Bentall Procedures with a Novel Valved Conduit Incorporating "Sinuses of Valsalva"

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ABSTRACT

The Bentall operation is preferred when a diseased aortic valve is associated with a dilated or dissected ascending aorta. Composite valved grafts have been devised to facilitate and expedite this procedure. The initial clinical results of the Bentall procedure using a vascular conduit modified to incorporate "pseudo-sinuses of Valsalva," with the aim of simplifying coronary button anastomoses and decreasing tension upon them, is described herein. Over a period of 40 months since its introduction, the novel conduit has been used, for a Bentall procedure in 37 consecutive patients. Of this group, 31 were men and 6 were women, with a mean age of 61.8±9.9 years. Five were Marfan patients, 8 were patients after acute or chronic dissection, and 8 were patients who required redo procedures. In 22 patients, the modified conduit was used in association with a biological valve (4 stentless valve) and in 15, with a mechanical valve. The mean durations of CPB and X-clamp time were 117±32 and 88±22 minutes, respectively. No operative or late deaths occurred after a mean follow-up period of 20±12 months. This study indicates that the new vascular prosthesis appears to facilitate implantation by maintaining a more natural shape of the reconstructed aortic root.
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INTRODUCTION

Bentall and De Bono, in their classical paper, first described the surgical approach to aortic valve disease associated with pathology of the ascending aorta. Simultaneous replacement of the aortic valve and the entire ascending aorta with coronary reimplantation has since become a standard operation for all cases of aortic valve disease associated with aneurysm or dissection of the aortic root and ascending aorta. Many modifications of the standard surgical technique have been described throughout the years. Cabrè et al. described an original approach for those cases in which mobilization of the coronary ostia was difficult. The open technique (Carrel button) of coronary reimplantation has gained popularity in the past few years because it reduces tension on the coronary anastomosis, bleeding, and risk of pseudoaneurysmal formation. Minor technical surgical variations also have been described by Nevoux et al. for those cases of low-lying coronary ostia, or by Westaby and colleagues to avoid tension on the right coronary anastomosis. Tension on the coronary ostia anastomoses can either be due to difficulty in mobilizing the coronary ostia because of adhesion or calcification, or because of excessive coronary displacement due to the aortic root aneurysm. In both cases, conduit pessurization might result in further increase of tension with a higher incidence of bleeding and late pseudoaneurysmal formation.

The popularity and increased need for this type of operation have stimulated the development of a composite-valved conduit to facilitate and expedite the surgical procedure. Usually, these types of composite-valved conduits tend to have a low tapering at the point where the Dacron conduit is attached with the mechanical valve prosthesis to minimize the distance between the Dacron conduit and coronary ostia. Improvements in both the surgical technique and material have contributed greatly toward decreasing the surgical risk of this type of operation performed currently with a low operative mortality and good long-term results.

In 2000, we introduced a Dacron conduit (Gelseco Valsalva™, Terumo Vascutek, Renfrewshire, Scotland, UK) with an original design, into clinical practice, with the aim of obtaining a more anatomical reconstruction of the aortic root. In particular, this newly designed conduit tends to reproduce the bulged section of the aortic root that corresponds to the sinuses of Valsalva. Importance of the sinuses of Valsalva in regulating the aortic valve motion during the cardiac cycle has been studied extensively in the last few years.

The authors demonstrated that by using this modified Dacron conduit it was possible to obtain more physiologic...

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**Table I. Type of Aortic Valve Prosthesis**

<table>
<thead>
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<th>Type of Prosthesis</th>
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<tr>
<td>CarboMedics (23-27 mm)</td>
<td>11</td>
</tr>
<tr>
<td>St. Jude Medical (23 mm)</td>
<td>2</td>
</tr>
<tr>
<td>Sorin Bicarbon (25 mm)</td>
<td>1</td>
</tr>
<tr>
<td>Hancock II (25 mm)</td>
<td>3</td>
</tr>
<tr>
<td>Edwards PeriMount (23-27 mm)</td>
<td>16</td>
</tr>
<tr>
<td>Toronto SPV (25-27)</td>
<td>4</td>
</tr>
</tbody>
</table>

* Seven of these patients received the CarboSeal Valsalva™ valved conduit.

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**Table II. Patient Characteristics**

<table>
<thead>
<tr>
<th>Variables</th>
<th>n=37</th>
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<tr>
<td>Age (years); mean±SD</td>
<td>63.8±9.9</td>
</tr>
<tr>
<td>Sex (M/F)</td>
<td>31/6</td>
</tr>
<tr>
<td>EF (%) ; mean±SD</td>
<td>54±11</td>
</tr>
<tr>
<td>NYHA I/II/III/IV (n.)</td>
<td>9/11/14/3</td>
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<tr>
<td>Marfan syndrome (n.)</td>
<td>5</td>
</tr>
<tr>
<td>Aortic dissection (n. acute/chronic)</td>
<td>1/7</td>
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<tr>
<td>Aortic regurgitation &gt;2 (n.)</td>
<td>31</td>
</tr>
<tr>
<td>Redo cardiac surgery (n.)</td>
<td>8</td>
</tr>
<tr>
<td>Associate procedures (n.)</td>
<td>7</td>
</tr>
<tr>
<td>Follow up (months); mean±SD</td>
<td>20±12</td>
</tr>
</tbody>
</table>

SD = standard deviation

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Figure 1. The Gelseco Valsalva™ graft.
valve motion characteristics, either after the remodeling or reimplantation type of valve-sparing procedure. Nonetheless, given its peculiar shape, this modified Dacron graft also has been used in the Bentall-type of aortic root reconstruction where it might facilitate the surgical technique and decrease the tension on coronary ostia anastomoses simultaneously. The aim of this article is to describe the authors' experience with this modified composite graft in a consecutive series of patients who underwent a Bentall procedure.

\[ \text{Figure 2. Free-hand drawing of the modified Dacron graft with a mechanical valve prosthesis for the Bentall procedure. (Used with permission from But Heart J 2000;117:497-498.)} \]

\[ \text{Figure 3. The CarboMedics Valsalva }^\text{TM} \text{ conduit.} \]

\[ \text{Figure 4. A pericardial stented biological valve prosthesis inserted is to the modified Dacron graft.} \]

PATIENTS

Between February 2000 and July 2003, 37 patients underwent combined aortic root and aortic valve replacement at the University of Rome Tor Vergata by use of this modified valved conduit in association with different mechanical valves (14 patients), biological valves (19 patients), or stentless valves (4 patients) (Table I). The last 7 patients who underwent the Bentall operation with a mechanical valve received the new valved conduit (Carbo-Seal Valsalva Aortic Ascending Prosthesis\textsuperscript{TM}, CarboMedics Inc., Austin, TX, USA), on which the CarboMedics mechanical aortic valve is attached to this modified Dacron tube graft by the manufacturer (see Table I).

The mean age of the patients was 63.8 ± 9.9 (range: 58 to 79) years, 31 (84%) of the patients were men. One (3%) procedure was for acute aortic type A aortic dissection; 7 (20%) patients had a chronic dissecting aneurysm. Five (14%) patients had Marfan’s syndrome, and 8 (22%) patients had undergone previous surgical cardiac interventions. The majority of patients (16) had a chronic atherosclerotic aneurysm.

Significant coronary artery disease (>70% stenosis of at least one major coronary artery) was present in 6 (16%) patients and in 1 (3%) patient it was associated with mitral valve disease. Patients’ characteristics are shown in Table II.

\[ \text{Table II. Patient characteristics.} \]

GRAFT DESCRIPTION AND SURGICAL TECHNIQUE

The design and characteristics of the modified Dacron graft have been described in detail elsewhere. Briefly, it is composed of three components: a standard Dacron graft with transverse corrugation; a short portion of the same Dacron graft with its corrugation set perpendicularly (longitudinally) to the rest of the graft (to mimic the proportion of a normal aortic root the length of this portion, called the “skirt” of the graft, is equal to the diameter of the graft and can stretch horizontally up to 25% to 30% more than the diameter of the graft); and the collar, another short tract of a standard Dacron tube of the same diameter with horizontal corrugation attached at the end of the skirt (Fig 1). This small ring is usually needed to attach a valve prosthesis when performing a Bentall operation (Fig 2), and it can be cut away in case of a valvesparing procedure. Under the pressure of blood, the tissue in the skirted portion of the graft stretches in the horizontal plane to reconstruct the bulged aortic root and, hence, the pseudocoarctation. Use of this modified graft, and its
physiologic advantages over a standard Dacron graft in all types of aortic valve-sparing procedure has been reported extensively. In the case of the Bentall procedure, the novel Dacron graft might have some specific features that assist the surgeon in proper reconstruction of the aortic root. Its use does not require change in the familiar technique as in a standard Bentall procedure.

After the valve has been excised and coronary button is isolated, the chosen aortic valve prosthesis and end of the modified graft (using the short collar at its base) are both attached to the aortic annulus in a single-step fashion. The coronary ostia are prepared as a Carrel patch and re-attached to the skirted portion of the graft in the proper position using a 5-0 polypropylene suture. Finally, the distal end of the graft is stretched to be anastomosed with the distal aorta. Distal anastomosis is performed in the usual fashion (in our patient cohort, an open technique under circulatory arrest was used in 4 patients). Operative data are presented in Table III.

More recently, a new valve conduit—constituted of a CarboMedics mechanical aortic valve and this modified conduit—has been made available commercially (CarboGraft Valves™, CarboMedics Inc., Austin, TX, USA) (Fig. 3). However, in the cases of biological valve prosthesis or different brands of mechanical valves, it remains necessary to attach the valve prosthesis and Dacron tube at the time of surgery (Fig. 4).

**CLINICAL RESULTS**

All patients survived and were discharged from the hospital in good clinical condition. The mean time of cardio-pulmonary bypass and mean cross-clamping time were 117±32 and 88±22 minutes, respectively. Early (<24 hours) re-interventions for excessive bleeding was necessary in 5 (14%) patients.

**Table III. Operative Data**

<table>
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<th>Parameter</th>
<th>Value</th>
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<tr>
<td>Aortic cross-clamp time (min); mean±SD</td>
<td>88±22</td>
</tr>
<tr>
<td>Cardiopulmonary bypass time (min); mean±SD</td>
<td>117±32</td>
</tr>
<tr>
<td>Duration of circulatory arrest (min); mean±SD</td>
<td>11±6</td>
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<tr>
<td>Blood loss at 24 hrs (mL); mean±SD</td>
<td>830±320</td>
</tr>
<tr>
<td>Blood loss at 48 hrs (mL); mean±SD</td>
<td>1050±350</td>
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SD = standard deviation

Figure 7. Schematic drawing of the new conduit. When the conduit is stretched to perform the distal anastomosis with the aorta, the lesion is clamped at the level of the stenotic bulbar junction, which prevents lesion on the right coronary ostium. (Used with permission from Nat Heart 1 2006;1(7):657-63)
patients. In 2 (5%) patients, a surgical source of bleeding was present at the distal aortic anastomosis, whereas in the other 3 (8%), no surgical sources were present. Three (8%) patients had late pericardial effusion that required drainage. Thirteen (35%) patients suffered from a single episode of atrial fibrillation treated successfully with intravenous Amiodarone. The mean postoperative length of stay for all patients was 9.5 (range: 4 to 16) days. At the last follow-up visits, all patients were in NYHA class I or II without any incidence of endocarditis or thromboembolic events. Postoperative echocardiography showed normally functioning valve prosthesis. The mean follow-up time was 202.12 (range: 1 to 4) months.

CONCLUSION

Composite valve replacement is an accepted form of treatment for degenerative or dissecting aneurysm involving the aortic root. Progress in preoperative and postoperative patient management, in conduct of cardiopulmonary bypass and myocardial protection, as well as in techniques and materials used for root replacement, must be credited for the low mortality and morbidity of this elective procedure in the current era. The most commonly reported complications of this type of surgery are the postoperative bleeding and late incidence of pseudoaneurysm. Both complications are usually secondary to excessive tension on the suture line and on the coronary ostia anastomoses, in particular. The optimal method of anastomosing the coronary ostia to the tube graft remains a matter of debate. Generally, the open button technique is preferred over the inclusion-wrap technique because it provides less tension on the coronary anastomoses. Of note is that the incidence of pseudoaneurysm has ranged from 8.1% to 15.6% in different series using the inclusion-wrap technique, whereas it decreased significantly after the open technique was adopted.

This new aortic Dacron conduit has been designed for use in all types of surgery of the aortic root. Its use is designed to facilitate the surgical procedure and obtain a natural anatomical configuration of the aortic root, particularly appealing in valve-sparing procedures. In the case of the Bentall operation, its advantage provides some specific technical aspects almost entirely, because artificial sinuses of Valsalva are unnecessary in the presence of a prosthetic valve. However, having a port for Dacron graft resilient in the horizontal plane facilitates surgery, especially in the more technically demanding cases in which the coronary ostia are difficult to reach (e.g., redo cases, calcified and rigid coronary ostia). Furthermore, when this port of Dacron is filled with blood, the graft's root bulges out toward the coronary ostia, thus being more compliant with their anatomic position. This process reduces the need for extended coronary mobilization, provides less tension on the sutures, and contributes to a reduced anastomotic stretching. As a result, the incidence of bleeding at the anastomotic site, with subsequent pseudoaneurysmal formation, should be reduced remarkably.

In all patients who received a Bentall operation with the new conduit using echocardiography and angiography (Figs. 5 & 6), the presence of a spherical-shaped aortic root and good take off of the two coronary arteries was demonstrated. This anatomical aspect confirmed the surgeon's perception that the new conduit could decrease the tension on the coronary ostia anastomoses by filling the space occupied previously by the aortic root aneurysm. The decrease of tension is evident, not only at the moment of performing the coronary anastomoses, but also when the conduit is pressurized. Second, the tension exerted on the distal portion of the graft when stretched to perform the anastomosis between the Dacron graft and distal aorta is not transmitted all the way through the surgical area.
way along the graft down to the right coronary artery. For its particular geometry, the skirt of the new conduit, which represents the newly reconstructed aortic root, can be only pulled as a single unit, which prevents any undue tension on the coronary suture (Fig 7). Furthermore, the entire newly reconstructed aortic root follows movement of the beating heart without exerting traction on the hinge points represented by the two coronary ostia. Third, because of the bulged shape of the root, access to the coronary button anastomoses, when checking for bleeders at the end of the procedure, is greatly facilitated (Fig 8). In particular, a small pressure exerted with the surgeon’s thumb on the skirt of the graft easily brings the left coronary button into view (Fig 9).

Considering the particular shape of the reconstructed aortic root, a certain amount of vortices will be present inside the root. Therefore, one can speculate that the presence of vortices into the newly reconstructed aortic root would even more tend to wash the area of transition between the prosthesis valve and Dacron, decreasing the incidence of thromboembolism (Fig 10).

In an ongoing experimental study (unpublished data), we determined that the vortices produced in the new Dacron graft do not influence the mechanism of the opening and closing of the valve prostheses. In particular, no differences were noted in the pressure gradient, and in the closing and leakage volume, both in the presence of a mechanical and biological valve.

When coronary flow characteristics were compared among patients who underwent a Bentall operation by means of a conventional cylindrical Dacron conduit or with the new Dacron conduit, the presence of pseudoostiums of Valvulosa did not influence coronary flow reserve but, rather, allowed a greater diastolic component of coronary flow at the baseline.

This initial experience showed good clinical results and indicate the new Dacron graft is user-friendly, with a potential for facilitating surgery and reducing postoperative complications.

REFERENCES

Dear Mr. Hargreaves,

Further to our telephone conversation, please find enclosed article: Bentall Procedure with A Novel Valve Conduit Incorporating Sinuses of Valsalva* by Dr. Ruggero DePaulis et al. published in SURGICAL TECHNOLOGY INTERNATIONAL XII.

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I look forward to talking to you shortly, in the meantime should you require any further assistance, please do not hesitate to contact me on 1 (415)-436-9790.

Yours sincerely

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06/03/2006