Long-term Outcomes of Modified Bentall Procedure

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ABSTRACT

Introduction: The aim of this study is to compare various modifications of Bentall procedure for early complications and long-term follow-up results.

Patients and Methods: One hundred forty-nine patients underwent proximal aortic root replacement with composite valve-conduit graft between 1995 and 2014. Bentall procedure and its modifications (Cabrol procedure and hemi-inclusion) were evaluated for short- and long-term outcomes. Patients with concomitant procedures, arch repair, or valve-sparing procedures were excluded from the study.

Results: In this study, 64 patients have met the inclusion criteria: 20 patients were included in the button Bentall group, 32 patients in the hemi-inclusion Bentall group, and 12 patients in the Cabrol group. Preoperative patient demographics were similar in all groups. The hemi-inclusion technique had better early outcomes, including less intraoperative blood transfusion, short cardiopulmonary bypass, and better in-hospital mortality rates ($p< 0.05$). However, the long-term all-cause mortality rates did not differ between the groups ($p> 0.05$).

Conclusion: The hemi-inclusion Bentall technique might be used as a safe alternative approach for various aortic root diseases due to better hemostatic properties and lesser in-hospital mortality rates.

Key Words: Aorta; aortic valve; hemorrhage

Modifiye Bentall Prosedürlerinin Uzun Dönem Sonuçları

ÖZET

Giriş: Bu retrospektif çalışmanın amacı, aort kökü hastalığı olan hastalarda Bentall prosedürleri çeşitli modifikasyonlarının kısa ve uzun dönem sonuçlarını araştırmaktır.

Hastalar ve Yöntem: 1995-2014 yılları arasında 149 hastaya kompozit kapak-tup grefti ile proksimal aort kökü replasmanı yapıldı. Bentall prosedürü ve modifikasyonları (Cabrol prosedürü ve Hemi-inklüzyon) kısa ve uzun dönem sonuçları açısından değerlendirildi. Eşlik eden prosedürler, ark tamiri veya kapak koruyucu prosedürleri olan hastalar çalışma dışı bırakıldı.

Bulgular: Hastaların 64'ü dahil edilme kriterlerini karşılamıştır (Buton Bentall grubunda 20 hasta, Hemi-inklüzyon Bentall grubunda 32 hasta, Cabrol grubunda 12 hasta). Preoperatif demografik veriler tüm gruplarda benzer bulunmuştur. Hemi-inklüzyon tekniği, daha az intraoperatif kan kaybı ve transfüzyon gereksinimi, kısa kardiyopulmoner bypass ve daha iyi hastane içi mortalite gibi kısa dönem sonuçlarla sonuçlanmıştır ($p< 0.05$). Uzun dönemli tüm nedenlere bağlı mortalite oranları açısından gruplar arasında fark bulunmamıştır ($p> 0.05$).

Sonuç: Hemi-inklüzyon Bentall tekniği, daha iyi hemostatik özellikler ve daha az hastane içi mortalite oranları nedeniyle çeşitli aort kökü hastalıkları için güvenli bir alternatif yaklaşım olarak kullanılabilir.

Anahtar Kelimeler: Aorta; aort kapak; kanama

INTRODUCTION

Aortic root replacement (ARR) with a composite valve-conduit graft is used in the management of various pathologies involving the aortic annulus, aortic valve, and sinus of Valsalva segment. Since its introduction by Bentall and De Bono in 1968, the original technique has been challenged and modified due to the high incidence of complications. Currently, the Bentall technique with coronary button mobilization remains as the procedure of choice in many centers[1,2].

Intraoperative bleeding from the aortic annulus and coronary ostial anastomosis sites are the major obstacles during the button Bentall procedure. Several novel surgical techniques have been introduced to control the perioperative bleeding to prevent reoperation, and to

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decrease the morbidity and mortality rates[3-7]. However, most of the studies are limited with only technical explanations and insufficient data on long-term outcomes. Therefore, the ideal surgical approach for proximal aortic repair remains controversial[8,9].

In this retrospective study, we aimed to evaluate the early and long-term outcomes of the hemi-inclusion modification as an alternative to button Bentall and Cabrol methods for the treatment of various aortic root pathologies[6].

PATIENTS and METHODS

Study Design and Patient Population

We retrospectively reviewed 149 consecutive patients undergoing ARR between January 1995 and January 2014 from the Istanbul School of Medicine database. The institutional ethical review board has approved the study and granted a waiver of consent (2014/287). The indications for surgery were aortic root dilatation, acute or chronic type A aortic dissection, aortic valve disease associated with ascending aorta involvement, and sinus of Valsalva rupture. Excluded from the study were 85 patients, 17 of whom had concomitant arch replacement, 32 patients underwent coronary artery bypass, 29 had valve-sparing root surgery, and 7 patients required redo ARR. The review yielded a total of 64 patients and cohort distributed into three groups according to the operative technique: button Bentall (n= 20) vs. hemi-inclusion Bentall (n= 32) vs. Cabrol (n= 12). The symptomatic statuses of the patients were graded according to the NYHA classification. Preoperative aortic root dimensions were measured using echocardiography and/or computed tomography.

Operative Techniques

In all operations, the right axillary artery cannulation and the right atrial venous cannulation were carried out. Vent process was performed through the right superior pulmonary vein. In Bentall and Cabrol procedures, the coronary ostia were removed in the form of a button. After the proximal site of the composite conduit was inserted into the aortic annulus, an 8-mm Dacron tube was anastomosed between the composite graft and coronary inlets during the Cabrol procedure. However, in the Bentall technique, the proximal end of the coronary arteries anastomosed into the openings made in the aortic vascular graft. In the hemi-inclusion procedure, coronary anastomosis was performed using the side-to-side technique. After transection of the aortic root at the level of the sinotubular junction and above the coronary ostia, a suitable composite valve graft was implanted in the aortic valve. Then, the coronary ostia were anastomosed directly into the new ostia of a Dacron composite tube-valve graft. Finally, the external aortic wall was sewed to the Dacron tube graft, which remained inside, at the level of the sinotubular junction[6] (Figure 1).

Data Collection and Study Endpoints

All perioperative clinical data were obtained by retrospective review of the medical records. Demographic data, comorbidities, aortic dimensions, electrocardiographic variables, associated anomalies, operative data, and ICU and hospital course, including complications, thrombo-embolic events, bleeding, and mortality were reviewed. Follow-up data were obtained by a combination of clinical notes review and telephonic communication with patients, their families, and referring physician. The follow-up time for survival was measured

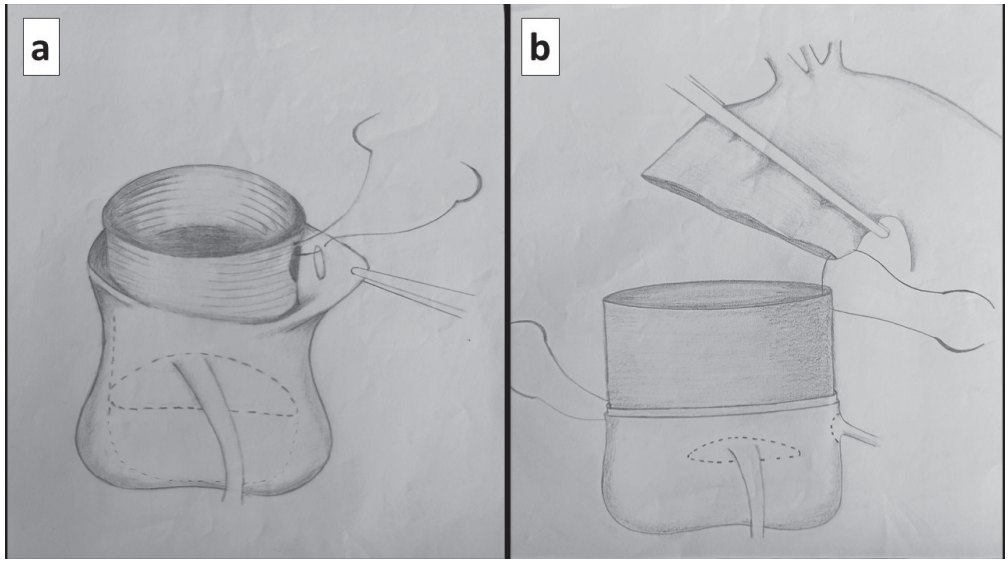

Figure 1. a) Reimplantation of coronary artery after the implantation of aortic composite graft. b) Replacement of composite graft and supporting stitches to minimize the dead space.

from the date of operation to the date of death or last contact. Clinical follow-up was updated through June 2019.

The study endpoints are: (1) long-term composite graft complications, including requirement of reoperation, prosthetic valve-related complications, and thrombo-embolic events; (2) long-term survival defined as freedom from all-cause mortality; and (3) in-hospital freedom from all-cause major adverse events as defined according to the established guidelines[10].

Statistical Analysis

All statistical analyses were performed using GraphPad Prism 7 software (La Jolla, CA, USA). Categorical variables were reported as percentage and analyzed with Fisher exact test or chi-square test. Comparisons between the two groups were performed using the student t test with Welch's correction. Multi-comparison analysis between groups was performed via Brown–Forsythe ANOVA test. Survival data were analyzed using log-rank (Mantel-Cox) approach. All statistical results with a $p< 0.05$ were considered as significant.

RESULTS

Preoperative Patient Characteristics

The demographic data and preoperative risk factors are summarized in Table 1. The median age of the patients was found to be 51.98 ± 16.26 years and 47 patients were male. Body mass index was 26.81 ± 0.36 kg/m^2 and body surface area was 1.95 ± 0.11 m^2. Sixteen patients had bicuspid aortic valve. Hypertension was present in 67% of the patients and a history of Marfan syndrome was documented in 13% of the patients. Emergent surgeries were required in 11 patients (17%).

Intraoperative Findings

The mean CPB time and cross-clamp (XC) time were found to be significantly shorter in hemi-inclusion technique compared to the other two methods ($p< 0.05$). The time from termination of CPB to the end of surgery was considered as hemostasis time. It was significantly shorter in hemi-inclusion technique compared to the other two methods. Intraoperative PRBC transfusion rate was found to be low in the hemi-inclusion group compared to the button Bentall and Cabrol groups but did not reach statistical significance ($p> 0.05$) (Table 2).

Postoperative Results

The postoperative drainage (< 24 hours) was significantly lower in the hemi-inclusion group compared to other groups (ANOVA, $p< 0.05$). Two patients in the button Bentall group and one patient in the Cabrol group required re-exploration due to postoperative hemorrhage. The source of bleeding in the first two patients was hemorrhage from the proximal tube graft anastomosis, and in the other patient, oozing from the coronary graft anastomosis was identified. In all the three patients, bleeding was controlled by enforcing additional sutures.

Two patients in the button Bentall group and one patient in the Cabrol group had severe acute renal failure that required a period of continuous venovenous hemofiltration, but this was followed by recovery of renal function and stabilization of the serum creatinine level. Two patients in the hemi-inclusion group had transient renal injury that resolved spontaneously.

Neurologic complications occurred in three patients (two patients had transient deficits and one patient experienced stroke). These patients had undergone button Bentall operations (n= 2) or Cabrol (n= 1). Based on the cranial computed tomography of these three patients, diffuse hypoperfusion was considered as the underlying cause of these complications.

Short- and Long-term Outcomes

The mean follow-up duration was 8.40 ± 2.41 years. In-hospital mortality was 10.93% (two patients in button Bentall, two patients in Cabrol, and three patients in hemi-inclusion groups; n= 7).

No differences were found between groups in terms of long-term mortality ($p= 0.438$). The overall survival rate was 89.06%, 85.93%, and 73.43% at 1, 5, and 7 years, respectively (Figure 2). One patient died 13 months after surgery due to pulmonary embolism. Another patient died due to cerebral hemorrhage at 34 months after the procedure. Eight late deaths (four cardiac and four noncardiac) occurred 5 years after operation. None of the deaths was related to the aortic valve or aortic root. However, we detected pseudoaneurysm in one patient in the button Bentall group during the 9-year follow-up.

DISCUSSION

In this study, we compared the hemi-inclusion technique with the current standard of care methods using multiple parameters. Our primary endpoint measures of overall survival and long-term complications from composite graft, requiring reoperation remained as low as the button Bentall group. However, compared with the other techniques, the hemi-inclusion approach offered better early outcomes. This finding could be explained with less intraoperative bleeding, short CPB and XC times, and less transfusion requirement through perioperative course.

An important goal for a minimal in-hospital mortality rate in aortic root surgery is to reduce blood transfusions and achieve better hemostasis. The key to achieve a successful outcome requires meticulous hemostasis and excellent surgical technique. Today, the modified Bentall procedure implementing a "button" technique for coronary reimplantation is considered the procedure of choice for ARR[11]. Early mortality rate

Table 1. Preoperative characteristics

	Button Bentall (n= 20)	Cabrol (n= 12)	Hemi-inclusion (n= 32)	p
Male gender (% of patients)	65	75	75	
Age (y)	51 ± 17	51 ± 18	51 ± 18	> 0.99
Body surface area (m^2)	1.96 ± 0.15	1.93 ± 0.15	1.93 ± 0.15	0.588
Preoperative symptoms (% of patients)				
Asymptomatic	30	8.33	37.25	
Dyspnea	75	91.66	25	
Chest pain	35	75	25	
Cardiac failure	30	58.33	21.88	
Syncope	0	25	0	
Shock	0	41.66	6.25	
Arrest	0	0	8.33	
NYHA classification (n)				0.298
I	5	1	8	
II	3	1	7	
III	12	3	14	
IV	0	7	3	
Systolic blood pressure (mmHg)	109.06 ± 29.36	107.85 ± 28.92	108.27 ± 30.95	0.910
Diastolic blood pressure (mmHg)	55.47 ± 14.7	54.85 ± 14.62	54.80 ± 15.10	0.909
Aortic regurgitation (n)				0.310
None	0	0	0	
Mild	5	2	9	
Moderate	8	5	15	
Advanced	7	5	8	
ECHO findings (cm)				
LV end-diastolic diameter	5.28 ± 1.1	5.17 ± 1.09	5.17 ± 1.18	0.785
LV end-systolic diameter	3.65 ± 1.03	3.58 ± 1.02	3.58 ± 0.85	0.853
IV septal thickness	1.13 ± 0.19	1.12 ± 0.18	1.12 ± 0.18	0.884
Aortic root	4.46 ± 0.95	4.39 ± 0.99	4.39 ± 0.95	> 0.999
Sinotubular junction	6.48 ± 7.46	6.5 ± 7.46	6.5 ± 8.68	0.994
Left ventricular EF (%)	54.21 ± 11.66	53.25 ± 11.52	53.25 ± 11.18	0.822
Bicuspid aortic valve (n)	6	5	5	
Comorbidities (n)				0.585
Marfan syndrome	3	1	5	
Diabetes mellitus	6	2	5	
Hypertension	14	10	19	
Hyperlipidemia	8	2	8	
COPD	9	4	13	
Peripheral arterial disease	1	1	0	
Chronic renal failure	2	3	0	
Turner syndrome	0	1	0	
Emergent surgery	1	7	3	

Table 2. Perioperative results

	Button Bentall	Cabrol	Hemi-inclusion	p
Cardiopulmonary bypass time	140.45 ± 28.82	160.83 ± 20.04	103.28 ± 15.23	0.04
Aortic clamp time	116.90 ± 23.22	134.42 ± 8.67	77.88 ± 5.34	0.018
Hemostasis time	103.25 ± 26.66	124.58 ± 22.60	62.18 ± 11.56	0.028
Intra-op erythrocyte transfusion	2.05 ± 0.76	2.5 ± 0.67	1.28 ± 0.52	0.101
Intubation time (hours)	22.08 ± 30.17	22.08 ± 31.64	21.89 ± 25.51	> 0.999
Duration of ICU stay (days)	3.54 ± 2.96	3.54 ± 2.98	3.54 ± 2.99	> 0.999
Postop hospitalization (days)	10.87 ± 7.49	10.87 ± 7.58	10.87 ± 7.90	> 0.999
Postoperative erythrocyte transfusion	2.29 ± 1.86	2.29 ± 1.93	1.86 ± 1.51	> 0.999
Postoperative bleeding (cc)	1043.25 ± 345.37	1331.67 ± 398.56	659.69 ± 189.49	0.039

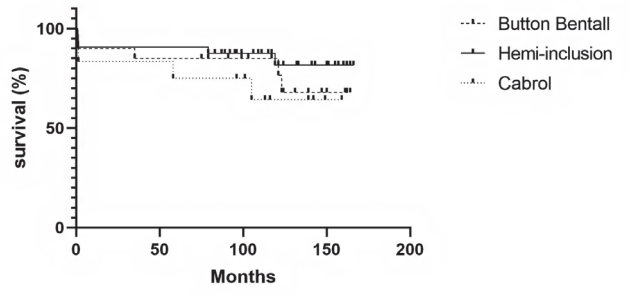

Figure 2. Kaplan-Meier survival analyses.

was reported between 1.9% and 8.9% in patients undergoing root replacement with a composite conduit[12-14]. This difference might be interpreted by the composition of heterogeneous patient population with respect to comorbidities. A lack of reporting of surgery-related complications may also be influenced by publication bias or selective outcome reporting, or both. Perioperative myocardial infarction, perigraft hematoma, coronary kinking, tension at the coronary buttons, and coagulation issues decreased over time with improvements in surgical care, but they were neither fully eliminated nor reported in detail. Coronary, annular, and distal anastomoses remain to be the most common sites that lead to perioperative hemorrhage[13].

The hemi-inclusion technique was first introduced by Cebi et al. for various aortic root pathologies, including aneurysm of the aortic root, ascending aortic aneurysm with calcified aortic valve stenosis, and aortic type A dissection[6]. In this technique, the coronary ostia were not mobilized. The anastomosis was performed in a side-to-side nature and the aortic wall was sewed to the Dacron tube graft, at the level of the sinotubular junction. The perigraft space between the aortic annulus and sinotubular junction anastomosis was also eliminated using additional pledgeted sutures. Thus, accumulation of any minor oozing originating from the ostial anastomosis and the annulus suture line was prevented. The potential advantages of this technique are shorter CPB and XC times and less perioperative transfusion that might be interpreted as a positive impact on short-term mortality. The Cabrol technique and modified Bentall operation require preparation and resection of the coronary ostia in the form of a button and anastomosis of the coronary buttons are performed in an end-to-end fashion. Therefore, those steps might prolong the XC and CPB times.

Longer CPB time, coagulopathy, low cardiac output, stroke, and perioperative myocardial infarction are well-known independent risk factors for early mortality[1,15]. did not show any significant difference between groups. The main causes of late mortality were identified as low cardiac output, distal aortic dissection or rupture, cerebral hemorrhage/stroke, and other noncardiac-related deaths.

This technique might be safely used in patients with connective tissue disease, calcified aortic wall without an extension into the coronary ostia, or high risk for intraoperative bleeding. As the structural aortic-coronary artery integrity is preserved, no potentially diseased aortic wall stays within the coronary ostial anastomosis as seen in the modified technique. Moreover, physical stabilization of the anastomoses creates an immobile space between the prosthesis and the native aortic wall. Thus, it might lower shear stress and stretch as generated by button mobilization, prevent potential leakage, and reduce the frequency of long-term pseudoaneurysm formation as seen in the modified technique.

Although one can argue that valve-sparing operations should be considered to be an alternative approach to the hemi-inclusion technique, the long-term valve durability after valve-sparing is suboptimal and this complex procedure requires prolonged CPB and aortic XC times. The reoperation rates,

progressive annular dilatation, and stenosis in the valve orifice remain as major concerns of this technique.

The heterogeneity of preoperative diagnosis of the patient groups and relatively low number of cases might limit the application of our findings in individual patients. Retrospective nature of the study and the long period for which the operations were performed might underestimate the actual occurrence of non-fatal complications.

CONCLUSION

The hemi-inclusion technique might be safely used in various aortic root pathologies. The advantage of shorter CPB time and reduced intraoperative bleeding rates might improve short-term survival after high-risk aortic root procedures.

Ethics Committee Approval: The institutional ethical review board has approved the study and granted a waiver of consent (2014/287).

Informed Consent: Written informed consent was obtained from patients who participated in this study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept/Design - EG; Analysis/Interpretation - EG; Data Collection - EG; Writing - EG; Critical Revision - MB; Final Approval - EG, MB; Statistical Analysis - EG; Overall Responsibility - EG.

Conflict of Interest: The authors have no conflict of interest to declare.

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