Original Article

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Bypass Assisted Beating Heart Mitral Valve Replacement for Rheumatic Mitral Valve Disease with Moderate Left Ventricular Dysfunction: A Surgical Experience

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Abstract

Objectives: This study was aimed at assessing whether bypass assisted beating heart surgery reduces pump time, ventilation, and hospital stay, avoids myocardial ischemic and reperfusion injury, gives better long term results over classical cold cardioplegic arrest, for mitral valve replacement in rheumatic mitral valve disease with moderate left ventricular dysfunction. *Materials and Methods:* 60 patients with rheumatic mitral valve disease with moderate left ventricular dysfunction (Ejection fraction (%) 36.73±4.06), divided into equal and comparable groups, underwent classical mitral valve replacement with St. Jude bileafelet mechanical valve. Group 1 had pump assisted beating heart surgery and Group 2 had cold cardioplegic arrest. All ventilated, with minimal inotropic support and discharged by 3-10 days. Cardiac enzymes were assessed 6 & 12 hours post declamping. Follow up done by 2D echocardiography on post-operative day 3, 6 months and 1 year. Data was statically evaluated by using Microsoft Excel 2013 version, with values represented as mean±SD. Continuous variables compared with paired student's t-test. *Result:* One patient died, due to anticoagulant non-compliance. There was elevation of cardiac enzymes in Group 2, normal in Group 1. Ejection fraction at day 3 and 6 months for Group 1 (47.8±3.25, 53.43±2.6) and Group 2 (39.4±3.1, 40.1±3.5). No further improvement at 1 year. Left ventricular dimensions (mm) at 6 months and 1 year for Group 1 (39.8±2.76/24.6±1.49, 37.8±2.1/24.3±1.32) compared to Group 2 (44.5±5/27.9±4, 42.4±4/27.4±3.7). Ventilation period (hours) and hospital stay (days) for Group 1 (2.95±1.1, 4.1±0.6) compared to Group 2 (7.52±0.9, 8.5±0.8). *Conclusion:* Mitral valve replacement in rheumatic mitral valve disease with moderate left ventricular dysfunction, bypass assisted beating heart surgery, reduces pump time, ventilation, hospital stay, avoids myocardial ischemic and reperfusion injury and gives better long term results.

Keywords: Rheumatic Heart Disease; Ventricular Dysfunction; Left; Reperfusion Injury; Heart Arrest; Induced.

Introduction

Treatment of rheumatic mitral valve disease varies from conservative medical management, closed mitral valvotomy, balloon mitral valvoplasty and mitral valve replacement. Mitral valve replacement under cold cardioplegic arrest by classic left atrial approach has been the gold standard treatment for those patients where the more conservative treatment modalities are not suitable. Although mitral valve surgery in an arrested heart gives a bloodless surgical field with adequate exposure, the recent insights into the ill effects of ischemia and reperfusion to the myocardium, has led cardiac surgeons to seek more physiological options for the same [1,2].

Bypass assisted beating heart surgery can address many of the problems including ischemia and reperfusion myocardial injuries, meanwhile providing a safe and controlled environment to perform mitral valve replacement, especially in patients with left ventricular dysfunction [3,4]. This retrospective study was primarily designed to assess whether bypass assisted beating heart surgery reduces pump time, ventilation, and hospital stay,

avoids myocardial ischemic and reperfusion injury, gives better long term results over classical cold cardioplegic arrest, for mitral valve replacement in rheumatic mitral valve disease with moderate left ventricular dysfunction.

Material and Methods

Sixty patients with rheumatic mitral valve disease with moderate left ventricular dysfunction who underwent classical mitral valve replacement by the left atrial approach, using St. Jude bileafelet mechanical valve, at Sri Venkateswara Institute of Medical Sciences, Tirupati, between 2009 and 2010, were included in the study. The patients were divided into two equal and comparable groups for the study. The study was cleared by the Institutional Ethics Committee.

The surgical approach to all the patients was by a classical median sternotomy. In Group 1, the valve replacement procedure was carried out on beating heart under normothermic conditions. After heparinisation, stable cardiopulmonary bypass was established using aortic and bicaval cannulation. A vent was placed through the right superior pulmonary vein into the left atrium. A vascular cross clamp was placed on the ascending aorta between the arterial perfusion cannula and the cardioplegic cannula. No cardioplegic solution was administered, rather continuous perfusion of the coronary arteries was maintained with warm oxygenated blood (36-37 °C) from the pump oxygenator through insertion of a Y-shaped line in the arterial perfusion line, at a rate of 250-300 ml/min, which allowed the heart to continue beating during the entire operation. Cross clamp was employed to eliminate even the slightest chance of air embolism. Body temperature was kept at 36°C - 37°C. The maximum flow rate was calculated as per body surface area (2.5 L / min / m^2). The mean systemic pressure was maintained above 60 - 80 mmHg. During the procedure, the patients were placed in Trendelenburg position to ensure prevention of air embolism [5]. The left atrium was opened and the mitral valve was examined and excised. Chordae sparing technique was used whenever possible. Mitral valve replacement was done using appropriately sized St. Jude bileafelet mechanical valve, using 2/0 pre pledgeted interrupted ethibond sutures. Left atrial appendage was closed internally in all cases. After valve replacement, the left atriotomy was closed in two layers by non-absorbable sutures after adequate de airing. We used aortic root vent for further de airing and maintained them until the patients were weaned off bypass. Simultaneously, the lung was briefly inflated to help air removal.

In Group 2, a vascular cross clamp was placed on the ascending aorta between the arterial perfusion cannula and the cardioplegic cannula. A cold blood cardioplegic solution (4°C) was administered to stop electrical and mechanical heart activity during diastole. Repeated doses of this solution was administered once every 20 minutes to maintain cardiac arrest. To maintain perfusion under moderate hypothermic conditions, a heat exchanger was used to lower the body temperature to approximately 35°C. Finally, the mitral valve was replaced by the same surgical technique as mentioned above. The hematocrit level was maintained between 20 - 25% during bypass, in both groups. Besides, the pump flow rate was between 2 - 2.5 L / min / m2 and the mean arterial pressure was maintained between 60 and 80 mmHg during bypass.

Myocardial function was monitored intra-operatively using five-lead electrocardiography. Arterial blood pressure, central venous pressure, and urine output were also monitored continuously. Arterial blood gas was done every 30 minutes. All patients were successfully weaned off cardio-pulmonary bypass with minimal inotropic support (Adrenaline or Dopamine). The bypass time ranged between 70 to 120 min. All cases were ventilated electively for 3-6 hours. Oral anticoagulation was started on the 2nd postoperative day with Acenocoumarol to maintain an INR of 2 - 3.0. In addition, intravenous antibiotics, a combination of ceftriaxone/sulbactum and amikacin, were administered during the hospital stay. There were no additional post-operative rhythm disturbances. 4 patients had to be re explored for bleeding.

Follow up was done by same cardiologist, using 2D echocardiography (Philips IE 33 machine), assessing the Ejection fraction (EF) and left ventricular (LV) dimensions (end diastolic and end systolic). EF was assessed pre-operatively as well as during 3rd day, 6 months and 1 year post-operative period. Changes in LV dimensions were also noted pre-operatively and at 6 months and 1 year post-operative period. Cardiac enzyme quantitative assay (CPK and CPK-MB) was done post- operatively at 6 and 12 hours to look for evidence of any myocardial ischemic damage. Both the groups were also compared based on hours of ventilation and days of hospital stay.

All the data was statically evaluated by using Microsoft Excel 2007 version. The values are represented as mean±SD. Means of continuous

variables were compared with paired student's t-test. A p value of <0.05 was considered significant.

Results

The study included 60 patients with rheumatic mitral valve disease with moderate left ventricular dysfunction, who underwent classical mitral valve replacement surgery. The age ranged from 30 to 60 years with mean age of 43.63±3.98, with 37 males and 23 females and male to female ratio of 1.67:1. 36 (60%) patient were in atrial fibrillation, 25 (41.6%) had moderate pulmonary hypertension. The patients were divided into two equal and comparable groups based on use or nonuse of cold cardioplegia.

CPB time was compared and was found to be between 72-92 minutes (79±4.21) in Group 1 and between 94-120 minutes (106.2±5.88) in Group 2, which was statistically significant (p<0.05). All patients were electively ventilated. In Group 1, patients were extubated within 1-5 hours (2.95±1.1), whereas in Group 2, patients were extubated in 6-10 hours (7.52±0.907), which was statistically significant (p<0.05). In Group 1, patients were discharged by 3-5 post-operative day (4.1±0.607) and in Group 2, discharge was by 6-10 post-operative day (8.5±0.86), which was also statistically significant (p<0.05) (Table 1).

Effect on left ventricular function was analysed pre-operatively and post-operatively by assessing Ejection fraction (EF (%)) and left ventricular dimensions (end systolic and end diastolic). The pre-operative mean EF was comparable in both groups with Group 1 at 36.8±4.28 and Group 2 at 36.66±3.89. Both groups showed significant improvement in EF at the end of 6 months post-operative period with no further improvement at the end of 1 year. Post-operatively, in Group 1, EF improved to 47.86±3.25, 53.43±2.68 and 55.93±1.61, on day 3, after 6 months and 1 year respectively. In Group 2, post-operative EF had statistically significant lower improvement with 39.4±3.16, 40.1±3.56 and 41.23±3.26), on day 3, after 6 months and 1 year respectively (p<0.05).

Left ventricular dimensions (mm) were comparable in both groups in the pre-operative period, but showed significant improvement in both groups post-operatively. Group 1 had 55.67±2.5 and 35.56±3.07 preoperatively, which significantly improved to 39.86±2.7 and 24.63±1.49, 37.86±2.06 and 24.36±1.32 at 6 months and 1 year follow up. Significantly lower improvement was observed in Group 2 with 54.76±2.72 and 35.7±2.62, 44.5±5 and 27.93±4.4, 42.4±4 and 27.43±3.71 at pre-operatively, and 6 months and 1 year follow up (p<0.05) (Table 2).

Table 1: Patient demographics, Comorbidity distribution and surgical data for the study population

Patient demographics			
Age (years)		43.63±3.98	
Sex distribution (M:F)		1.61:1	
Comorbidities			
Atrial fibrillation		36(60%)	
Moderate PAH*		25(41.6%)	
Surgical data			
	Group 1	**Group 2**	**'p' value**
CPB time (min)	79±4.21	106.2±5.88	<0.05
Ventilation time (hours)	2.95±1.1	7.52±0.907	<0.05
Hospital stay (days)	4.1±0.607	8.5±0.861	<0.05

* Pulmonary artery hypertension

Table 2: Comparison of Ejection fraction ((EF) (%)) and Left ventricular (LV) dimensions (mm) – Pre operative and postoperative periods

Parameter				**Group 1**	**Group 2**	**'p' value**
EF* (%)	Pre-operative			36.8±4.28	36.66±3.89	>0.05
	Post-operative	D_3		47.86±3.25	39.4±3.16	<0.05
		6 months		53.43±2.68	40.1±3.56	<0.05
		1 year		55.93±1.61	41.23±3.26	<0.05
LV** Dimensions (mm)	Pre-operative	Diastolic		55.67±2.5	54.76±2.72	>0.05
		Systolic		35.56±3.07	35.7±2.62	
	Post-operative	6 months	Diastolic	39.86±2.7	44.5±5	<0.05
			Systolic	24.63±1.49	27.93±4.4	
		1 year	Diastolic	37.86±2.06	42.4±4	<0.05
			Systolic	24.36±1.32	27.43±3.71	

*EF- Ejection fraction; **LV- Left ventricle

Cardiac enzymes were quantitatively analysed in the post-operative period to assess the extent of myocardial ischemic and reperfusion injury in both the groups. In Group 1, CPK (IU/L) was 120.73±4.6 and 142.1±4.06 at 6 and 12 hours post-operative period, which was not statistically significant. CPK-MB (IU/L) fraction also showed insignificant elevation from 11.9±1.06 at 6 hours post-operative period to 19.5±4.08 at 12 hours. Group 2 showed statistically significant elevation of CPK and CPK-MB levels at 6 and 12 hours post-operative period (182.1±4.66 and 382.4±4.46, 56.46±4.2 and 89.33±4.67) (Table 3).

There were 4 (6.6%) re-exploration for bleeding, no rhythm disturbances in the immediate or delayed post-operative period. There was no mortality in this group of 60 patients.

Table 3: Cardiac enzyme levels during postoperative period in both groups

Enzyme		Group 1	Group 2	'p' value
CPK* (IU/L)	6 hours	120.73±4.6	182.1±4.66	<0.05
	12 hours	142.1±4.06	382.4±4.46	
CPK-MB** (IU/L)	6 hours	11.9±1.06	56.46±4.2	<0.05
	12 hours	19.5±4.08	89.33±4.67	

*CPK- Creatine phosphokinase; ** CPK-MB- Creatine phosphokinase MB fraction

Discussion

Chronic rheumatic disease is endemic in the developing world in contrast to the West and remains the most common cause of both mitral stenosis and regurgitation. Calcification, particularly at the commissural edges and occasionally extending posteriorly into the annulus and subvalvular apparatus, is common in later stages of the disease. The mechanism of mitral regurgitation in rheumatic heart disease is type IIIa dysfunction. Sometimes, anterior leaflet chordal elongation can cause type II dysfunction.

Anterior leaflet prolapse and posterior leaflet restriction are also among the most common mechanisms of mitral regurgitation. Around one third of the patients with rheumatic heart disease have pure mitral stenosis, while the rest have a combination of mitral stenosis and regurgitation [5,6]. In order to perform a precise and complete surgical procedure on the heart, it is optimum to have mechanically quiescent heart with bloodless field. These optimal conditions are provided at the cost of global myocardial ischemia (due to cross clamp) and necessitate appropriate myocardial management to limit the damage that would otherwise result from the period of global myocardial ischemia. Damage from a period of ischemia may result in a variable and sometimes prolonged period of both systolic and diastolic dysfunction without muscle necrosis. This condition is now termed as myocardial stunning. The period of ischemia may also result in irreversible damage (myocardial necrosis). Studies have shown that this can develop after as little as 20 minutes of normothermic ischemia [7,8].

The ideal method of maintaining myocardial integrity during cardiac repair in man, employing CPB, would be provision of physiologic perfusion of both coronary arteries through an intact aortic root with the heart beating slowly. The advantages and results of beating heart surgery in coronary bypass procedure is well established. The idea of a quiet blood less field surgery was conceived at a time when cardiac surgery was still developing. Depolarised arrest of the heart during surgery induced by potassium and the added effect of reducing myocardial metabolism with systemic cooling with crystalloid or blood cardioplegia and the metabolic changes produced thereupon is well documented [1].

Apoptosis occurs in human heart in conditions such as heart failure, MI and hibernation and in open heart surgery where it contributes to ischemia-reperfusion injury. Apoptosis can be overcome in cardiac surgical procedures by giving continuous blood perfusion on a beating heart, instead of cardioplegia and its uneven distribution [2,3] and temperature gradients.

In normal heart there is a physiological differential blood flow within myocardial layers. The endocardium receiving the maximum flow [5,9,10]. Even with the use of cardioplegia inadequate cardioplegia delivery is an important factor for ischemic injury [11]. This unequal distribution of cardioplegia leading to inadequate myocardial protection can cause ischemia and reperfusion injury, especially to the endocardium. The uneven distribution of cardioplegia in the coronary arteries has been well studied. It has been demonstrated that during cardioplegia arrest the right ventricle is not as well cooled as the left ventricle leading to damage

to the right ventricular function in an already compromised heart [11]. Delivery of effective cardioplegia is depends on the infusion pressure, specifically so in a hypertrophied myocardium or in a heart with coronary lesions [12].

The above procedure will bypass ischemic time, rewarming, reperfusion time and reperfusion injury, as evidenced by near normal postoperative ejection fraction, CPK-MB, ECG, which is not the normal outcome in the currently followed procedure of CPB with cross clamp & cardioplegia (crystalloid or blood cardioplegia) [12].

The concept of beating heart surgery is very useful in mitral and tricuspid valve repairs, where the competence of the repair can be assessed and dealt with on the table without the use of Trans Esophageal Echocardiography [13]. At our center we extended the concept and principles of beating heart surgery to non-coronary cases also by giving oxygenated blood from the oxygenator using continuous normothermic coronary perfusion method without systemic cooling. This procedure overcomes ischemic time, swelling of myocardial cells and sodium- potassium imbalance at the intra and extracellular levels in the myocardium and also reducing the CPB time [14,11].

In the present study, the mean bypass time was 79±4.21 minutes in the patients who underwent mitral valve replacement on CPB assisted beating heart and 106.2±5.88 minutes in those of the arrested heart group and the difference was statistically significant ($p<0.05$). This was comparable to the results of similar studies conducted by Ghosh S et al [16]. Gersak B also indicated a statistically significant difference between the two groups regarding the mean bypass time [17]. Similar results were also obtained by Babaroglu S [4]. In this study, the patients in both groups were electively ventilated after the surgery and were extubated in the surgical ICU. The patients who underwent mitral valve replacement on CPB-assisted beating heart had a mean ventilation period of 2.95±1.1 hours, whereas those in the arrested heart group had a mean ventilation period of 7.52±0.907 hours, which showed a statistically significant difference between the two groups, consistent with those of the studies by Babaroglu S, Ghosh S and Gersak B [4,16,17].

Reduction of post-operative hospital stay indirectly reduces the cost of surgery and so was considered as one of the variables in this study. The patients who underwent mitral valve replacement on CPB-assisted beating heart stayed for an average period of 4.1±0.607 days in the hospital post-operatively, whereas the average post-operative hospital stay for the arrested heart group was 8.5±0.861 days, which was statistically significant and in agreement with well-established studies [4].

The difficulty encountered during our experience was that the amount of blood returns due to continuous perfusion technique and increased use of suction leading to blood cell destruction as measured by hemoglobin degradation products.

It is necessary to mention, that this procedure is not recommended when there is clot in LA or friable mass like myxoma is present beating heart is in no way a problem for technical considerations and accuracy of surgical technique is concerned retraction of heart while beating is injurious to myocardium. But our study revealed that continuous normothermic coronary perfusion even in beating heart does not raise significant myocardial isoenzymes.

Conclusion

In our opinion, the concept of bypass assisted beating heart surgery is a viable method where by we can avoid ischemia, reperfusion injury, potassium and sodium changes at the cellular level leading to a near normal ejection fraction in the postoperative period, minimal use of ionotropic drugs and minimal artificial ventilation.

In this study, we concluded that bypass assisted beating heart technique, when used in patients undergoing mitral valve replacement in rheumatic mitral valve disease with moderate LV dysfunction, there can be significant reduction in pump time, ventilation, hospital stay, avoids myocardial ischemic and reperfusion injury and gives better short and long term outcome when compared to patients undergoing similar surgery under cold cardioplegic arrest.

However, the efficacy of this procedure needs to be determined in a larger prospective randomized control trial to compare it with conventional techniques.

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Conflict of Interest

There are no conflict of interests during this study.

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