Off-Pump Aortic Valve Bypass Using a Valved Apical–Aortic Conduit

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Conventional aortic valve replacement in the elderly patient with critical aortic stenosis and associated calcified “eggshell” ascending aorta, prior sternal wound infection, or multiple patent arterial or venous bypass grafts is unattractive to the cardiac surgeon and high risk for the patient. Attempts to treat this patient population with percutaneous balloon valvuloplasty and/or percutaneous valve insertion have thus far met with disappointing results.

We have extended the technique of aortic valve bypass introduced more than 30 years ago to treat this high-risk adult patient population.

Between two institutions (Indiana University School of Medicine–Indianapolis, Indiana and University of Maryland School of Medicine–Baltimore, Maryland), we have utilized this technique in 100 patients; 59 were elderly adult patients with critical aortic stenosis (mean age, 75 ± 11 years, the oldest being 88 years). Forty-six patients (82%) had had prior cardiac surgery. Forty-four (79%) had multiple patent arterial or venous bypass grafts and 12 had a calcified ascending aorta; these 56 patients form the basis of this report. Nearly all procedures were performed via a left anterior-lateral thoracotomy.
Operative Technique

Figure 1  Valved conduit for aortic valve bypass. The only approved commercially available valved conduit for aortic valve bypass is the one manufactured by Medtronic, Inc. (Minneapolis, MN) and is shown in this photo. It comes in sizes from 12 to 22 mm in diameter and can be used for any size patient. The most commonly employed size for adult patients has been 20 mm in diameter. The conduit contains a stentless porcine aortic valve that is glutaraldehyde preserved and has an estimated valve area of 3 cm². Because the conduit is a second avenue for left ventricular outflow, we believe that a conduit smaller than what would normally be used for a conventional aortic valve replacement is acceptable and in most instances desirable. The porcine valve in the conduit is positioned between the proximal and middle third of the conduit. This position of the valve would allow ample room for placement of vascular clamps, when or if the conduit valve required replacement in late follow-up. The Medtronic conduit is supplied with more than ample woven graft material proximal and distal to the conduit valve. All but 2 cm of the woven graft proximal to the valve is excised and the distal end of a left ventricular apical stent, sold separately (Fig. 2), is sewn to the proximal end of the valved conduit. All of the excess graft material that is supplied with the apical stent is excised. In general, the conduit is 2 mm larger in diameter and the stent is chosen to minimize any gradient across the porcine bioprosthesis. (Color version of figure is available online at http://www.us.elsevierhealth.com/opotechstcvs.)
A curved left ventricular connector or stent is supplied in sizes from 12 to 22 mm by Medtronic, Inc. and is sold separately. The stent was developed in the early 1970s by Hancock-Extracorporeal (Hancock, Medtronic Inc., Minneapolis, MN) to our specifications and has been continually supplied since that time. It was originally supplied in both straight and angled configurations but we have routinely used the right-angled connector for the aortic valve bypass done through a left thoracotomy. Work in our animal laboratory many years ago demonstrated that a semi-rigid stent was necessary to prevent progressive narrowing of the apical left ventriculotomy. Direct application of a prosthetic graft to the apical myocardium has been reported by Cooley and coworkers\(^1\) and resulted in obstruction at the ventriculotomy site. The apical connector is designed to project 3 to 10 mm into the cavity of the left ventricle. It is lined with a low-porosity woven graft and its external surface is covered with a more porous graft material to promote tissue ingrowth. The 90° angle in the stent prevents kinking of the conduit as it negotiates the acute angle from the LV apex to the descending thoracic aorta.

A newly designed left ventricular apical connector is under development and has the advantage of having a tapered tip. It comes with an applicator that allows insertion into the apex of the left ventricle without cardiopulmonary bypass and with minimal or no blood loss. This device is being developed by Correx, Inc. (Boston, MA) but is not yet approved for human use. It is inserted straight without a right angle; however, once inserted, a suture can be drawn taut and tied to introduce a right angle into the semi-rigid stent. (Color version of figure is available online at http://www.us.elsevierhealth.com/optechstcvs.)
Figure 3  (A) Aortic valve bypass conduit with model 150 Medtronic valved conduit. The proximal end of the valved conduit is sutured to the external rim of the stent. The valved conduit that we currently use is Model 150, which has a modified orifice porcine valve, a second-generation porcine prosthesis that has demonstrated excellent durability. The woven prosthetic graft is a low porosity. It is not a coated graft but formal preclotting of the graft has not been necessary because the prosthesis is usually placed without cardiopulmonary bypass. If cardiopulmonary bypass is contemplated, then preclotting of this woven graft should be considered. (B) Aortic valve bypass conduit with Medtronic freestyle valve (Medtronic Inc., Minneapolis, MN). An alternative to the conduit (A) and the one we have used selectively and the one exclusively used by one of us (J.S.G.) is to insert a Medtronic “Free-Style” porcine root into a section of a collagen-coated graft. This has the theoretical advantage of using a third-generation porcine valve with sinuses of Valsalva and its aminooelic acid anticalcification properties. Use of the “freestyle” valve as part of a conduit is “off-label.” (Color version of figure is available online at http://www.us.elsevierhealth.com/optechstcvs.)
Operative position. The patient is brought to the operating room and, after satisfactory general endotracheal anesthesia, a double lumen endotracheal tube is inserted so that the left lung can be deflated. A Swan–Ganz catheter (Edwards Lifesciences, Irvine, CA) is positioned and a transesophageal echo probe is also positioned. The patient is then turned to a right lateral decubitus position with the shoulders perpendicular to the top of the operating table. The right hip is flexed and the left hip is left straight. This leg positioning allows access to the left femoral artery and vein should access to these structures be desirable for insertion of one or more bypass cannula. We routinely expose both the artery and the vein, but if the patient is reasonably hemodynamically stable, neither vessel is cannulated. If, however, the patient is unstable, has severe pulmonary hypertension, or has low cardiac output, then a small 8-mm sidearm Dacron graft (Boston Scientific, Natick, MA) is attached to the apical aortic conduit distal to the porcine valve before the aortic anastomosis is initiated. The sidearm graft is used for arterial inflow for bypass after the aortic anastomosis has been completed. We would then cannulate the femoral vein over a guidewire, placing the tip of the venous catheter in the right atrium. Positioning the guidewire and the venous cannula is confirmed with transesophageal echocardiography.

Left anterior-lateral thoracotomy incision. A left anterior-lateral thoracotomy incision is made over the 6th rib. The incision is carried anteriorly to the costal margin.
Figure 6 Left anterior-lateral thoracotomy. The anterior two-thirds of the rib is excised subperiosteally. Entrance into the left chest is done through the bed of the 6th rib. The diaphragm is retracted inferiorly. The left lower lobe inferior ligament is divided with cautery up to the level of the inferior pulmonary vein. This gives access to 8 or 10 cm of descending thoracic aorta for the aortic anastomosis. The descending thoracic aorta is gently palpated and any heavy islands of dense calcification are avoided. A preoperative chest computed tomographic scan is routinely done so that potential islands of calcification can be anticipated. To date, we have always been able to find a portion of the aorta in this region acceptable for the aortic anastomosis. This transthoracic approach through the bed of the 6th rib gives excellent access to the descending thoracic aorta, as well as the apex of the left ventricle. Rib excision avoids excessive spreading of adjacent ribs, which are usually quite brittle in these elderly patients. It avoids the redo sternotomy, which would have been necessary in more than 80% of our patients. The entire procedure can usually be done without cardiopulmonary bypass; however, institution of bypass through a sidearm graft on the conduit and cannulation of the femoral vein is possible in patients who are particularly unstable. The pleura overlying the desired portion of the descending thoracic aorta is opened.
Before the aortic anastomosis is initiated, the assembled conduit should be brought to the operative field and the length of the conduit should be determined before performing the aortic anastomosis. Care should be given to orient the left ventricular apical stent to the long axis of the left ventricular cavity. Because the conduit is supplied with excess graft material, most often several centimeters to the distal end of the graft are excised. A partially occluding vascular clamp is used to partially occlude the descending thoracic aorta at the desired location of the aortic anastomosis. Care must be taken during positioning of the clamp to allow the flow to the distal aorta to avoid distal ischemia. Once the clamp is applied, the patient is heparinized with 3 mg/kg of body weight. An aortotomy is done with a scalpel. The aortic anastomosis is most commonly done with interrupted 2-0 Tycron sutures (Ethicon Inc., Somerville, NJ) with 3 × 7 pledgets placed on the external surface of the aorta. All 10 or 12 pledgetted sutures are placed in the aorta before passing them through the distal end of the premeasured conduit. The conduit is then lowered into the chest and the sutures are tied and cut. The quality of the aorta in many patients in this age category is somewhat friable; the anastomosis done in a relatively deep hole with the interrupted suture technique sliding the conduit down like a standard aortic valve replacement has served us well since the early 1970s. If the quality of the aorta and the exposure is good, then a running anastomosis can be done with 3-0 or 4-0 polypropylene sutures. Once the aortic anastomosis has been completed, the partial occluding clamp is slowly released to allow heparinized blood to enter the distal two-thirds of the apical aortic conduit. Hemostasis at the aortic anastomosis should be assured before proceeding with the left ventricular anastomosis.
Figure 8  Ventricular anastomosis. A sterile 16-French Foley catheter (C.R. Bard Inc., Murray Hill, NJ) with a 5-mL balloon and a standard brass laboratory corkbore are used to make the circular ventriculotomy. Corkbores can be obtained as a set through Fisher Scientific, Inc (Thermo Fisher Scientific Inc., Pittsburgh, PA). The external diameter of the corkbore should fit within the inner diameter of the apical stent. A point on the apex of the left ventricle, approximately 1 to 1½ cm to the left of the ventricular septum marked by the left anterior descending coronary, is selected for insertion of the apical stent. Lidocaine 100 mg is given as an IV bolus before the left ventricular sutures are placed. Four double-arm ed sutures of 2-0 braided Dacron with large felt pledgets were placed at four equally distant points, parallel to the proposed site of the apical ventriculotomy. These sutures are threaded through the sewing ring of the apical stent and held out of the way by the assistant. The 16-French sterile urinary catheter is placed through the corks bore, which has been selected for the apical ventriculotomy, and the 5-mL balloon on the Foley is filled with sterile saline solution, usually 7 to 9 mL total. The balloon is distended to a diameter slightly larger than the diameter of the corkbore so that the balloon cannot be pulled back through the lumen of the corkbore. This volume of saline is aspirated back into a syringe and saved. The standard brass corkbore is our preferred cutting instrument because it is sharp enough to cut through the left ventricular myocardium but not sharp enough to cut through a Foley balloon.

The operating room table is then placed in Trendelenburg position and a second dose of Lidocaine 100 mg is administered IV. A small stab wound is made in the middle of the left ventricular apex and dilated with a clamp so that the tip of the Foley catheter can be inserted into the left ventricular apex. Once the Foley balloon is inserted and the predetermined amount of saline solution is injected into the balloon inside the left ventricular cavity, the traction is then placed on the Foley catheter while the corkbore, threaded over the Foley catheter, is used to excise a circular piece of myocardium. The corkbore is then rotated until the corkbore has entered the left ventricular cavity, and the inflated catheter core of muscle and corkbore are withdrawn simultaneously. The tip of the surgeon’s left thumb is inserted into the apex while the apical stent is grasped with the surgeons right hand and lowered into the apical left ventricular incision. The four previously placed sutures in the left ventricular apex are then drawn tight and tied. Additional pledgetted sutures are placed as needed for hemostasis. Air that might be trapped in the proximal third of the conduit is removed by inserting a 20-gauge needle into the prosthesis before inserting the apical stent. Once hemostasis has been obtained at the apex, the pericardium is drawn back around and sutured to the sewing ring to give the apical anastomosis additional support. The Foley balloon catheter filled with saline has many purposes. It flattens out the left ventricular apex as traction is applied so that it acts as a backstop to prevent the corkbore from injuring the endocardium of the septum or papillary muscles and it traps the ventricular core of muscles inside the corkbore. The corkbore cuts out a piece of the myocardium but does not injure any other interventricular structures. We have not used the ventricular punch supplied by Medtronic because it requires a relatively large apical incision for insertion and its stainless steel edge can cut and rupture the Foley balloon.

Direct measurement of left ventricular pressure was obtained after conduit insertion to assure relief of the left ventricular outflow gradient. Patients were not anticoagulated postoperatively except for low-dose aspirin (80 mg) because they have a stentless bioprosthetic valve as an integral part of their conduit.
Completed aortic valve bypass. The completed procedure shows the direction of blood flow through the conduit into the aorta. Approximately 70% of cardiac output is through the conduit. Flow to the coronary arteries and brachiocephalic arteries is antegrade via the native aortic valve.

Chest closure is done in a routine fashion. One or two chest tubes are placed and the dependent chest tube should be left until drainage is less than 150 mL per 24 hours (usually 3 to 4 days). Blood transfusion is rarely needed unless the patient has postoperative anemia. Most elderly patients can be discharged within 1 week.
Conclusions

There are several advantages of aortic valve bypass surgery compared with conventional aortic valve replacement. Cross-clamping of the ascending aorta is never required. Cardiopulmonary bypass is used infrequently and when necessary, only for a brief period of time. As we have gained experience with the technical aspects of aortic valve bypass surgery, cardiopulmonary bypass has been used less frequently.

New instruments have been developed to further simplify insertion of the aortic valve bypass conduit through a limited thoracotomy without blood loss and without cardiopulmonary bypass and in a manner that would be comfortable for most cardiac surgeons. These instruments have been tested in animals and await introduction into the clinical arena. We feel this surgical approach to aortic stenosis in elderly patients with significant comorbidity can compete favorably with catheterization laboratory percutaneous aortic valve insertion.

We observed excellent hemodynamic results after aortic valve bypass surgery in all patients. Left ventricular ejection performance was unchanged or improved after option, indicating that the apical stent does not lower left ventricular function. Measured gradients after aortic valve bypass were low (mean gradient, 8.8 ± 3.3 mm Hg) and similar or lower than results after conventional aortic valve replacement, suggesting excellent relief of left ventricular outflow obstruction. Measured gradients across the native valve are equivalent to gradients across the aortic valve bypass. Aortic valve bypass surgery affords durable relief of left ventricular outflow tract obstruction.

Reference