Valve-sparing aortic root replacement (VSRR) at the Johns Hopkins Hospital evolved from a long institutional experience with aortic root replacement in the setting of Marfan syndrome. As such, our experience is skewed toward young patients with aortic root aneurysm, competent aortic valves, and good ventricular function without other major comorbidities. Valve preservation is attractive to these young patients primarily because it avoids long-term anticoagulation associated with mechanical valves.

Our first VSRR procedures were remodeling (Yacoub or David II) operations, but late anular dilation and aortic incompetence in some patients led to a programmatic change in 2002 favoring reimplantation procedures for anular stabilization. At the same time, we began using the Gelweave Valsalva graft to preserve sinuses, which we believe is important for long-term valve function. We have used the Valsalva graft for our reimplantation procedures exclusively since 2002.

The technique described herein is the current iteration of that procedure.
Operative Technique

Figure 1  All patients have intraoperative transesophageal echocardiograms (TEE) and are operated via median sternotomy. Pulmonary artery catheters are not routinely used.

The TEE is reviewed before sternotomy and the following parameters noted: maximum aortic diameter, maximum sinus diameter, annular diameter, sinotubular junction (STJ) diameter, degree of aortic, mitral, and pulmonary insufficiency, valve morphology, and ventricular function.

After sternotomy, opening of the pericardium, and systemic heparinization, the aorta is cannulated near the base of the innominate artery. Axillary arterial cannulation is reserved for the rare cases when extensive arch procedures are contemplated. Bicaval venous cannulation is preferred over a single atrial cannula, as the superior vena cava cannula when passed through the right atrial appendage retracts the right atrium and improves exposure of the aortic root. Bypass is commenced and the operative field is continuously flooded with carbon dioxide (7 L/min). A sump vent is placed through the right superior pulmonary vein into the left atrium and the vena cavae are encircled with snares.

The aorta is clamped and 800 to 1000 mL cold blood cardioplegia is given into the root, if significant aortic insufficiency is present, cooling on cardiopulmonary bypass is continued until the heart fibrillates. The aorta is clamped and opened, and cardioplegia is given directly into the coronary arteries. Additional 100 mL doses of cardioplegia are given into each coronary artery every half hour thereafter, and cold topical saline is dripped over the heart for additional myocardial protection.

We begin by snaring the vena cavae and routinely exploring the right atrium to identify and close a patent foramen ovale. In our experience, intraoperative TEE only identifies half such defects, so routine surgical exploration is warranted.
Returning to the aortic root, we transect the aorta about 5 mm above the STJ and separate the root from the undersurface of the right pulmonary artery to allow the root to come forward; this dissection should hug the pulmonary artery to avoid left coronary artery injury. Then the right and noncoronary sinuses are freed from surrounding atrial and right ventricular outflow tract tissue down to the level of the annulus. In some patients the right coronary sinus annulus is so deeply displaced into the heart and behind the infundibular septum that it is nearly impossible to dissect below it; these patients may be better served by valve replacement.

The aortic valve is inspected and the anular diameter is confirmed by a valve sizer. Anomalous coronary position and number, and valve leaflet anomalies and fenestrations are noted.

We choose our graft size based on optimal STJ diameter. We have not had success with direct measurement of leaflet lengths and use of various formulae to predict graft size. Stay sutures of 2-0 silk are placed above each of the three commissures and various STJ diameters are tried to find the one that provides the best leaflet apposition. If the valve is competent preoperatively and there is a good vertical surface of leaflet coaptation, the STJ diameter should be preserved, or slightly reduced. Greater degrees of aortic regurgitation will usually mean greater reduction in STJ size. A graft 2 to 4 mm larger than this optimal STJ is chosen, because the graft must sit outside the aortic tissue. In adults, a 30-mm graft is most commonly used. It is better to oversize than undersize the graft, because a large graft can always be plicated down to a smaller dimension, but the converse is not true.
Figure 3 Stay sutures are placed above each coronary artery, and the sinuses are excised, leaving a 4- to 5-mm sinus remnant attached to the annulus. The coronary arteries are widely mobilized; the dissection remains close to the annulus rather than the coronary to avoid “button-holing” the undersurface of the coronary artery. The area of fibrous continuity between the aorta and pulmonary artery should be separated down to a level flush with the nadir of the right sinus annulus. Some dissection of right ventricular muscle from the aorta at the anterior (right-noncoronary) commissure is sometimes necessary, but one should avoid overzealous use of the cautery here, as our only case of permanent heart block necessitating a permanent pacemaker resulted from a thermal or electrical injury to the AV node during this dissection.

In our technique, pledgetted mattress sutures of 2-0 Tevdek are placed about 2 mm below the nadir of the annulus in each of the three sinuses; only two subanular sutures are used if a bicuspid valve is present. The mattress suture should not be too wide, as it may distort the base of the leaflet. If the surgeon prefers, additional subanular sutures can be placed but our experience suggests they are rarely necessary, as the bottom suture line is to secure the graft below the valve and not for hemostasis. Additional subanular sutures can be placed after the graft is lowered and the initial subanular sutures are tied. This will allow the additional subanular sutures to follow the natural curve of the annulus and be accurately placed through the graft, rather than be placed in a single plane, which is difficult to achieve near the left-right commissure, and places the conduction system at risk anteriorly.
The Valsalva graft is prepared next. As the graft is gelatin rather than collagen-impregnated, it presents a potential flame hazard. If electrocautery is used, the graft should be wetted first; alternatively, scissors alone can be used, which is our preference.

The graft is available in sizes 24 to 34 mm in increments of 2 mm; custom order grafts are available in smaller and larger sizes. The graft size refers to the diameter of the bottom collar and the tubular portion. The sinus or skirt segment, which has vertically oriented pleats to allow more expansion, has a diameter 20% larger. The height of the sinus segment is the same as the width.

The bottom collar of the graft is trimmed to two to three rings, and five to six rings are left at the top end.

The graft has a black seam, which we routinely orient at the anterior commissure for standardization, and two other black longitudinal lines 120° apart. We prefer to align the black marks with the commissures and use a surgical marker to identify the mid-sinus location, where the subanular sutures are passed.
The horizontal mattress subanular sutures are passed from inside out through the bottom collar of the graft. The commissural stay sutures are retrieved through the graft, which is then lowered and the three subanular sutures are tied.

Using pledgetted 4-0 Prolene sutures, we fix the top of the commissures, just above the valve leaflets, to the STJ of the graft. This height is appropriate for the majority of patients. This usually creates some tension on the commissures, but one should resist the temptation to locate the commissure lower, which will result in leaflet prolapse. The Prolene sutures are tied outside the graft, and the stay sutures are removed.

**Figure 5** The horizontal mattress subanular sutures are passed from inside out through the bottom collar of the graft. The commissural stay sutures are retrieved through the graft, which is then lowered and the three subanular sutures are tied.
At this point, the valve apparatus is oriented and fixed within the Valsalva graft with “three sutures below and three sutures above,” and one has a good feel for whether the graft size is appropriate and the positioning of the valve within the graft is accurate. It is critical that the graft extend well below the lowest point of the annulus, which assures that the entire valve apparatus is within the graft, which is critical for anular stabilization and hemostasis. STJ = sinotubular junction.
Figure 7  The internal suture line approximating the annulus and sinus remnant to the inside of the graft is the next step. We begin in the left coronary sinus, using a continuous 4-0 Prolene and an RB-1 needle. Whenever possible, one should direct the needle away from the valve to minimize the chance of leaflet injury. As this is the hemostatic suture line, it should be completed meticulously and in unhurried fashion. Folds of the graft are sites of potential internal leak and bleeding and can be avoided by pulling on the aortic tag at the top of the commissure, straightening the course of the annulus and graft to facilitate sewing. We prefer to perform the internal sutures line in the order of left sinus, noncoronary sinus, and finally, the right sinus.
Figure 8  The coronary arteries are implanted next. Positioning of the left coronary is rarely problematic and usually is in the middle of the left sinus. In some patients, a near vertical course of the left coronary creates a vertical shelf, or lip, at the base of the left coronary ostium, which can obstruct the coronary orifice if not managed properly (A). We prefer to excise much of the inferior rim of these coronary buttons and sew directly to the ridge (B).

We use 4-0 Prolene and a narrow straight Teflon strip (rather than a circular “Lifesaver”) to reinforce the coronary anastomoses. Biogluue helps with needle holes but should be used with care, as it may obscure significant anastomotic deficiencies and actually increase the risk of late pseudoaneurysm.

The right coronary artery requires special attention, as malposition of its anastomosis is one of the more common pitfalls of aortic root replacement. Our rule of thumb is to place it as far anterior on the graft as the anterior commissure suture line will allow, and just below the STJ of the graft. We prefer to complete the right coronary anastomosis before the graft-to-distal aortic anastomosis, so that the valve leaflets can be seen well and protected from injury.

Making the hole in the graft too large can lead to button aneurysms and too wide can lead to a sandwiching and stenosis of the coronary ostium (C).
Saline testing of the valve will identify potential leaflet prolapse, which can be addressed by mid-leaflet plication (A) or leaflet resuspension (B). Our young connective tissue defect patients have very thin free margins of the leaflets that are usually not amenable to a continuous Gore-Tex suture for leaflet resuspension, but the choice of method to address prolapse should be tailored to the patient and quality of the leaflet tissue. In general, the Trusler valvuloplasty (folding plication at the commissure) should be avoided, as it involves suturing the weakest area of the valve, frequently the site of “stress fenestrations,” and also the area of greatest mechanical stress. In congenital heart surgery, the Trusler repair has suffered a disappointing rate of failure and has been largely abandoned.
We allow 10 to 15 minutes of reperfusion for every hour of aortic clamping. In our hands, mean aortic clamp time is 90 minutes.

The acceptable amount of residual regurgitation depends on the mechanism. In general, anything more than 1/100 is not acceptable, but mild central regurgitation due to thickened nodes of Arantius in the absence of leaflet prolapse is probably stable and is acceptable. Any degree of regurgitation due to leaflet prolapse is likely not stable and should lead to direct efforts to address the prolapse.

The procedure is sometimes aborted because of uncontrollable proximal bleeding or severe aortic regurgitation. If bleeding is the reason and its source cannot be identified, it may be better to take down the repair completely and proceed to a Bentall procedure using a mechanical or biological prosthesis. However, if severe aortic regurgitation is the reason and valve repair is not an option, it is possible to excise the valve and insert a prosthesis within the graft. Choice of the valve prosthesis size takes into consideration the internal diameter of the graft and the outside diameter of the prosthetic valve sewing ring, unless an unstented bioprosthesis is used.

Three other scenarios warrant comment. First, VSRR is a reasonable operation in the setting of acute ascending aortic (type A) dissection. The dissection always stops at the annular plication of the graft above each of the commissures will facilitate matching of the graft to aorta.

Before release of the aortic clamp, if there is concern about valve competence, it is prudent to exchange the left atrial vent for a left ventricular vent to assure left ventricular decompression early during reperfusion and recovery. Thorough deairing of the left heart before release of the aortic clamp is an investment with significant later dividends.

As the clamp is released, attention is paid to promptness of coronary artery filling, rewarming of the ventricular mass, left ventricular vent return, and ventricular distention. Early distension of the ventricle is ominous and should lead to prompt reclamping and exploration of the root to identify a leaflet problem.

Although a small amount of bleeding under the base of the graft is common early on reperfusion, heavy bleeding warrants early reclamping and re-exploration to fix a gap between the graft and the sinus remnant.

If the base of the graft seems loose below the valve, pledged plicating mattress sutures of 2-0 Tevdek can be placed at the bottom of the graft below the commissures. A snug fit will improve hemostasis and achieve some degree of annular reduction, which is often desirable in reimplantation procedures.

Figure 10  If there is a significant size discrepancy between the distal end of the graft and the ascending aorta, individual plications of the graft above each of the commissures will facilitate matching of the graft to aorta.

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lus, and although the sinus remnant may be friable and challenging to manipulate and suture, and hematoma at the root may obscure landmarks, these are not insurmountable obstacles. The issue is whether this operation, which usually takes longer and carries some uncertainty of outcome, is advisable in an emergency when issues of bleeding from fibrinolysis, potential malperfusion, and other organ compromise already impose a 10 to 25% operative mortality. Second, when concomitant mitral repair is necessary, it is optimal to repair the mitral first and assess the adequacy of that repair, even if just by saline testing. If mitral replacement becomes necessary, there is no advantage to a valve-sparing aortic procedure, and it is prudent to replace both valves. Third, when there is dilatation or chronic dissection of the arch, consideration should be given to concomitant arch replacement. However, routine prophylactic replacement of the arch for the nondilated, nondissected arch in Marfan syndrome is not indicated. Every effort should be made to replace the intrapericardial portion of the ascending aorta. Finally, many young patients with root aneurysm have pectus excavatum lesions. The hemodynamic and ventilatory effects of pectus are controversial, but patients will occasionally insist on concomitant correction, which can be achieved by sternal closure over a Nuss bar. The postoperative pain and ventilatory embarrassment from the bar are considerable, but this will make subsequent late reoperation easier and safer and can still permit early re-exploration if postoperative hemorrhage ensues.

Although the Bentall procedure is safe and highly reproducible in the hands of most cardiac surgeons, VSRR carries a significant learning curve, and given the omnipresent potential for abortion of the procedure and switch to the Bentall, VSRR should be practiced by those who can complete a Bentall expeditiously.

Postoperative management is similar to any other aortic root operation. Beta-blockers and aspirin are prescribed for 1 month.

Echocardiograms are obtained at discharge, at 1-month follow-up, and annually thereafter. Surveillance imaging of the remainder of the aorta depends on the underlying diagnosis.

Patients are counseled that this is an operation with limited information on long-term results, and therefore, the risk of needing further surgery is not insignificant.

Suggested Reading


