The Externally Supported Ross Operation: Early Outcomes and Intermediate Follow-Up

Roni M. Jacobsen, MD, Michael G. Earing, MD, Garick D. Hill, MD, Michael Barnes, MPAS, PA-C, Michael E. Mitchell, MD, Ronald K. Woods, MD, PhD, and James S. Tweddell, MD

Division of Pediatric Cardiology, Department of Pediatrics, Division of Cardiovascular Medicine, Department of Internal Medicine, and Department of Cardiothoracic Surgery, Medical College of Wisconsin, Milwaukee, Wisconsin

Background. **The externally supported Ross (supported Ross), consisting of a Dacron (DuPont, Wilmington, DE) graft to support the neoaortic root, has been used in adolescent and adult patients to prevent neoaortic dilatation. Outcomes after the supported Ross technique were compared with the Ross procedure using the standard aortic root replacement technique (standard Ross).**

Methods. **This was a retrospective analysis of 36 adolescent and young adult patients who underwent the Ross procedure between 1992 and 2013. The outcomes of supported Ross procedures in 26 patients were compared with the Ross procedure in 10 patients. End points included survival, neoaortic root dilatation, development of neoaortic regurgitation, and the need for reintervention.**

Results. **The median age at operation was 14 years (range, 11 to 31 years), and indications for the operation were mixed lesions (47%), followed by aortic regurgitation (42%) and stenosis (11%). There were no early deaths. The mean follow-up was 2.2 years (range, 1 to 11 years). At the 1-year ($p = 0.01$) and 3-year ($p < 0.05$) follow-up, patients in the supported Ross cohort had a smaller neoaortic root z-score. Neither cohort had a large number of patients with significant neoaortic regurgitation, with 1 patient in the supported cohort compared with 3 patients in the standard cohort. Overall, 4 patients (40%) in the standard Ross cohort had required reintervention, including 3 directed at the neoaortic root. One patient in the supported Ross cohort required early reintervention for revision of the right coronary artery.**

Conclusions. **At intermediate follow-up, patients who underwent the supported Ross technique were less likely to have neoaortic root dilatation compared with patients who underwent a standard Ross procedure. Further studies are needed to evaluate the long-term durability of this technique, particularly in regards to the development of significant aortic regurgitation, the rate of reintervention, and application to younger and smaller patients.**

(Ann Thorac Surg 2015;■:■–■)

The Ross procedure was first performed in 1967 as a surgical option for aortic valvular disease [1]. Multiple studies have demonstrated excellent early and late survival; however, a subgroup of patients requires reintervention due to progressive neoaortic dilatation with associated neoaortic regurgitation [2–4]. Risk factors predicting the need for reintervention are common among adolescents and young adults who might otherwise be considered for the Ross procedure and include aortic regurgitation, large preoperative aortic annulus size, bicuspid aortic valve, and significant preoperative aortic root dilation [3, 4]. The overall consensus from these studies is that patients with significant preoperative aortic annulus dilation and aortic insufficiency are not good candidates for a standard Ross procedure [2]. In efforts to improve the freedom from reoperation, the surgical technique of the Ross procedure has undergone an array of modifications.

In 2005 Slater and colleagues [3] presented the externally supported Ross (supported Ross) technique, which uses a Dacron (DuPont, Wilmington, DE) graft to support the neoaortic root to prevent progressive dilatation. Although early outcomes appear to be good, data comparing this technique to other techniques for the Ross procedure remain limited, particularly in regards to the risk for reoperation [3].

Since 2006 the supported Ross technique, using a Gelweave (Vascutek Ltd, Renfrewshire, United Kingdom) sinus of Valsalva graft to support the neoaortic root, has been our technique of choice for the Ross procedure to palliate older children, adolescents, and young adults with aortic valve disease. The goal of our study was to determine the early and intermediate outcomes of patients who underwent the supported Ross technique at our center and compare these results with those patients palliated with the Ross procedure using the standard aortic root replacement technique (standard Ross).

Accepted for publication April 23, 2015.

Presented at Sixty-first Annual Meeting of the Southern Thoracic Surgical Association, Tucson, AZ, Nov 5–8, 2014.

Address correspondence to Dr Jacobsen, 9000 W Wisconsin Ave, MS 713, Milwaukee, WI 53226; e-mail: rjacobsen@chw.org.

0003-4975/$36.00
http://dx.doi.org/10.1016/j.athoracsur.2015.04.123

Patients and Methods

The Children's Hospital of Wisconsin Institutional Review Board approved the study and waived the need for parental or patient consent.

Patients

The cardiovascular surgical database at our institution (1992 to 2014) was used to identify 89 patients who had previously undergone a Ross procedure. Patients were considered eligible candidates for a Ross procedure if they were considered to be adult size. The final decision to proceed with a Ross procedure was made by each patient's family after an informed discussion addressing factors such as physical activity level, sports participation, and reproductive concerns. Of the 89 patients identified, the study included 36 adolescent and young adult patients, with similar age and size. A supported Ross was performed in 26 of the 36 patients, and 10 patients underwent a standard Ross. We compared the characteristics and outcomes in the supported and standard Ross cohorts. During this same period, 84 patients underwent aortic valve replacement.

A single surgeon performed the Ross procedure in all 36 patients. The Ross procedure was performed as a root replacement in both the supported and standard Ross groups. The only difference in technique between the two cohorts was whether a Gelweave sinus of Valsalva graft was used for the supported Ross.

Standard cannulation and cardiopulmonary bypass were used. After cardioplegic arrest, an aortotomy was performed and the aortic valve inspected for the possibility of repair. After determining an aortic valve replacement was necessary, a transverse incision was made in the pulmonary artery and the autograft inspected to make certain it was suitable for the Ross procedure. Then, the aortic valve cusps were excised. The sinus aorta surrounding the coronary ostia were excised (coronary buttons) and the proximal coronary arteries mobilized. The pulmonary autograft was harvested using standard techniques.

For the supported Ross, the autograft annulus was measured during a preoperative echocardiogram and confirmed by gentle sounding with Hagar dilators. A Gelweave sinus of Valsalva graft 4 to 6 mm larger than the annular dimension of the pulmonary valve was selected. The sinus of Valsalva graft was then cut within a ring or two of the sinus component. The proximal end of the autograft was secured with a continuous 5-0 polypropylene suture (Johnson and Johnson, New Brunswick, NJ), and the distal end was tacked at the commissures with 5-0 polypropylene suture.

The autograft root was positioned so that one of the sinuses was centered on the left coronary artery button and the proximal suture line was completed with running 4-0 polypropylene sutures. The left coronary button was implanted into the sinus using 5-0 polypropylene suture. In the case of the supported Ross, the coronary button was implanted incorporating all 3 layers.

Next, the distal autograft was anastomosed to the ascending aorta using running 4-0 polypropylene suture. The left ventricular vent was clamped, and antegrade cardioplegia was administered through the root to determine the competency of the autograft. Pressurization of the aortic root and lack of left ventricular distension were considered evidence for autograft patency. While the root was distended, the site for implantation of the right coronary artery was identified. In some cases, particularly in patients with a bicuspid aortic valve, the right coronary was implanted into the noncoronary sinus of Valsalva. Finally, the right ventricular outflow tract was reconstructed with a pulmonary homograft.

Transesophageal echocardiography was routinely performed upon weaning from cardiopulmonary bypass to assess autograft function and proximal coronary artery flow and to evaluate the right ventricular outflow tract reconstruction.

Data were extracted from the medical record and included preoperative, operative, and postoperative variables. Echocardiograms at the time of the operation, time of discharge, and at 6 months, 1 year, 3 years, and 5 years, and at the most recent postoperative follow-up were reviewed offline.

Absolute dimensions of the aortic and neoaortic annulus, sinus, sinotubular junction, and root were measured for each echocardiogram when possible. The maximum systolic dimensions of the aortic and neoaortic annulus (measured at the level of valve hinge points of the leaflets) and sinuses of Valsalva (at the midsinus level) were measured from the two-dimensional parasternal long-axis views. The indexes for these measurements were calculated from the patient's body surface area by using the formula by Haycock and colleagues [5]. The z-scores for these diameters were determined using standardized data [6].

The degree of aortic stenosis was determined, in the setting of normal cardiac output, in the 4-chamber apical and suprasternal views on all available echocardiograms. Mild stenosis correlated with a peak jet velocity less than 3 m/s or a mean gradient of less than 25 mm Hg, moderate stenosis with a peak velocity of 3 to 4 m/s or a mean gradient of 25 to 40 mm Hg, and severe stenosis with a peak velocity exceeding 4 m/s or a mean gradient exceeding 40 mm Hg.

The degree of valve regurgitation was assessed by measurement of the vena contracta, measured in the parasternal long-axis views [7]. A color Doppler jet width of less than 4 mm indicated trivial to mild aortic regurgitation, 4 to 6 mm indicated moderate regurgitation, and >6 mm indicated severe regurgitation. Moderate and severe regurgitation was also verified by the presence of left ventricular dilatation and holodiastolic flow reversal in the descending or abdominal aorta, or both. The absolute systolic and diastolic dimensions of the left ventricle were measured to determine the presence and degree of left ventricular dilatation and left ventricular hypertrophy. A left ventricular end-systolic dimension index of 19 to 22 mm^2 or larger was considered mild