age is 15 years old, so I would argue that a lot of these patients are really what we regard as adults. In terms of their size and potential for growth, these are adults.

Can I just ask you one quick question first, in order to get the whole picture, was there any early mortality or any heart block in these patients?

Dr Alsoufi: There were two early deaths following initial valve replacement; one patient following emergency aortic and mitral valve replacement for severe endocarditis associated with root abscess, and another patient with rheumatic aortic valve disease in whom a mechanical valve was implanted but developed intraoperative coronary ischemia due to coronary orifice obstruction by the mechanical prosthesis which was removed and replaced by a homograft. He required postoperative mechanical support and died from failure of cardiac recovery.

Heart block requiring insertion of a permanent pacemaker was evident in 2 patients, one following MVR and one following AVR.

Dr Barron: I want to ask you two really specific questions, one relates to the aortic valve and one to the mitral valve.

You say in your paper that you believe that probably the Ross operation is still the better operation for aortic valve replacement in children and you’ve published very good results of the Ross operation in children from your own center. What are your reasons for not offering the Ross procedure even if they need the 2-valve replacement?

And the second question is about the mitral. Given that a lot of these patients are really what we regard as adult-size patients, and from your valve sizes you describe in the paper you’re able to really put an adult-size valve in most of these patients, why not put a mechanical valve in these patients? And then if you do a mechanical valve and a Ross, even if they need double-valve replacement, you might not need to operate on them again for many years, hopefully only for a homograft replacement.

Dr Alsoufi: I agree with your observation that our patient cohort is composed of older children and that is basically due to the fact that small sized bioprosthetic valves are not commercially available. For patients undergoing MVR, several studies including a recent one from our institution demonstrated that pros thesis-patient mismatch, when a relatively large prosthesis is placed in the mitral position, is associated with high early mortality risk because of risk of compression of adjacent cardiac structures, especially in younger children. So obviously, in younger children, the choice of placing a bioprosthetic valve is non-existent because those prostheses are not available in smaller sizes. The same concept remains true for AVR. In younger patients, the Ross procedure is commonly performed for AVR while homografts are less commonly utilized in certain indications.

As for the Ross procedure, several studies including a recent one from our institution that was presented in the past AATS meeting suggested a survival advantage for the Ross procedure over a mechanical aortic valve. In general, we don’t offer the Ross procedure at our institution to patients who require mitral valve replacement although we offer it to those who require mitral valve repair. The reason is that the patient still requires life-long anticoagulation and therefore will not enjoy the benefits of the Ross procedure. Nonetheless, in view of fair longevity of bioprosthetic mitral valves, in addition to increased reported valve-related morbidity and mortality of mechanical mitral prostheses in children, a combination of a Ross procedure and a bioprosthetic mitral valve may seem to be a reasonable option in selected patients requiring a double valve replacement.

Among almost 150 children who’ve required double valve replacement at our institution, the majority received mechanical valves compared to only 13 who received bioprosthetic valves.

Mr Barron: So what were your criteria?

Dr Alsoufi: Treatment is individualized for each patient and all replacement options are discussed with the final choice largely dependent on anatomic factors, additional surgeries, comorbidities, size limitations, patient’s social status and preference.

In summary, for single AVR, our institutional preference in children is the Ross procedure; for MVR, the most common choice is a mechanical valve; and for double valve replacement, it is usually mechanical valves. Nonetheless, what we conclude from this series is that in certain patients in whom size and growth are not major concerns, and in whom anticoagulation is not desired such as in patients non-compliant with medications or in females, single or double systemic valve replacement with a bioprosthetic valve is a valid choice and is associated with good survival and low valve-related complication rates at the expense of an almost inevitable need for reoperation in the future.