Custom-tailored valved conduit for complex aortic root disease

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Objectives: Commercially available conduits containing a valve are not always suitable for simultaneous reconstruction of the left ventricular outflow tract and replacement of the aortic root. We describe our experience with custom-made conduits for patients with complex disease of the aortoventricular junction.

Methods: Twenty-seven patients with a destroyed aortoventricular junction resulting from endocarditis and/or multiple previous operations had reconstruction of the left ventricular outflow tract with a tailored tubular Dacron graft. The graft was tailored to correct the defect in the outflow tract and sutured with continuous polypropylene sutures directly to the interventricular septum and the intervalvular fibrous body or sewing ring of a prosthetic mitral valve. The coronary arteries were reimplanted as high as anatomically possible and a mechanical (16 patients) or bioprosthetic valve (11 patients) was implanted into the graft below the coronary arteries. Median age of the patients was 55 years. The follow-up was complete, with echocardiographic studies and a median period of 32 months.

Results: There were 3 operative and no late deaths. One patient required early reoperation for dehiscence of a patch used to reconstruct the posterior mitral valve annulus. Twenty-four patients were alive at the last follow-up and had a normally functioning aortic valve prosthesis and no false aneurysms.

Conclusion: Intraoperatively tailored tubular Dacron graft for concomitant reconstruction of the left ventricular outflow tract and replacement of the aortic root is a useful and safe operative technique for patients with destroyed aortoventricular junction.

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Extensive destruction of the aortoventricular junction resulting from prosthetic valve endocarditis, multiple aortic valve replacements, false aneurysms, or iatrogenesis is a challenging surgical problem. Various approaches have been described to deal with it.[1-9] Aortic valve homograft and pulmonary valve autograft are accepted as appropriate options in some patients.[1-4] Modifications to the classic Bentall procedure, which requires an intact aortic annulus to anchor the proximal anastomosis, have also attempted to address the problem.[5-7] Several patch materials have been incorporated in complex cases of aortic root reconstruction, probably more frequently than has been published.[8,9] A review of the literature on this topic suggests that surgical techniques using aortic valve homograft appear to be the most common option for repair of the damaged aortoventricular junction, especially in

ACD

Abbreviations and Acronyms
LVOT = left ventricular outflow tract

cases of superimposed endocarditis.[1-4] However, many surgeons favor the use of prosthetic material,[10,11] sustaining an old controversy. The present study describes a technique to address the issue of aortoventricular destruction with a custom-made Dacron conduit and prosthetic valves.

Patients and Methods

Between February 1999 and September 2006, 27 consecutive patients had aortic root replacement with a tailored-made tubular Dacron graft with reimplantation of the coronary arteries and implantation of a prosthetic valve because of a destroyed aortoventricular junction. Table 1 shows the clinical profile of the patients. The aortic root had been previously replaced in 8 patients and was aneurysmal in the remaining 19. The destruction of the aortic annulus was due to prosthetic valve endocarditis in 14 patients and healed endocarditis with false aneurysm in 1, remote application of BioGlue (CryoLife, Inc, Kennesaw, Ga) during aortic root replacement in 2 patients, previous patch enlargement of the aortic annulus in 4, previous aortic and mitral valve replacement with inadequate intervalvular fibrous body in 4, and iatrogenic during removal of calcified homograft or xenograft aortic root in 2.

Surgical Technique

Median sternotomy was used in all patients. Cardiopulmonary bypass was established by cannulating the proximal transverse arch and right atrium. Intermittent cold blood cardioplegia was used for myocardial protection by injecting it directly into the coronary artery ostia. Systemic temperature was maintained at 34°C to 35°C. Other operative data are summarized in Table 1. The basic principle of the operative technique was complete excision of all prosthetic and pathologic tissues from the aortic root and left ventricular outflow tract (LVOT) and mobilization of both coronary arteries. In 3 patients there was practically no remaining sinus wall around the coronary artery orifices, and a patch of saphenous vein was sutured around to create a button suitable for reimplantation. A tubular Dacron graft 3 to 6 mm larger than the diameter of the LVOT, or large enough to allow the implantation of a prosthetic aortic valve of appropriate size for the patient's body surface area, was selected, and one of its ends was tailored to correct the defect created in the LVOT. This end of the graft was sutured directly to the interventricular septum and intervalvular fibrous body or sewing ring of a prosthetic mitral valve with continuous 3-0 polypropylene sutures. This suture line was meticulously done and every bite reviewed before moving on to the next stage of the procedure. Additional interrupted sutures were often needed in areas where the graft was not correctly aligned on the LVOT. This suture was interrupted at the lateral and medial fibrous trigones if they were present or the sewing ring of the prosthetic mitral valve if this valve was replaced. Next, the coronary arteries were reimplanted into the graft. We have found that it is easier to reimplant the coronary arteries into the

TABLE. Patient characteristics

Patient age (y)	
Median	55
Range	28–85
Sex: male/female	18:9
Associated diseases	
Hypertension	10
Diabetes	2
Renal failure	2
No. of previous operations	
None	1
One	15
Two	8
Three	2
Four	1
Previous operations	
Aortic root replacement*	8
Aortic valve replacement†	17
Mitral valve replacement‡	6
Tricuspid valve repair	2
Coronary artery bypass	1
Repair of sinus of Valsalva aneurysm	1
Repair of LVOT with pericardium	1
Repair of ventricular septal defect	1
New York Heart Association functional classification	
Class II	5
Class III	8
Class IV	14
Operations performed	
Size of tubular Dacron graft (mm)	
Median	30
Range	26–34
Aortic valve implanted	
Mechanical	16
Bioprosthesis	11
Mitral valve surgery	
Reconstruction of the mitral annulus	6
Replacement with mechanical valve	6
Replacement with bioprosthesis	3
Repair	2
Tricuspid valve repair	4
Coronary bypass surgery	7
Other operations	
Septal myectomy	2
Coronary ostial patch repair	3
Aortic clamping time (min)	
Median	125
Range	77–184
Cardiopulmonary bypass time (min)	
Median	148
Range	96–246

LVOT, Left ventricular outflow tract. *Five homografts; 2 Freestyle; 1 Bentall with mechanical valve. †Eleven mechanical; 3 bioprostheses; 3 stentless valves in subcoronary position. ‡Five mechanical; 1 repair.

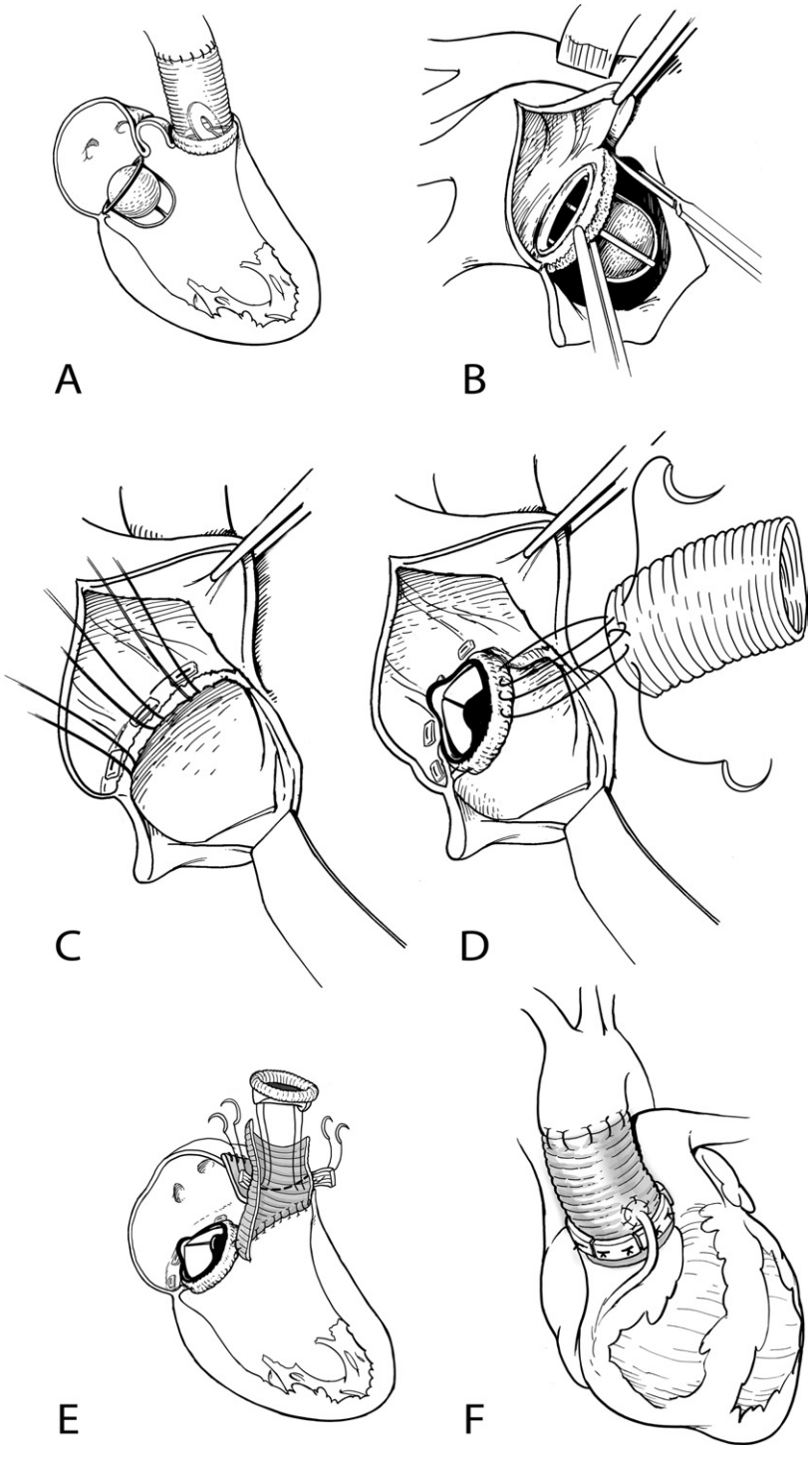

Figure. Operative technique in a patient with a false aneurysm in the intervalvular fibrous body and previous replacement of the mitral valve and aortic root (A). The valved conduit and the false aneurysm are excised and the mitral valve prosthesis is approached through an incision in the dome of the left atrium (B). A new prosthetic mitral valve is secured in the posterior mitral annulus from the lateral to the medial fibrous trigones (C). A tubular Dacron graft is sutured to the left ventricular outflow tract and mitral valve prosthesis (D). The dome of the left atrium is closed with a separate Dacron patch, and a prosthetic valve is implanted into the Dacron graft (E). The coronary arteries are reimplanted either before or after the prosthetic aortic valve is implanted (F).

Dacron tube before the prosthetic aortic valve is implanted. Obviously, the coronary arteries should be implanted as high as anatomically feasible to allow room for the prosthetic aortic valve. This was accomplished in all patients without having to interpose a graft to extend the coronary arteries. A mechanical or bioprosthetic aortic valve was secured inside the graft at a level below the coronary arteries with multiple interrupted horizontal mattress 2-0 polyester sutures. It was not difficult to pass the sutures through the graft in the spaces beneath the coronary arteries. With the exception of the first few cases, these sutures were buttressed on a strip of Dacron graft and tied outside the graft (Figure 1) to prevent small tears in the graft

when the sutures were tied. The nominal size of the mechanical or bioprosthetic valve implanted was 5 mm smaller than the graft, because the sizes of most artificial valves are not metric.

In 11 patients in whom the mitral valve had to be replaced or repaired, exposure was obtained by incising the dome of the left atrium from its insertion in the aortic root toward the right pulmonary artery. In 9 patients, the mitral valve was replaced along with the intervalvular fibrous body. In 6 of them, the posterior mitral annulus had to be reconstructed with fresh autologous or bovine pericardial patch because of abscess (3 patients) or extensive dystrophic calcification (3 patients). The technique of reconstruction of the mitral annulus was described in previous publications in this *Journal*.[5,12] In these patients, the prosthetic mitral valve was implanted first and secured to the native or reconstructed posterior mitral annulus from the lateral to the medial fibrous trigones. Superiorly, the tubular Dacron graft used to reconstruct the LVOT was sutured directly to the sewing ring of the prosthetic mitral valve. A separate patch was used to close the dome of the left atrium. The remaining parts of the operation progressed as described above.

Intraoperative echocardiography was used for all patients to assess valve and ventricular function after discontinuation of cardiopulmonary bypass.

Results

Three patients died perioperatively, 1 of cerebral hemorrhage, 1 of myocardial infarction, and 1 of multiorgan failure after reoperation on the mitral valve because of early dehiscence of a posterior mitral annulus patch. All 3 patients who died and 1 survivor required re-exploration for bleeding. Two of 27 patients had a perioperative myocardial infarction (1 died), 1 had renal failure requiring hemodialysis (died), 7 had atrial fibrillation, and 3 had pulmonary complications. Only 1 of the surviving patients had to be treated for low output syndrome. The most common postoperative complication (14 patients) was complete atrioventricular block requiring permanent pacemaker implantation. In 5 of these patients, the atrioventricular block had already been present preoperatively; thus, performing a radical operation such as the one described above caused a new atrioventricular block in 9 (30%) patients. The median postoperative hospital stay was 8.5 days (range 5-42 days), and the median intensive care unit stay was 1 day (range 1-15 days), with a median ventilation time of 8.6 hours (range 5 hours-5.5 days). The transfusion requirements for all patients were a median of 2 red blood cell units (range 0-17 units), with the two outliers, with 13 and 16 red blood cell units transfused, which also were outliers for prolonged intensive care unit stay with 15 and 10 days, respectively. The patients with confirmed endocarditis underwent a complete course of 6 weeks with the appropriate intravenous antibiotics on an outpatient basis.

There were no late deaths. All surviving patients were followed up by their referring cardiologist and contacted annually by our research personnel. For this study, the follow-up was closed on the December 30, 2006, and extended from 0 to 91 months, with a median of 32 months. All patients had postoperative echocardiographic assessment, confirming normally functioning prosthetic valves with no paravalvular leaks or false aneurysms. Two patients with mechanical valves had anticoagulation-related hemorrhage. Twenty-four patients were alive at the last follow-up contact, and there were no other valve-related or cardiac-related events. Eighteen patients were in functional class I, 3 in class II, and 3 in class III. There were no deaths, reoperations, or recurrences of endocarditis during the follow-up time. All 13 patients who were discharged in sinus rhythm remained in sinus rhythm.

Discussion

Reoperative aortic root replacement, particularly in the setting of a previous aortic root replacement or destroyed aortoventricular junction resulting from endocarditis, false aneurysms, previous patch enlargement of the aortic annulus, or absent intervalvular fibrous body after explanation of prosthetic aortic and mitral valves is complex and challenging. These problems have not been adequately addressed in previous series of reoperative aortic root surgery.[13-15] Excision of the pathologic tissues can lead to partial or complete destruction of the aortoventricular junction, or the extent of the destruction can be such that the tissues cannot hold any suture. In such circumstances, attempts to implant a prosthetic valve directly to the level of the aortoventricular junction may prove dangerous. We believe that the implementation of the above-described procedure can help surgeons who are faced with this condition.

Aortic homograft has been extensively used for reconstruction of the aortic root, and some investigators believe it is superior to prosthetic valves for the treatment of aortic root endocarditis.[1-4] We, like others, believe that the most important aspect in treating patients with aortic root endocarditis is radical excision of all infected and necrotic tissues surrounding the aortic root.[10,11,16] The outcome for such patients is probably more dependent on the success of this process than on the type of valve used for replacement.[16] Aortic valve homograft is not immune to persistent infection.[17] In addition, aortic homografts may not be readily available.

We have used pericardium to patch small defects in the LVOT.[16] Others have used autologous rectus abdominis fascia.[9] These materials are useful as a patch, but a valved conduit would still be necessary to re-establish continuity between the left ventricle and ascending aorta.

Before the days of commercially available conduits containing mechanical valves, surgeons had to construct them as we still do when using stented bioprosthetic valves.[18] In 1981, Cabrol and colleagues[19] described the technique of folding one of the ends of the Dacron tube for a length of

2 cm and securing a mechanical valve with a running suture. The folded end was then straightened and sutured to the aortic annulus. Although having a skirt of Dacron graft is a useful technique, in cases of destroyed aortoventricular junction such as described in this article, it is easier to tailor the end of the graft to patch the anatomic abnormality of the LVOT and suture it before implanting an aortic valve prosthesis. This approach provides better exposure, and the surgeon can inspect the graft-LVOT anastomosis from within and put additional sutures if needed because bleeding from that area would be disastrous. This technique is versatile, safe, and durable. In addition, by reimplanting the coronary arteries before the valve is placed into the conduit, one can often avoid the undesirable Cabrol technique of coronary artery reimplantation.[19,20] The surgeon can also safely dislocate the aortic prosthesis at a level above the remnants of the aortic annulus, without compromising the coronary buttons or the anterior mitral valve leaflet. Finally, in the unfortunate event of a repeat reoperation for bioprosthetic valve failure, access to the prosthesis and the replacement of the aortic valve can be facilitated not only by the translocated aortic valve prosthesis but also by the way the anchoring sutures are placed onto the Dacron graft.

Follow-up of this small series of patients has shown no late deaths, endocarditis, false aneurysms, or reoperations among hospital survivors up to 7 years. Two cases of anticoagulation-related hemorrhage outline the fact that usage of mechanical valves should be weighted against the risk of reoperation for bioprosthetic valve failure.

In conclusion, tailored tubular Dacron graft for concomitant reconstruction of the LVOT and replacement of the aortic root is a useful and safe operative technique for patients with destroyed aortoventricular junction. However, one should not forget that the outcome of complex surgical cases with aortoventricular destruction depends not only on the appropriate selection of surgical techniques but also on individual surgical experience.

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