The Ross operation after removal of a transcatheter aortic valve replacement in pediatric patients

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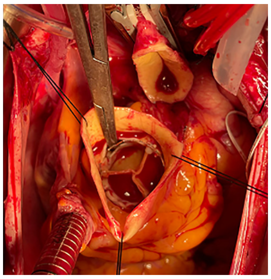


Balloon-expandable TAVR prosthesis before removal.

CENTRAL MESSAGE

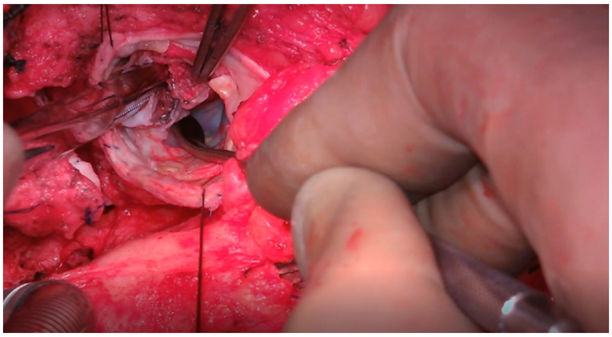
The Ross procedure can be performed safely after TAVR removal in pediatric patients with good short-term outcomes. Although mortality is low, morbidity is higher than the Ross performed alone.

▶ Video clip is available online.

The ideal choice for aortic valve replacement (AVR) in pediatric populations is unknown. Options include bioprosthetic and mechanical valves and the pulmonary autograft (Ross operation). Each contains a unique risk-benefit profile with no gold standard.[1] Pediatric transcatheter aortic valve replacement (TAVR) is an intriguing option, and its use is expanding with short-term results being similar to those of surgical AVR.[2] The Ross procedure, with improved autograft durability[3] (see also Reference [E1]), remains our preferred option. Currently, there are no data reporting the results of the Ross operation after TAVR removal from a native left ventricular outflow track in either adults or children. The purpose of our study is to report and better understand the safety and short-term outcomes of Ross after TAVR removal in children.

OPERATIVE TECHNIQUE

All procedures were performed on cardiopulmonary bypass with mild hypothermia (Video 1). The TAVR was removed by longitudinally dividing the prosthesis and wrapping the stent frame around a clamp to separate it from the aortic root.[3] Our Ross technique has been previously reported.[4] To summarize, the autograft is harvested from the right ventricular outflow track and the muscular cuff is trimmed to within 2 to 3 mm of the pulmonary annulus. The autograft is implanted in a subannular position using interrupted monofilament sutures. If the native aortic annulus is >25 mm, an extra-aortic 3 to 4 mm polyethylene terephthalate subannular stabilization graft is



VIDEO 1. Video presentation of an operative removal of transcatheter aortic valve replacement valve and Ross operation in a pediatric patient. Video available at: https://www.jtcvs.org/article/S2666-2507(22)00584-3/fulltext.

secured by passing 6 pledgeted sutures from within the left ventricular outflow track under the nadirs of each sinus and intercommissural triangle. The chosen graft is sized 5 to 6 mm larger than the size of pulmonary autograft annulus and then tied down over a dilator sized to the autograft annulus. Following autograft implantation, excess tissue above the autograft commissural posts is resected to within 2 mm of the commissures. For patients with either a paucity of native aortic tissue or those with enlarged aortic aneurysms, we insert a short polyethylene terephthalate tube graft to stabilize the sinotubular junction of the autograft (sizes typically 24-26 mm).

CASES

This study was exempted from the University of Utah institutional review board because case reports including ≤3 patients are exempted from review and consent if all data are de-identified and part of standard of care.

Descriptions of native aortic valve pathology, initial catheter-based procedures, and indications for TAVR are listed in Table 1. All 3 TAVR implants were balloon-expandable valves.

Patient 1

A 20-year-old man received a 26-mm TAVR for mixed aortic insufficiency/aortic stenosis (AI/AS). Twenty-four months later he developed progressive aortic root and ascending aortic dilation with AS (mean, 26 mm Hg). He had partial aortomitral disruption during TAVR removal requiring repair by resuspending the injured portion of the anterior leaflet of the mitral valve to the annulus through the left ventricular outflow track. He received a 27-mm pulmonary homograft and a 24-mm ascending aortic interposition graft for an ascending aneurysm.

Patient 2

A 16-year-old man received a 29-mm TAVR for AI/AS. Twenty-six months later he developed moderate AI through a paravalvular leak with increasing left ventricular dilation (Figure E1). He received subaortic annular stabilization and a 24-mm pulmonary homograft with a 22-mm ascending aortic interposition graft for an ascending aneurysm.

Patient 3

A 15-year-old man received a 29-mm TAVR for AI/AS. Thirty months later he developed severe AS (mean, 51 mm Hg) and mildly diminished left ventricular function. He received subaortic annular stabilization and a 28-mm pulmonary homograft with a 22-mm ascending aortic interposition graft for an ascending aneurysm.

RESULTS

There were no operative mortalities, no neurologic events, 1 patient with heart block, and 1 postoperative bleeding event. Mean intensive care unit length of stay was 3 days (range, 2-4 days), mean total hospital length of stay was 6.3 days (range, 4-12 days), and all patients were extubated within 24 hours of surgery. Mean cardiopulmonary bypass time was 228 minutes and mean aortic crossclamp time was 197 minutes.

One patient was empirically started on dual antiplatelet therapy postoperatively for a presumed embolic event and experienced a gastrointestinal bleed postoperative day 14 with no long-term sequelae. Another patient required implantation of a permanent pacemaker that was complicated by left subclavian vein thrombosis requiring pacemaker revision. Follow-up echocardiography and clinical status are listed in Table 2.

DISCUSSION

We are the first to report that the Ross operation after TAVR removal from native left ventricular outflow tracks can be performed with good short-term outcomes in a pediatric population. The Ross is a well-proven operation with excellent long-term outcomes and is our preferred surgical option for AVR in children. When performed at experienced centers, mortality and major morbidity are low, and the

TABLE 1. Description of native aortic valve (AV) pathology, initial catheter-based intervention and indications for both transcatheter aortic valve replacement (TAVR) and Ross operation

Patient	Native AV pathology	Initial AV procedure	Age at initial procedure, Yr	Indication for TAVR	Age at TAVR, Yr	Indication for Ross
1	Bicuspid valve, severe stenosis	Balloon valvuloplasty	13	Mixed- severe AS (peak 103, mean 54 mm Hg), moderate AI	17	Mixed AS/AI and Asc Ao aneurysm 4.21 cm
2	Unicuspid valve, severe stenosis	Balloon valvuloplasty	11	Severe AI, LVIDd 6.4 cm	14	Moderate PVL, LV dilation 6.4 cm
3	Bicuspid Valve, Severe stenosis	Balloon valvuloplasty	Neonate	Moderate AI, dilated LV, mildly decreased LV EF	13	Severe AS (peak 81, mean 51 mm Hg), mild AI, moderately decreased LV EF

AV, Aortic valve; *TAVR*, transcatheter aortic valve replacement; *AS*, aortic stenosis; *AI*, aortic insufficiency; *Asc Ao*, ascendnig aortic; *LVIDd*, left ventricle internal diameter in diastole; *PVL*, perivalvular leak; *LV*, left ventricle; *EF*, ejection fraction.

TABLE 2. Echocardiographic and clinical patient follow-up data

Patient	Echocardiography findings	Clinical status	Follow-up period
1	Trivial AI, no AS, no PS, no PI, normal biventricular function	Having arrhythmias and pacemaker related complications reducing exercise capacity and reports decreased quality of life	12 mo
2	Trivial AI, no AS, no PS, no PI, normal biventricular function	Doing well clinically, exercise restrictions removed	6 mo
3	Mild AI, no AS, no PS, no PI, moderately decreased LV function	Complains of persistent upper/lower extremity swelling and decreased exercise capacity, concern for genetic cardiomyopathy	9 mo

AI, Aortic insufficiency; *AS*, aortic stenosis; *PS*, pulmonary stenosis; *PI*, pulmonary insufficiency; *LV*, left ventricle.

autograft offers excellent hemodynamics and growth potential.[1,3,4]

Current data from adult patients suggest that AVR after TAVR removal results in significant morbidity (mitral valve intervention, 32%; bleeding, 12%; stroke, 9%; and heart block, 18%) and mortality of 13%.[5] Our limited pediatric experience of Ross after TAVR removal shows decreased overall morbidity (although a similar incidence of heart block and mitral intervention) and mortality. The reasons for these different experiences are speculative but likely related to the lack of pediatric preoperative comorbidities and anatomic substrate.

Our programmatic approach to aortic valve disease has evolved. Historically, referrals for TAVR were sent directly from referring cardiologists to an interventional cardiology team without surgical consultation. Recently, a multidisciplinary valve clinic was initiated where all patients undergo echocardiograph and computed tomography evaluations with both a cardiologist and surgeon meeting with the family to decide the best course of treatment. To date, our program has implanted 35 TAVR valves in pediatric patients (including 13 valve-in-valve and 22 native outflow track) and our short-term results have been reported.[2] We currently do not have any long-term data about the durability of the TAVR valve in children and cannot make a more meaningful long-term comparison of TAVR versus Ross.

To date, we have explanted 10 TAVR valves; 5 patients received the Ross operation (1 was a TAVR valve-in-valve in a bioprosthetic valve and the fifth occurred after this report was written). In addition, 2 patients had a tissue AVR, 2 patients had a mechanical AV, and 1 patient required a ventricular assist device and transplantation. Two patients developed endocarditis requiring TAVR removal.

Pitfalls

All of our patients had mixed AI/AS with large and pliable annuli compared with adults with mostly AS and calcified annuli. Despite this, we encountered challenges separating the TAVR from the mitral valve apparatus in all cases. Due to incomplete somatic growth, the TAVR implantation was commonly more proximal to protect the coronaries rendering the sealing cuff of the TAVR adhered to or closely abutting the anterior leaflet of the mitral valve. After the first explant we have started to transect the TAVR stent longitudinally to release tension and wrapping the remaining stent around a clamp has resulted in no mitral injuries. In contrast to adult series, our avoidance of self-expanding TAVR valves has allowed for safe coronary button harvesting and no ascending aortia damage during prosthesis removal. However, in patients who received a TAVR in the native outflow track, we experienced aortic annular damage during removal. In such cases, additional hemostatic sutures were placed through the native remnant of the aortic wall and the autograft annulus for support.

Although of interest, our objective is not to report on a comparison of TAVR versus Ross AVR in a pediatric population. Such an analysis will require longitudinal data and follow-up. That being said, our surgical bias and concerns for TAVR outcomes led to the creation of a valve clinic as described and in turn has lent to an exponential growth in our Ross program.

CONCLUSIONS

The Ross operation can be safely performed after TAVR removal with good short-term outcomes in pediatric populations. Although mortality was low following Ross after TAVR removal, similar morbidities and technical challenges exist as in adult populations and more experience will be required to make meaningful comparisons.

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E-Reference

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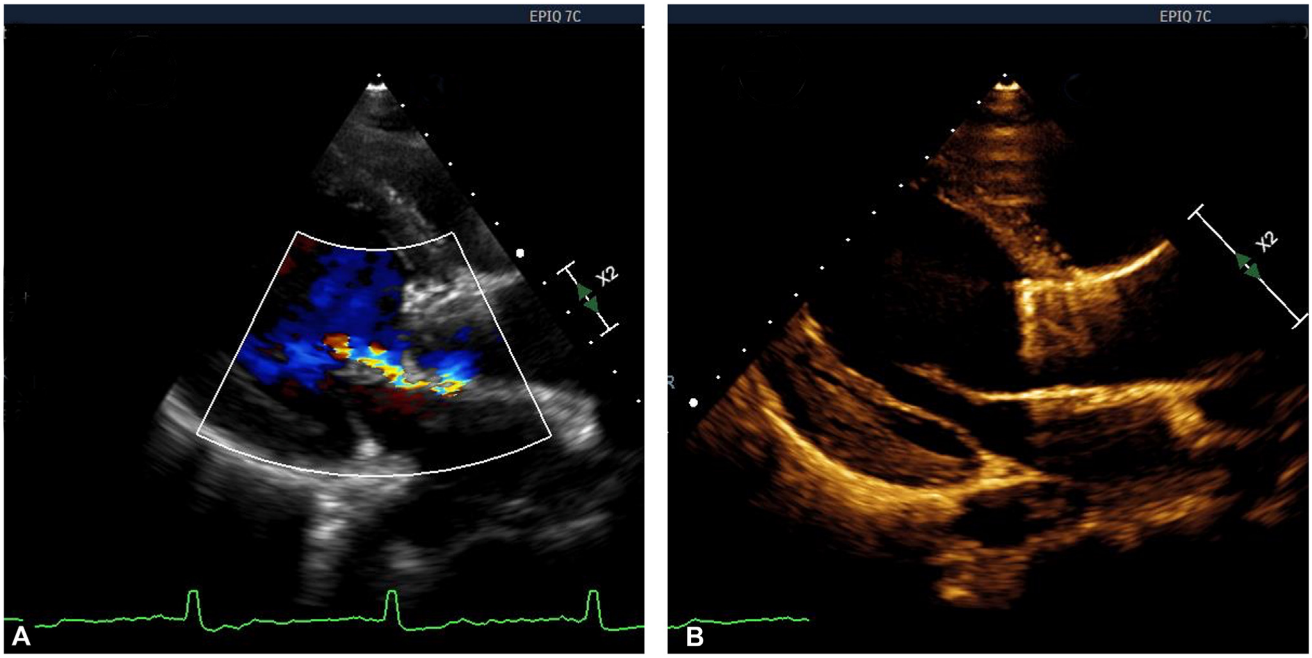

FIGURE E1. Preoperative echocardiography of a transcatheter aortic valve replacement (TAVR) valve before removal and Ross operation. A, Color showing moderate paravalvular leak. B, Anatomical proximity of TAVR stent to the anterior leaflet of the mitral valve.