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Bentall operation on beating heart technique.

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Abstract

Background: In 1968, Bentall proposed the artificial vessels with ascending aorta and aortic valve replacement and re-implantation of left and right coronary arteries to treat aortic disease with ascending aortic aneurysmal dilatation. Successful Bentall operation can be achieved by greater myocardial protection, no distortion and unobstructed coronary artery bypass grafting, as well as ensured anastomotic stoma.

Patients and methods: From June 2007 to November 2013, 421 consecutive patients with a variety of cardiac pathologies underwent beating heart surgery at our institution utilizing the myocardial perfusion strategies described above. Among them, 21 cases underwent beating heart Bentall surgery, the etiology of patients was Marfan syndrome (5 patients; 23.8%), degenerative disease (2 patients; 9.5%), bicuspid aortic valve (2 patients; 9.5%), Takayasu's arteritis (1 patient; 4.8%), and rheumatic disease in the remaining 11 patients (52.4%). Surgical Technique: Surgical procedures were performed and valve was resected, and sutured with artificial blood vessels with valve in continuous or interrupted sutures manner in aortic rings.

Results: None of the patients had perioperative myocardial infarction. Major complications included low output syndrome in 1 patient (4.8%), need for prolonged mechanical ventilation in 2 (9.5%). Postoperative echocardiographic data were available for 17 of 21 patients (81.0%). 17 patients were evaluated; none of the patients had peri valvular leak or prosthetic valve dysfunction. Conclusion: Bentall operation can improve the functional recovery and quality of life in most of the surviving patients. Outcomes obtained using warm blood retrograde coronary sinus perfusion in beating heart surgery seems to compare favorably to those of traditional cardiac arrest surgery.

Keywords: Bental, Coronary arteries, Myocardial protection, Anastomotic stoma, Takayasu's arteritis, Retrograde coronary, Sinus perfusion.

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Background

Many diseases can cause aortic lesion and ascending aortic aneurysm, such as Marfan Syndrome (MFS), Takayasu's arteritis, congenital and rheumatic aortic valve diseases, and degenerative aortic disease. In 1968, Bentall proposed the artificial vessels with ascending aorta and aortic valve replacement and re-implantation of left and right coronary arteries to treat aortic disease with ascending aortic aneurysmal dilatation [1], and achieved good clinical results. Bentall operation became the preferred method of treatment for this kind of disease. However, the vascular anastomosis, operation design, complicated surgery process, higher surgical risks, and characteristic of more complications, kept the overall mortality rate being high at around 10% [2,3].

Successful Bentall operation can be achieved by greater myocardial protection, no distortion and unobstructed coronary artery bypass grafting, as well as ensured anastomotic stoma. This is due to the ascending aorta aneurysmal dilation accompanied with aortic valve disease, significant left ventricular involvement can lead to irreversible pathological left ventricular myocardial damage. Badly managed myocardial protection during cardiopulmonary bypass and myocardial ischemia-reperfusion injury exacerbate myocardial damage, lead to postoperative low cardiac output syndrome and, consequently, poor prognosis [4]. For those patients with preoperative myocardial hypertrophy and in those with poor ventricular function who require prolonged periods of aortic cross-clamping, good myocardial protection is particularly important [5]. Therefore, based on previous reports [6-9], we carried out mitral valve and aortic valve replacement with beating heart technique on the basis of experience. Beating heart Bentall surgery proceeds with warm blood retrograde infusion coronary sinus under mild hypothermia cardiopulmonary bypass. With this technique, the heart is kept beating throughout the operation and is perfused simultaneously in a retrograde fashion with warm, oxygenated blood [5]. This technique eliminates ischemia-reperfusion injury, allowing for sustained normal myocardial energy metabolism throughout the period of aortic clamping. The aim of this study is to report our clinical experience with beating heart technique in patients requiring Bentall operation.

Patients and Methods

From June 2007 to November 2013, 421 consecutive patients with a variety of cardiac pathologies underwent beating heart surgery at our institution utilizing the myocardial perfusion strategies described above. Among them, 21 cases underwent beating heart Bentall surgery, the etiology of patients was Marfan syndrome (5 patients; 23.8%), degenerative disease (2 patients; 9.5%), bicuspid aortic valve (2 patients; 9.5%), Takayasu's arteritis (1 patient; 4.8%), and rheumatic disease in the remaining 11 patients (52.4%).

Preoperative demographics and clinical data are summarized in Table 1. There were 7 males (33.3%) and 14 females (66.7%). Mean age was 44.7 ± 18.2 y (range, 23 to 67; median, 43). Preoperatively, 16 patients (76.2%) with hypertension, 3 (14.3%) with diabetes, 10 (47.6%) with combined mitral and tricuspid valve disease, and 9 patients (42.9%) presented with congestive heart failure. Also, 3 patients (14.3%) with localized dissection of ascending aorta, and 2 patients (9.5%) with coronary artery disease, and 3 patients (14.3%) had a stroke before surgery (Table 1). Preoperative echocardiography revealed Marfan syndrome in 5 patients (23.8 %), bicuspid aortic valve in 2 (9.5%), aortic stenosis in 8 (38.1%), aortic insufficiency in 6 (28.6%), mitral regurgitation in 7 patients (33.3%), mitral stenosis in 3 (14.3%), tricuspid regurgitation in 5 (23.8%), and formation of aortic aneurysm in all patients, with diameter of 54.7 ± 6.3 mm (range, 42 to 81; median, 55). Mean ejection fraction (EF) was 46.4 ± 15.9 (range, 27% to 71%; median, 44) based on echocardiographic assessment (Table 1). One patient (4.8%) had EF below 30%, 12 patients (57.1%) between 31% and 50%, and 8 patients (38.1%) had EF above 50%. ECG showed 4 patients with atrial fibrillation. Heart failure was classified as per standard New York Heart Association functional class guidelines from I to IV, as shown in Table 1.

Table 1. *Patients' characteristics ($\bar{x}$ s).*

Variables	Number	Percent
Male	7	33.3
Female	14	66.7
Age at surgery, years (range)	44.7 ± 18.2	(23-67)
Hospital stay, days (range)	17.6 ± 7.9	(15-32)
ascending aortic dimension(mm)	54.7 ± 6.3	(42-81)
Congestive heart failure	9	42.9
Hypertension	16	76.2
Diabetes mellitus	3	14.3
Multiple valve disease	10	47.6
Coronary artery disease	2	9
localized dissection of ascending aorta	3	14.3
Stroke	3	14.3
Atrial fibrillation	4	19
NYHA functional class		
II	2	9.5
III	12	57.1
IV	7	33.3
LVEF, % (range)	46.4 ± 15.9	(27-71)
EF>50%	8	38.1
EF=31% to 50%	12	57.1
EF=16% to 30%	1	4.8

LVEF: Left Ventricular Ejection Fraction; NYHA: New York Heart Association.

Surgical technique

Surgical procedures were performed at systemic cardiopulmonary bypass temperature of 32°C to 35°C. After heparinization, the ascending aorta and both superior and inferior venae cavae were cannulated. Cardiopulmonary bypass was initiated and both cavae were snared. The right atrium was incised and a purse-string of 4-0 polypropylene was placed around the mouth of the coronary sinus. A catheter was inserted into the coronary sinus, which was then snared. Perfusion of the coronary sinus was initiated with warm blood at mean pressures of 50 mm Hg to 55 mm Hg, and flows greater than 280 ml/min. The aorta was then cross-clamped, and the aorta was incised longitudinally.

Aneurysm wall was not excised, aortic valve was resected, and sutured with artificial blood vessels with valve in continuous or interrupted sutures manner in aortic rings. 1.0 cm in diameter lateral holes were made in artificial blood vessel wall corresponding to the left and right coronary arteries ostia, coronary artery graft surgery completed using around 2 mm of coronary arteries to the opening of aortic wall. Thus, the coronary artery opening cannot be made as a button shaped incision, but to avoid the possible distortion of coronary arteries graft, full thickness of the surrounding aortic wall was continuously sutured to coronary arteries at opening of the artificial blood vessel. After unclamping the aorta, if aortic wall or aortic root has small amount of bleeding, aneurysm can be sewn with sac-like tube into right atrium for drainage. If atrial fibrillation occurred, RFA Maze-III surgery is done with beating heart and mitral valve replacement or repair through arterial septal or aortic path, and then precedes Bentall operation. If needed, a tricuspid valve procedure was performed with the heart perfused and beating, and the aorta unclamped. Among 21 patients in this group, we performed mitral valve replacement or repair and tricuspid valve repair in 10 patients, while 4 patients underwent RFA Maze-III surgery, as shown in Table 2.

Table 2. *Operative data ($\bar{x}$ s).*

Variables	Number	Percent

concurrent operation		
MV Rep+TVR+RFA Maze-III	2	9.5
MV Rep+TVR	3	14.3
MV Rep+RFA Maze-III	2	9.5
MVR	3	14.3
CPB time, minutes (range)	103 ± 32.8	(92-0167)
ICU stay, days (range)	2.7 ± 1.3	(2-6)
IABP, number of patients	1	4.8
Complications		
Low-output syndrome	1	4.8
Prolonged ventilator	2	9.5
Reexploration for bleeding	1	4.8
Neurologic event	1	4.8
Myocardial infarction	0	0

MV: Mitral Valve; R: Repair; Rep: Replacement; TV: Tricuspid Valve; CPB: Cardiopulmonary Bypass; IABP: Intra-Aortic Balloon Pump; ICU: Intensive Care Unit.

Results

Table 2 summarizes operative variables and observed rate of postoperative complications.

Mean cardiopulmonary bypass time was 103 ± 32.8 min (range, 92 to 167; median, 107). None of the patients had perioperative myocardial infarction. Major complications included low output syndrome in 1 patient (4.8%), need for prolonged mechanical ventilation in 2 (9.5%). One patient (4.8%) underwent re-exploration for bleeding. Intra-aortic balloon pump support was required postoperatively in 1 patient (4.8%).

Table 3 summarizes postoperative and follow-up data.

Mean length of hospital stay was 17.6 ± 7.9 d (range 15 to 32; median, 21.0) (Table 2). Follow-up duration was 5.1 ± 0.4 months (range, 3 to 6). Three patients were lost to follow-up. No early mortality occurred in 21 patients. There was 1 late death, cause unknown. There were two post operation heart failures reported. Echocardiographic follow-up data are also summarized in Table 3. Postoperative echocardiographic data were available for 17 of 21 patients (81.0%). 17 patients were evaluated, none of the patients had peri valvular leak or prosthetic valve dysfunction, as shown in Table 3.

Logistic regression analysis (Univariate and multivariate) was performed to analyse the risk factors for post-operative complications. In our study, having only 17 available follow ups with 3 complications, no statistical significance was noted for the risk factors for post-operative complications (Table 4).

Table 3. *Patient follow-up ($\bar{x}$ s).*

Variables	Number	Percent
Mean follow-up, months (range)	5.1 ± 0.4	(3-6)
NYHA functional class		
I	3	14.3
II	9	42.9
III	3	14.3
IV	2	9.5
Unknown	4	19
Postoperative LVEF (%) (range)	49.2 ± 14.4	(33-75)
EF>50%	13	61.9
EF=31% to 50%	4	19
Unknown	4	19
Death	1	4.8
Early death	0	0
Late death	1	4.8
Heart failure	2	9.5
Lost to follow-up	3	14.3

LVEF: Left Ventricular Ejection Fraction; Early mortality was defined as death occurring within 30 d of surgery, whereas late mortality was defined as death occurring after 30 d.

For the 17 patients for whom preoperative and postoperative EF data was available (Figure 1), a comparison between preoperative and postoperative EF by paired t test revealed a trend for greater EF postoperatively, although this did not reach statistical significance (p=0.5942).

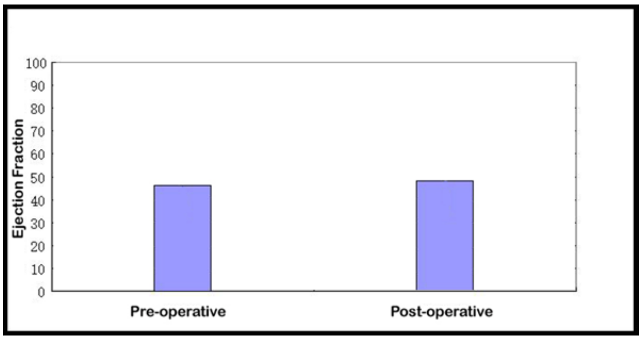

Figure 1. Preoperative versus postoperative ejection fraction (EF (%)) in 17 patients (p=0.5942).

Effect of Bentall surgery on left ventricular EF estimated by echocardiography

There was a trend toward higher EF in the postoperative state as compared with preoperative state by paired t test, although this did not reach statistical significance (p=0.5942).

Table 4. *Multiple logistic regression analysis for the relationship of risk factors with post op complications.*

Parameter		Reference value	Standard error	Wald χ^2-test	df	Significance	95% Confidence interval	
							Lower	Upper
Threshold	(Input State=0.00)	-40.649	3715.168	0.000	1	0.991	-7322.245	7240.948
	(Input State=1.00)	-16.125	3685.854	0.000	1	0.997	-7240.267	7208.017
	(Age=23.00)	-55.028	3681.219	0.000	1	0.988	-7270.086	7160.029
	(Age=34.00)	-55.028	3397.437	0.000	1	0.987	-6713.883	6603.827
	(Age=36.00)	-55.028	3681.219	0.000	1	0.988	-7270.086	7160.029
	(Age=41.00)	-55.028	3470.559	0.000	1	0.987	-6857.199	6747.142
	(Age=42.00)	-55.028	3470.559	0.000	1	0.987	-6857.199	6747.142
	(Age=43.00)	-55.028	3397.437	0.000	1	0.987	-6713.883	6603.827
	(Age=45.00)	-55.028	3341.546	0.000	1	0.987	-6604.338	6494.282
	(Age=46.00)	-55.028	3341.546	0.000	1	0.987	-6604.338	6494.282
	(Age=47.00)	-28.159	3704.223	0.000	1	0.994	-7288.303	7231.984
	(Age=50.00)	-28.159	3704.223	0.000	1	0.994	-7288.303	7231.984
	(Age=51.00)	-55.028	3470.559	0.000	1	0.987	-6857.199	6747.142
	(Age=52.00)	-55.028	3470.559	0.000	1	0.987	-6857.199	6747.142
	(Age=53.00)	-55.028	3470.559	0.000	1	0.987	-6857.199	6747.142
	(Age=55.00)	-55.028	3470.559	0.000	1	0.987	-6857.199	6747.142
	(Age=67.00)	0a	-	-	0	-	-	-
	(High blood pressure=.00)	-8.946E-16	1227.435	0.000	1	1.000	-2405.729	2405.729
	(High blood pressure=1.00)	0[a]	-	-	0	-	-	-
	(Diabetes=0.00)	-2.039E-14	1874.938	0.000	1	1.000	-3674.811	3674.811
	(Diabetes=1.00)	0a	-	-	0	-	-	-

[a]Since this parameter is redundant, it is set to zero.

Conclusion

Due to complexity of Bentall procedure, usually requiring prolonged periods of aortic cross-clamping, while it's bigger wound often accompanied more poor left ventricular function, lead to serious complications. Despite recent developments in surgical techniques, anesthesia, and postoperative care, early and late mortality of Bentall procedure still high. Postoperative low-output syndrome and congestive heart failure have been shown to be the most frequent causes of mortality. Many research results showed CPB time is risk factors for early postoperative death in ascending aorta operation [3,10,11]. This is because the CPB time and prolonged aorta cross clam aggravate myocardial ischemia-reperfusion injury, lead to Low-output syndrome and Congestive heart failure. Meanwhile, metabolism and function of the other important organs of the body has adverse effects. Some scholar's experimental studies and clinical application [12-14] demonstrated cardiopulmonary bypass using mild hypothermia retrograde perfusion beating heart technique can reduce local inflammatory cytokines of myocardium, and produce sustained normal myocardial energy metabolism and stable membrane function, reduce maximum degree of myocardial cell ischemia and hypoxia injury, and reperfusion injury, effectively prevent myocardial lesion further injury. Meanwhile, with mild hypothermic retrograde perfusion, it's easy to conduct operation and can achieve good myocardial protection, can avoid interruption of irrigation operation, and save operation time. These findings provide the experimental and the clinical basis for using beating heart technique when prolonged periods of myocardial ischemia are anticipated, as is the case during Bentall operations.

Except myocardial protection, anastomotic bleeding can also be important factor in successful Bentall operation. After completion of anastomosis, we use conventional aortic aneurysm wall to wrap artificial blood vessel with aortic valve. Aortic aneurysm wall then anastomosis with the right atrial appendage [15]. So that the bleeding around anastomosis vessel with valve can be successfully drained into the circulation and the post-operative bleeding significantly reduced. Re-implantation coronary artery distortion and obstructive coronary arteries also affect the success of Bentall surgery. For coronary artery re-implantation, some authors advocate radical resection of aneurysm aortic wall and coronary anastomosis of free-style "button" methods [2,3]. Without excision of aneurysm wall, using end luminal full thickness continuous suture is better to avoid coronary distortions in coronary arteries bypass graft, also simplifies the operation and shorten the operation time. In the vast majority of cases, coronary artery was significantly moved up, without anastomosis tension. For lower coronary openings, the proximal anastomosis will take the method of continuous suture and gasket is positioned on the aortic annulus or on left ventricular surface, as long as coronary opening from aortic valve ring is more than 1cm, intraluminal continuous suture is used for coronary arteries re-implantation. Although surgery is performed under beating heart, there is no effect on the operation of the aorta due to the relative static state of the aortic root. Due to coronary sinus perfusion, continuous blood flow to left and right coronary arteries ostium, affects the coronary anastomosis, we use right atrium suction tube to drainage coronary artery ostium blood, and enhance outflow of blood can flow into the left ventricle through artificial aortic valve, which clearly reveal anastomotic stoma, and can’t affect the coronary anastomosis.

Related valvular disease and arrhythmia can be treated over the same period with cross clamped aorta with warm blood retrograde perfusion beating heart. At the same period, 4 cases of patients with atrial fibrillation were treated with RAF Maze-III surgery. Compared to the traditional method, RAF Maze-III under beating heart operation can fully monitor cardiac arrhythmia and observe patient's heart rhythm throughout the operation, can achieve accurate surgery treatment [16]. In 6 cases of mitral valve replacement surgery without atrial fibrillation, we precede the mitral valve replacement surgery through the aortic orifice or forming path. This is because the expansion of the aortic valve surgery can provide a clear view of the operation, while reducing the conventional method of mitral valve surgery through atrial incisions, shorten the operation time [17-20]. Aortic valve disease associated with ascending aortic aneurysmal dilatation, along with the aggravation of valvular disease and increased dilation of aneurysm, natural mortality has been increasing. Bentall operation can improve the functional recovery and quality of life in most of the surviving patients. However, available data suggest that despite the excellent Bentall operations results, the perioperative mortality rates is still up to about 2%-17% [2,3,21]. Mild hypothermia cardiopulmonary bypass and coronary sinus retrograde perfusion beating heart procedure has no effect on Bentall operation, our 30-day overall mortality was 0, late death was 4.5% for Bentall operations with beating heart warm blood retrograde. Also, we did not observe neurologic deficits in relation to air embolism, a potential concern when performing beating heart surgery without clamping the aorta. Outcomes obtained using warm blood retrograde coronary sinus perfusion in beating heart surgery seems to compare favorably to those of traditional cardiac arrest surgery.

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