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Original Article

Ten Years Experience of Aortic Root Replacement Using a Modified Bentall Procedure with a Carrel Patch and Inclusion Technique

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Objective: **A modified Bentall procedure with a Carrel patch and inclusion technique (Modified Bentall Procedure) has been used to treat combined disease of the aortic valve and aortic root. The current study examined the outcomes of this surgical technique.**

Materials and Methods: **Between April 1999 and March 2009, 16 patients (10 males, 6 females; 63.3 ± 9.4 years) underwent elective surgery involving the Modified Bentall Procedure and no additional surgery, so they were included in the study.**

Results: **The mean cardiopulmonary bypass time was 140.2 ± 34.4 min (range: 97–232 min), and aortic cross-clamp time was 97.3 ± 16.6 min (range: 76–132 min). There were no hospital deaths. No patients required additional surgery to correct excessive bleeding. The follow-up rate was 100% (16/16). The mean follow-up period was 5.6 ± 2.8 years (range: 0.7–9.9 years). One of the 16 patients died (6.3%) due to lung cancer, and 1 of the 15 surviving patients required additional surgery (6.7%) for a thoracic aortic aneurysm. Kaplan-Meier analysis found that 1-year and 5-year survival and event-free survival rates were all 100%.**

Conclusions: **The Modified Bentall Procedure provided satisfactory results over both the short term and long term.**

Key words: aortic root replacement, modified Bentall procedure

Introduction

The surgical reconstruction of the aortic root with a valved composite graft was first reported by Bentall and De Bono.[1] The reported disadvantages of the classical Bentall technique are excessive postoperative bleeding and pseudoaneurysm formation at the suture lines.[2, 3] Since its original development, the Bentall technique has undergone several modifications.[2] The current group of investigators use the Modified Bentall Procedure, as reported by Kawazoe et al. in 1993.[4] The current study examined this surgical procedure and its outcomes.

Materials and Methods

Between April 1999 and March 2009, 31 patients underwent aortic root replacement at Nagasaki University Hospital, Nagasaki, Japan. Sixteen of these patients (10 males, 6 females; mean age ± standard deviation (SD): 63.3 ± 9.4 years; range: 48–79 years) underwent elective surgery involving the Modified Bentall Procedure but no additional surgery, so they were included in the study. The patients' medical records were reviewed retrospectively to obtain data on patient demographics, symptoms, echocardiographic and computed tomographic findings,

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Table 1 Patient characteristics

	n = 16
Age	63.3 ± 9.4
Male/Female	10/6
Diagnosis	
AAE	12
Atherosclerotic aneurysm	2
Aneurysm of Valsalva	2
(Marfan syndrome)	3
(Previous surgery)	1
Ascending aorta diameter (mm)	59.1 ± 9.0
New York Heart Association Functional Class II / III	7/9

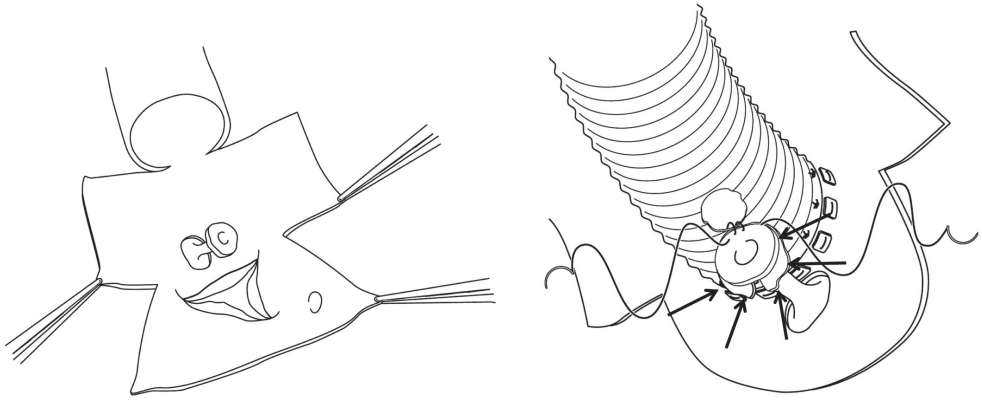

Fig. 1 Surgical procedure.
The coronary ostium was excised together with a collar of the aortic wall, leaving epicardium on the aortic wall (**A**). The coronary button was attached in an end-to-side fashion to the composite graft using polypropylene running sutures reinforced by an autologous pericardium patch (arrows) (**B**).

surgical procedures, complications, and survival rates. Follow-up was performed via hospital visits and/or telephone interviews.

Preoperative characteristics

The preoperative characteristics of the patients are summarized in **Table 1**. Indications for surgery were annuloaortic ectasia in 12 patients, atherosclerotic aneurysm in 2 (1 of whom had undergone previous surgery), and aneurysm of the sinus of Valsalva in 2. Three of the 16 study patients had Marfan syndrome (18.8%). The average diameter of the ascending aorta was 59.1 ± 9.0 mm. All 16 patients had moderate or severe aortic regurgitation. Based on the New York Heart Association (NYHA) functional classification system, 7 patients (43.8%) were graded as Functional Class II at the time of surgery, and 9 patients (56.3%) were Class III (mean class: 2.6 ± 0.3) (**Table 1**).

Surgical technique

Cardiopulmonary bypass was established using ascending aortic cannulation and right atrium drainage. After ventricular fibrillation was induced using a cardiac fibrillator, a venting cannula was placed into the right upper pulmonary vein. After cross-clamping of the ascending aorta, the aorta was transected, and then cold cardioplegic solution was injected into the coronary ostium. Using a hand-held cautery device, the coronary ostium was excised together with a 'collar'-like remnant of the aortic wall (extending 5 mm from the ostium), leaving epicardium on the aortic wall and further mobilizing the excised ostium and wall (**Fig. 1A**). Particular

attention was paid to avoiding perforation of the epicardium. After removal of the aortic valve, the optimal sizes of the prosthetic valve and graft were determined. The prosthetic valve was inserted into the graft (not fixed), and the valve and graft were implanted into the aortic annulus using everting mattress sutures (3-0 polyester suture). At this point in the surgical procedure, composite graft replacement was complete; therefore, a composite graft need not be created beforehand because it can be made intraoperatively using this technique. The current investigators use a biological replacement valve in patients of age 70 years and over. The left and then the right coronary buttons were attached in an end-to-side fashion to the composite graft using 5-0 polypropylene running sutures reinforced by an autologous pericardium patch **(Fig. 1B)**. The distal end of the tubular graft was closed manually, and a cardioplegia cannula was inserted into the distal end of the graft. The aortic root and the coronary button anastomoses were checked for possible bleeding by high-pressure administration of a cardioplegic solution. Distal anastomosis of the graft to the transected aorta was performed using a continuous 4-0 polypropylene suture. During anastomosis, the suturing needle was inserted into the distal aortic wall from the outside and into the graft and the proximal aortic wall from the inside (three layers).

After the cross-clamp was removed, the aortotomy was closed during rewarming of the patient, and the graft was completely included after weaning of the patient from cardiopulmonary bypass.

Intraoperative characteristics

Ten patients received a Dacron composite graft with a mechanical valve, 5 received a Dacron composite graft with a biological valve, and 1 received a Carbo-Seal composite valve graft (Sulzer Carbomedics Inc, Austin, TX, USA). The mean operating time was 294.0 ± 59.0 minutes (range: 202–402 minutes), cardiopulmonary bypass time was 140.2 ± 34.4 minutes (range: 97–232 minutes), and aortic cross-clamp time was 97.3 ± 16.6 minutes (range: 76–132 minutes) (**Table 2**).

Follow-up

The follow-up rate was 100% (16/16 patients attended at least 1 annual hospital visit). The mean follow-up period was 5.6 ± 2.8 years (range: 0.7–9.9 years).

Statistical analysis

Survival and event-free survival curves were calculated using the Kaplan-Meier method. Data are presented as means ± SD, ranges, and percentages.

Table 2 Operative data

Variables	Date
CPB duration (min)	140.2 ± 34.4 (97–232)
Aortic cross-clamp time (min)	97.3 ± 16.6 (76–132)
Post operative drainage (ml)	434.8 ± 247.5 (110–878)

Composite graft	No. of patients
ATS 21mm + 24mm	4
ATS 23mm + 26mm	4
ATS 25mm + 28mm	2
CEP 21mm + 24mm	3
CEP 23mm + 28mm	1
Mosaic 21mm + 24mm	1
Carbo-Seal 25mm	1

CPB, cardiopulmonary bypass; ATS, ATS bileaflet prosthesis; CEP, Carpenteir-Edwards permount

Table 3 Results

Complications	No. of occurrences	%
Atrial fibrillation or flutter	6/16	37.5
Ventricular fibrillation	1/16	6.2
Respiratory failure	1/16	6.2
Additional surgery	1/15	6.7

RESULTS

Short-term outcomes

There were no hospital deaths of patients in the study. None of the patients required additional surgery to correct excessive bleeding. The average volume of postoperative drainage was 434.8 ± 247.5 ml (range: 110–878 ml). The percentage of patients not requiring transfusion was 31.3% (5/16 patients). Postoperatively, atrial fibrillation or flutter occurred in 6 patients (37.5%). Ventricular fibrillation occurred in 1 patient (6.3%), and normal heart rhythm was restored electrically. One patient had postoperative respiratory failure requiring prolonged ventilation and a tracheostomy (**Table 3**).

Long-term outcomes

Of 16 patients, 1 patient died (6.3%) 5.5 years after surgery due to lung cancer. Therefore, based on Kaplan-Meier analysis, the 1-year and 5-year survival and event-free survival rates were all 100%. One of the 15 surviving patients required additional surgery (6.7%) for a thoracic aortic aneurysm (not a pseudoaneurysm) 7 years after the original surgery (**Table 3**). None of the study patients had an anticoagulant-related hemorrhage, valve thrombosis, coronary event, pseudoaneurysm, or prosthesis-related complication. All 16 patients underwent NYHA functional reclassification after surgery: 14 patients (87.5%) were graded as functional Class I, and only 2 patients (12.5%) were Class II (mean: 1.1 ± 0.3).

Discussion

The Bentall procedure and its major modifications have been the technique of choice for composite graft replacement of the ascending aorta and aortic valve in the treatment of a variety of pathological conditions. The reported disadvantages of the classical Bentall technique are excessive postoperative bleeding and pseudoaneurysm formation at the suture lines.[2, 3] Therefore, it is crucial to control bleeding during a Bentall operation in order to reduce the time needed for hemostasis. Since 1999, the current investigators have used a modified Bentall procedure with a Carrel patch and inclusion technique, as reported by Kawazoe et al.[4]

Hospital mortality and morbidity

The advantages of performing the Bentall procedures with a Carrel patch are that coronary ostial reimplantation into the prosthetic graft can be easily performed with good visualization and that stress on the anastomosis can be avoided. Milano et al. noted that the formation of pseudoaneurysms at all sites of anastomosis of tissue to the conduit (including the aortic annulus, coronary ostia, and distal aorta) has been a troublesome late complication of the inclusion technique.[5] Thus, to avoid anastomotic stress and bleeding, the coronary ostium can be detached to facilitate its mobility and then reinforced with autologous pericardium during anastomosis.[4] Sokullu et al. also used Teflon felt to control bleeding during coronary artery anastomosis.[6]

When creating coronary buttons, it is essential to avoid injuring the epicardium so that eventually the graft can be wrapped completely (and any tears can be sutured in the event of epicardial damage). Complete coverage by the epicardium serves to concentrate oozing from the needle hole in the wrapping and should reduce the time required for hemostasis and help control bleeding with a cell saver until protamine takes effect.

In the current study, the mean durations of aortic cross-clamping and cardiopulmonary bypass were 97.3 ± 16.6 and 140.2 ± 34.4 minutes, respectively. The average volume of postoperative blood drainage was 434.8 ± 247.5 ml (range: 110–878 ml). No patients required additional surgery to correct excessive bleeding. The percentage of patients not requiring transfusion was 31.3% (5/16 patients). There were no hospital deaths of study patients. Lewis et al. and Svensson et al. cited increased cardiopulmonary bypass time (≥163 minutes; odds ratio: 4.95) and aortic clamp time (≥98 minutes; odds ratio: 5.43) as factors associated with early mortality.[3, 7] The current study's modified Bentall technique proved effective in reducing the time needed for hemostasis, cardiopulmonary bypass duration, and aortic cross-clamp time.

Long-term survival and events

The Kaplan-Meier analysis confirmed that 1-year and 5-year survival and event-free survival rates were all 100%. One patient died of lung cancer 5.5 years after surgery. Another patient required additional surgery for a thoracic aortic aneurysm (not a pseudoaneurysm) 7 years after the original surgery. Kouchoukos et al.[2] and Yakut[8] indicated that the incidence of a coronary ostial pseudoaneurysm when using a button technique varies from 3.1% to 9%, but the current study found no incidence of coronary pseudoaneurysm. Miller and Mitchell described the use of a doughnut of Teflon felt or autologous pericardium placed around the coronary ostial aspect of the coronary buttons to prevent tearing of tissues.[9] Reinforcement with autologous pericardium during coronary artery anastomosis also prevented late pseudoaneurysm; however, pseudoaneurysms of coronary ostia anastomoses, as well as at the distal aortic suture line, have been observed.[9]

We use a biological valve for patients of age 70 years and older, and do not consider ongoing anticoagulation with warfarin to be necessary in these patients. None of the study patients suffered an anticoagulant-related hemorrhage or valve thrombosis. Numerous reports have indicated that a thromboembolic complication or anticoagulation-related hemorrhage is less likely with a biological valve.[10–13] We consider composite graft root replacement to be the treatment of choice for many pathological conditions affecting the aortic root and aortic valve.

Yacoub et al.[14] and David et al.[15] reported on remodeling and reimplantation as new procedures for aortic root aneurysms; however, these procedures are limited to use in patients with normal valve leaflets. There are still concerns about the management of severe aortic regurgitation. The Modified Bentall Procedure, as we have described here, provided satisfactory results in terms of both surgical and long-term outcomes. Today, various techniques are available for aortic root reconstruction; however, as explained by Silva et al.[16] complicated surgery is not necessary for cases in which the Bentall procedure is likely to produce satisfactory results.

Conclusions

The current study found that the Modified Bentall Procedure provided satisfactory results in patients requiring aortic root replacement. Pseudoaneurysms, coronary events, and prosthesis-related complications were not observed.

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