Sixteen-year results of composite aortic root replacement for non-dissecting chronic aortic aneurysms

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Key words:
Aortic aneurysm; Aortic dissection; Ascending aorta.

Background. **The aim of this study was to evaluate the early and long-term outcomes in patients undergoing a Bentall procedure or its button modification for chronic aortic aneurysms with aortic valve incompetence.**

Methods. **Between January 1986 and January 2002, 65 patients (84% males, mean age 58.9 ± 11 years) underwent aortic root replacement with a Bentall or a button-Bentall operation. Annuloaortic ectasia was the most frequent cause of aortic disease in this series (n = 37, 56.9%), followed by atherosclerotic aneurysms (n = 22, 33.9%), and post-stenotic dilation (n = 5, 7.7%). One patient (1.5%) underwent redo aortic root replacement, 3 (4.6%) had a Marfan syndrome, and 6 (9.2%) underwent a concomitant replacement of the aortic arch. The duration of follow-up ranged from 2 to 192 months (mean 89.6 ± 21.8 months).**

Results. **The 30-day mortality was 0%. Early non-fatal complications comprised: bleeding requiring surgical re-exploration (n = 1, 1.5%), low output syndrome (n = 1, 1.5%), acute renal insufficiency (n = 1, 1.5%), transient ischemic attack (n = 2, 3.1%), stroke (n = 1, 1.5%), and pulmonary insufficiency (n = 1, 1.5%). There was a late death due to a pulmonary neoplasm. The 16-year actuarial survival was 97 ± 2% (hazard 0.02 ± 0.02). No patient required reoperation. Furthermore, the long-term clinical follow-up was characterized by the complete absence of endocarditis, anticoagulant-related hemorrhage, valve thrombosis, and prosthetic failure. Finally, the NYHA functional status was significantly improved (1.1 ± 0.50, p < 0.001 vs preoperatively).**

Conclusions. **The late results of the Bentall and button-Bentall procedures were excellent. Our findings confirm that these techniques still constitute the gold standard in the surgical treatment of combined valve and ascending aorta pathologies.**

(Ital Heart J 2003; 4 (7): 454-459)

Received November 27, 2002; revision received March 31, 2003; accepted May 21, 2003.

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Since 1968 when Bentall and De Bono[1] first described the total replacement of the ascending aorta and aortic valve with a composite tubular graft with side-to-end reimplantation of the coronary artery ostia to the graft, this technique and its modifications[2,3] have become the gold standard in the surgical treatment of combined valve and ascending aorta pathology.

However, all these techniques can be associated with not-negligible rates of postoperative complications including hemorrhage[2,4], false aneurysm formation[3,5] and, in case of the Cabrol procedure[5], kinking and/or occlusion of the limbs of the coronary Dacron graft. In addition, these procedures are laden with a significant incidence of well-known valve-related complications such as hemorrhage, thromboembolism and infections. Thus, more recently, conservative "valve sparing" techniques[6,7] have been introduced as an alternative to the above-mentioned procedures and have been found to be extremely appealing in case of aortic root disease with secondary aortic regurgitation and a healthy, native aortic valve[8]. However, because of a not-low rate of residual aortic regurgitation and reoperation following these conservative approaches[9], such techniques can be safely used only in a relatively small number of patients and when the aortic valve is definitely normal. Thus, aortic root replacement (ARR) with a valved conduit and reimplantation of the coronary ostia, still remains the most employed treatment of combined valve and ascending aorta pathology.

The aim of the present study was to evaluate the long-term results, over a 16-year period, of the Bentall ARR procedure and of its button modification in patients with non-dissecting chronic aortic aneurysms.

Methods

Between January 1986 and January 2002, 65 patients with non-dissecting chronic aortic aneurysms (84% males, mean age 58.9 ± 11 years) underwent ARR with a Bentall operation or its button modification.

Between 1986 and 1996, the Bentall procedure was used in 30.9% of patients undergoing ascending aorta and aortic valve replacement in our Institution, whereas during the last 6 years it represented 55.2% of the procedures for ascending aorta and aortic valve replacement.

The preoperative characteristics are summarized in table I. Annuloaortic ectasia was the most frequent cause of aortic disease in this series (n = 37), followed by atherosclerotic aneurysms (n = 22), and post-stenotic (bicuspid valve) dilation (n = 5). Three patients (4.6%) had a Marfan syndrome with typical ocular and skeletal manifestations and one (1.5%) underwent a redo ARR. The operative data are shown in table II. Two patients (3.1%) underwent emergency operation owing to the development of symptoms and signs of impending aortic rupture. Femoral artery cannulation was employed in 6 patients (9.1%) and aortic arch cannulation in the others. In patients with hemodynamic instability and in those whose aneurysms were likely to be adherent to a prior sternal incision, the femoral artery and vein were cannulated before sternotomy. In the remaining cases, the venous return was via single atrial cannulation. Myocardial protection was achieved by antegrade infusion of a crystalloid cardioplegia solution and topical hypothermia.

Table I. Preoperative patient characteristics.

No. patients	65
Age (years)	58.9 ± 11
Sex (M/F)	55/10 (84%/16%)
Myocardial infarction	1 (1.5%)
Renal failure	1 (1.5%)
COPD	2 (3.1%)
Marfan syndrome	3 (4.6%)
Diabetes	2 (3.1%)
Hypertension	6 (9.2%)
Endocarditis	1 (1.5%)
Aortic valve regurgitation ≥ moderate	56 (86.1%)
Stroke	3 (4.6%)
NYHA class	3.1 ± 0.1
Congestive heart failure	1 (1.5%)
Aortic pathology	
Annuloaortic ectasia	37 (56.9%)
Atherosclerotic aneurysm	22 (33.9%)
Bicuspid aortic valve	5 (7.7%)
Previous aortic surgery	1 (1.5%)
Arch aneurysm	6 (9.2%)
Coronary artery disease	1 (1.5%)
LVEF (%)	50 ± 14

COPD = chronic obstructive pulmonary disease; LVEF = left ventricular ejection fraction.

Table II. Operative data.

Emergency operation	2 (3.1%)
Cardiopulmonary bypass time (min)	197 ± 23
Aortic cross-clamp time (min)	151 ± 44
Valve type	
Mechanical	59 (90.8%)
Biological	6 (9.2%)
Annular diameter (mm)	23.8 ± 1.2
Diameter of the ascending aorta (mm)	62 ± 3
Graft diameter (mm)	27.4 ± 1.2
Associated cardiac procedures	
CABG	3 (4.6%)
Mitral valve repair	1 (1.5%)
Arch replacement	6 (9.2%)
DHCA	6 (9.2%)
DHCA time (min)	38.4 ± 11.2
Cerebral perfusion	
RCP	1 (1.5%)
ACP*	
Direct**	1 (1.5%)
Kazui procedure	2 (3.1%)
Cabrol's fistula**	19 (29.23%)

ACP = antegrade cerebral perfusion; CABG = coronary artery bypass graft; DHCA = deep hypothermic circulatory arrest; RCP = retrograde cerebral perfusion. * direct cannulation of both the innominate branch and left carotid artery; ** perigraft space-right atrial fistula.

Six patients (9.2%) had extensive aortic disease involving the aortic arch and requiring concomitant partial or total aortic arch replacement. In these patients deep hypothermic circulatory arrest alone at 18-22°C (DHCA, n = 3) or, in alternative, retrograde cerebral perfusion (n = 1) or selective antegrade cerebral perfusion (ACP) by means of direct cannulation of both the innominate branch and left carotid artery (n = 1) or using the technique first proposed by Kazui et al.[10] (n = 1) were employed as methods for cerebral protection. Furthermore, 4 patients (6.1%) had an open distal aortic anastomosis and, in these subjects, the cerebral perfusion was ensured by DHCA (n = 3) or by Kazui ACP (n = 1). DHCA was our preferred method of cerebral protection in the past; more recently, the Kazui ACP method was introduced in our Institution. Nonetheless, although this technique carries the advantage of allowing a much longer interval of safe circulatory arrest, it is more time-consuming and care has to be taken when manipulating the cerebral vessels in order to avoid the dislodgment of atherosclerotic debris.

In our actual policy we avoid clamping and retrograde perfusion of the atherosclerotic aorta, which are the major risk factors for stroke in such cases. Furthermore, we use hypothermic circulatory arrest in most cases, taking care not to manipulate atherosclerotic vessels during the arrest and restricting it to a duration not exceeding 25 min. Finally, the Kazui technique is used in more complex cases.

All the procedures were performed as originally described[1]. In 56 patients (86%) the aortic valve was

moderately or severely insufficient. In 7 (10.7%) it was stenotic (5 bicuspid and 2 morphologically normal), and in 2 (3.1%) patients it was functionally but not macroscopically normal at surgical inspection. In the latter a composite root replacement was chosen because of the development of a severe dilation including the aorto-ventricular junction at surgery. We employed the classical Bentall procedure (side-to-side anastomosis) using the "inclusion" technique[1] (wrapping of the aneurysmal sack around the prosthesis) in 48 patients (73.8%). The "button technique" has been recently introduced in our Institution and was employed in 17 patients (26.2%). A Cabrol's fistula[2] between the periprosthetic space and the right atrium was created in 19 patients (29.2%) undergoing the classical "wrapping" procedure, in order to decompress the perigraft space, thus reducing tension at the suture lines which may be responsible for a pseudoaneurysm formation.

In circumstances where the mobilization of the coronary artery ostia was not feasible (e.g., reoperations, extensive calcification of the aortic wall and/or coronary sinuses) or when the coronary ostia were quite low (< 1.5 cm above the annulus) a Cabrol's technique[2] was preferred as the method for composite ARR. Furthermore, since 1997, a "valve sparing" operation (David I, "reimplantation" technique)[7] was preferred in case of valve cusps which were macroscopically normal, with the valve insufficiency secondary to root dilation. Subjects undergoing a Cabrol operation and those who had a "valve preserving" procedure, were excluded from the study.

From the first postoperative day onwards, all patients with mechanical prostheses started a regimen of lifelong treatment with warfarin sodium (Coumadin, Du Pont Pharmaceuticals, Wilmington, DE, USA). The target international normalized ratio (INR) was 2.5 to 3.0. Antiplatelet therapy was continued in patients submitted to concomitant coronary artery bypass surgery.

All clinical data were obtained by retrospective reviewing the medical records and postoperative follow-up information was obtained by written and/or telephone interview. The cumulative follow-up totaled 660 patient-years and was 100% complete. The maximum follow-up was 192 months with a mean of 89.6 ± 21.8 months. Infectious, thromboembolic and bleeding complications were recorded as required by the AATS/STS/EACTS guidelines[11]. Patients underwent transthoracic Doppler echocardiography at the time of discharge, and at mean of 62 ± 28 months postoperatively (range 3 to 146 months). Echocardiograms were performed using Hewlett Packard Sonos 1000/2500/5500 systems with 2.5 and 5.0 MHz ultrasound transducers (Hewlett Packard, Andover, MA, USA) and recorded on VHS videotape for subsequent review. Measurements and calculations were carried out in accordance with published criteria[12].

All data were analyzed using the SPSS for Windows, release 8.0 (SPSS, Inc., Chicago, IL, USA) statistical package. Continuous data are presented as mean ± SD; discrete variables are given as percentages. Discrete variables were analyzed using the χ^2 or Fisher exact text; continuous variables were analyzed using one-way ANOVA. The actuarial-freedoms from deaths/events were calculated using the Kaplan-Meier method and are reported together with their 95% confidence intervals. A p value < 0.05 was considered as being statistically significant.

Results

No death occurred within 30 days of surgery; thus, the early mortality rate was 0%. Early non-fatal complications occurred in 7 patients (10.7%). These included: bleeding requiring surgical re-exploration (n = 1, 1.5%), low output syndrome (n = 1, 1.5%), acute renal insufficiency (n = 1, 1.5%), stroke (n = 1, 1.5%), transient ischemic attack (n = 2, 3.1%), and pulmonary insufficiency (n = 1, 1.5%). During the follow-up period there was one late death occurring 18 months postoperatively due to a pulmonary neoplasm. The 16-year actuarial survival was 97 ± 2% (hazard 0.02 ± 0.02; Fig. 1). No patient required reoperation. Furthermore, the clinical follow-up was characterized by the complete absence of endocarditis, anticoagulant-related hemorrhage, valve thrombosis, and prosthetic failure. Thus, the freedom from these events was 100%. At follow-up there was an improvement in symptomatic status, as assessed by the NYHA class (1.1 ± 0.50, p < 0.001 vs preoperatively), with 81.2% of patients (52/64) in NYHA class I and 18.8% (12/64) who were in NYHA class II. No patient was in a NYHA functional class ≥ III. The echocardiographic measurements and calculations are shown in table III. Echocardiographic controls showed a significant reduction over time in the end-systolic and end-diastolic dimensions, peak transvalvular gradient, mean transvalvular gradient and mean aortic root diameter. In contrast, the changes in the thickness of the septum and posterior wall and in fractional shortening did not reach statistical significance.

Discussion

Different surgical techniques have been proposed for the treatment of the aneurysmal dilation of the aortic root and ascending aorta associated with aortic regurgitation. Wheat et al.[13] reported a procedure in which the aneurysm was resected down to the annulus, the coronary ostia were left *in situ* and the prosthesis was scalloped around them. In the same period, Groves et al.[14] proposed the supracoronary method and later, Creech[15] introduced the inclusion technique for

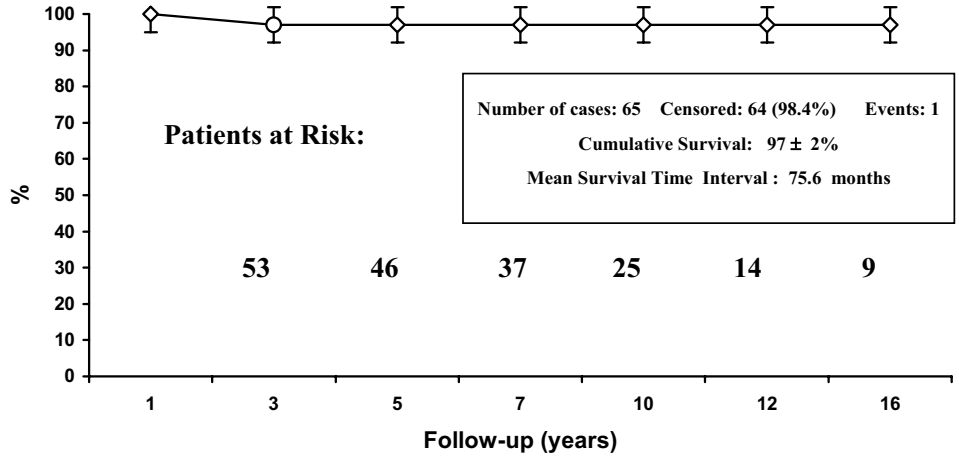

Figure 1. *Survival plot of separate aortic valve replacement.*

Table III. Echocardiographic measurements and calculations.

	Discharge	Follow-up	p§
ESD (mm)	38.5 ± 1.9*	34.6 ± 1.1	0.02
EDD (mm)	56.2 ± 4.4*	53.9 ± 3.1	0.03
ST (mm)	1.3 ± 0.1	1.3 ± 0.1	NS
WT (mm)	1.2 ± 01	1.2 ± 0.1	NS
LVEF (%)	51 ± 14	57 ± 12**	NS
PG (mmHg)	25 ± 3*	16 ± 3.1**	< 0.001
MG (mmHg)	12 ± 6*	5.1 ± 2.2**	0.001
EOA (cm^2)	2.4 ± 0.3*	2.5 ± 0.2	0.02
ARD (cm)	3.1 ± 0.9*	3.2 ± 0.9	< 0.001

ARD = aortic root diameter; EDD = end-diastolic diameter; EOA = effective orifice area; ESD = end-systolic diameter; LVEF = left ventricular ejection fraction; MG = mean transvalvular gradient; PG = peak transvalvular gradient; ST = septum thickness; WT = posterior wall thickness. * significant difference from preoperatively; ** significant difference from discharge; § significance of ANOVA over time.

the repair of aortic aneurysms. Total ARR with a conduit valve/composite graft was first introduced by Bentall and De Bono[1] in 1968. This technique has the advantage of eliminating all diseased aortic tissue from the aortic root; nonetheless, along with the risk of valve-related complications, it also carries the risk of bleeding at the level of the suture line for reimplantation with the formation of pseudoaneurysms at this level[16]. Cabrol et al.[2] proposed an alternative technique in which, the coronary circulation is re-established by means of an 8-mm Dacron tube connecting the coronary ostia and anastomosed to the tubular graft. Unfortunately, obstruction and thrombosis of the Dacron graft have been reported as complications of this technique[5]. The "button technique"[3] consists of an ARR with an end-to-side coronary anastomosis after excision of the coronary arteries from the aortic wall. Theoretical advantages of the coronary button technique include a better exposure of the anatomic structures, an improved surgical access for the control of hemostasis and a more anatomic reconstruction[17]. Potential disadvantages include the time necessary to mobilize the coronary ostia, the risk of damaging these vessels, the possibility of occlusion caused by tension and its non-feasibility in case of aortic dissection[17,18]. Besides, all these techniques carry a risk of residual valve incompetence and reoperation[5] and, in addition, the formation of aneurysms of the proximal aorta have also been reported[19]. Thus, in the last decade "valve sparing" procedures, as originally described by Yacoub et al.[6] and David and Feindel[7] have been employed when aortic incompetence was secondary to the dilation and the valve cusps were normal. In the present study we report our experience over a 16-year period employing either the classical Bentall procedure or its button modification in patients with a non-dissecting chronic aneurysm.

In this series the classical Bentall operation (side-to-side anastomosis) using the "inclusion" technique[1] (wrapping of the aneurysmal sack around the prosthesis) was employed in 48 patients (73.8%). In contrast, the "button technique" has been only recently introduced in our Institution and was employed in a smaller number of patients (n = 17, 26.2%). In addition, when the wrapping procedure was used, and especially in case of excessive bleeding, we created a Cabrol fistula[2] between the perigraft space and the right atrium in order to reduce bleeding and the incidence of late false aneurysm formation.

In the present series, there was no early death and during follow-up one patient died of a pulmonary neoplasm. The 16-year survival was 97 ± 2%. Furthermore, no patient of this series required reoperation and the long-term clinical follow-up was characterized by the complete absence of endocarditis, anticoagulant-related hemorrhage, valve thrombosis and prosthetic failure. Finally, a significant improvement in NYHA functional status was observed in all patients ($p < 0.001$ vs preoperatively). Our findings confirmed that the Bentall and button-Bentall techniques are safe procedures for ARR[20]

and the results of this series compare favorably with those reported in the literature for these techniques[19-22].

In our current policy, the "button" technique including the direct implantation of coronary buttons and a distal anastomosis to the completely divided ascending aorta[23] is the preferred method of root replacement. This technique allows an increased length of the arteries with a shorter gap between the anastomotic sites, and, in addition, the improved vascular grafts, operative technique, perioperative management and management of coagulopathy have reduced the incidence of postoperative bleeding after the button operation, thus making this procedure more feasible. Its recent introduction in our Institution further reduced, in our practice, the indications for the Cabrol procedure which is actually rarely used and only when the excision of the coronary ostial buttons is really difficult or not feasible (i.e. some redo procedures or complex repairs).

Furthermore, since 1997, a David I "valve sparing" operation ("reimplantation" technique) has been employed in a small number of patients in whom the valve cusps were macroscopically normal and the valve insufficiency secondary to root dilation. Finally, homograft replacements are restricted to only a few cases because of their limited availability.

Limitations of the study. Our investigation presents some strong limitations which have to be pointed out:
• the retrospective nature of this clinical study;
• the small number of patients;
• the small number of patients remaining at risk beyond 10 years;
• the fact that our results are based on very strict selection criteria which excluded from the study theoretically more challenging cases with chronic aortic aneurysms (i.e. patients in whom the mobilization of the coronary ostia was not feasible) who underwent different procedures (i.e. the Cabrol operation);
• in this report no comparison was carried out between procedures performed using "button" methods and those carried out using the "wrap inclusion" technique, because of the recent introduction of the "button" technique in our practice and the small number of patients in this subgroup, which would make such a comparison inappropriate.

In conclusion, in our opinion, the "button" technique, as employed by most centers worldwide, is the operative gold standard for the replacement of the ascending aorta and aortic valve.

Our favorable results are food for thought: considering the not negligible risk of reoperation associated with the conservative procedures, is the use of a more complex, high-risk "valve sparing" operation, when either the Bentall ARR and its button modification ensure excellent early and long-term results, really justified? Further larger series are necessary to answer this remarkable question.

Acknowledgments

We are very grateful to Mrs. Viviana Giavedoni, Mrs. Cristina Ceccotti and Mr. Devi Papais for their help in the preparation of this manuscript, and to Dr. Laura Pilotto for her linguistic contribution.

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