International Journal of Cardiovascular and Thoracic Surgery
2023; 9(3): 22-26
http://www.sciencepublishinggroup.com/j/ijcts
doi: 10.11648/j.ijcts.20230903.11
ISSN: 2575-4866 (Print); ISSN: 2575-4882 (Online)

Case Report

Mid-Term Outcomes of Beating Heart Mitral Valve Replacement in Secondary Mitral Regurgitation with Poor Left Ventricular Function

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To cite this article:
Abdelkader Boukhmis, Mohammed El-Amin Nouar, Yacine Djouaher. Mid-Term Outcomes of Beating Heart Mitral Valve Replacement in Secondary Mitral Regurgitation with Poor Left Ventricular Function. *International Journal of Cardiovascular and Thoracic Surgery*. Vol. 9, No. 3, 2023, pp. 22-26. doi: 10.11648/j.ijcts.20230903.11

Received: March 15, 2023; **Accepted**: April 3, 2023; **Published**: June 10, 2023

Abstract: Background: Ischemic cardiomyopathy patients often have a severely atherosclerotic ascending aorta and low cardiac function. In these patients, aortic cross-clamping and cardiac arrest increase the risk of postoperative strokes and low cardiac output syndrome. Objective: To evaluate the short and medium term outcomes of clampless beating heart mitral valve replacement in patients with secondary mitral regurgitation and a poor left ventricular function. Method: Here we describe two male patients, aged 71 and 54 years, with severe secondary mitral regurgitation and impaired left ventricular ejection fraction (LVEF) (24% and 30%, respectively). On-pump beating-heart mitral valve replacement with total chordal sparing was performed without aortic cross-clamping, through a full sternotomy approach. Results: Weaning from cardiopulmonary bypass, which lasted 43 and 52 minutes respectively, was easily achieved without the use of positive inotropes or vasopressors. The duration of mechanical ventilation (3 and 6 hours, respectively) and intensive care (24 and 48 hours, respectively) was short, considering the advanced stage of cardiomyopathy. Both patients had no postoperative neurological disorder. After a mean follow-up of 66 months (84 and 48 months, respectively), both patients were asymptomatic, without prosthetic valve dysfunction and their LVEF reached 42% and 51%, respectively. Conclusion: Beating heart mitral valve replacement, with total preservation of subvalvular apparatus, and without cross-clamping of the aorta, preserves left ventricular systolic function in the short and long-term, and reduces embolic events due to aortic manipulation. This technique can improve the outcomes of surgery for secondary mitral regurgitation in cases of severe left ventricular dysfunction.

Keywords: Heart Failure, Dilated Cardiomyopathy, Mitral Regurgitation, Beating Heart

1. Introduction

In the era of transcatheter edge-to-edge repair, surgical indications for secondary mitral regurgitation (MR) with severe left ventricular (LV) dysfunction remain limited, especially when not associated with significant coronary lesions (class IIb) [1]. This is due to the lack of a proven survival advantage of restrictive annuloplasty in these patients [2]. A randomized trial found that in secondary MR, mitral valve replacement (MVR) does not have a significant impact on survival after two years of follow-up compared to restrictive mitral annuloplasty, although it significantly reduces the incidence of recurrent MR, heart failure and re-hospitalizations [3].

Furthermore, despite the efficacy and safety of the various cardioplegic arrest protocols, each strategy has its limitations and pitfalls, and none has achieved general consensus. The ischemia-reperfusion injury they cause is often associated with non-negligible morbidity and mortality, particularly in cases of preoperative left ventricular dysfunction [4, 5]. This has led to a renewed interest in beating heart MVR [6]. This technique provides continuous coronary perfusion with oxygenated and normothermic blood, thus avoiding ischemia-reperfusion injury and constitutes physiological myocardial protection, particularly for patients with poor left ventricular function. Moreover, Calafiore [7] has highlighted the implication of aortic manipulation in the increased incidence of strokes in patients with extra coronary vasculopathy.

In order to improve the short and long term outcomes of secondary MR surgery with severe LV dysfunction, beating heart MVR without aortic cross-clamping has been proposed.

2. Case Presentation

Between 2014 and 2022, we operated on 22 patients with secondary MR, who underwent mitral valve replacement with or without coronary revascularization. Myocardial protection was always provided by cold blood cardioplegia except in two patients with reduced left ventricular ejection fraction (LVEF) (≤30%), who underwent beating heart MVR without aortic cross-clamping.

The two patients were male, 71 and 54 years old respectively, and had been previously hospitalized for heart failure. On admission, they were at NYHA stage IV and III respectively. and both had atrial fibrillation. Echocardiography showed severe MR (Stage IV and III respectively), dilated LV (LVEDD: 75 mm and 74 mm respectively), low LVEF (24% and 30% respectively) and high systolic pulmonary artery pressure (62 mmHg and 59 mmHg, respectively). Invasive coronary angiography did not reveal any significant coronary disease (Table 1).

Table 1. *Baseline characteristics of patients.*

	1st Patient	2nd Patient
Sex	Male	Male
Age (year)	71	54
Hospitalizations for heart failure	03	01
Dyspnea (NYHA)	IV	III
MR grade	IV	III
Aortic valve	Normal	Normal
LVEDD/LVESD	75/59 mm	74/48 mm
LVEF	24%.	30%
Systolic pulmonary artery pressure	62 mmHg	59 mmHg
Coronary angiography	Normal	Normal

LVEDD: Left ventricular end-diastolic diameter, LVEF: Left ventricle ejection fraction, LVESD: Left ventricular end-systolic diameter, MR: Mitral regurgitation, NYHA: New York Heart Association.

Surgical technique

Both patients were operated on by full sternotomy, with aorto-bicaval cannulation and a normothermic cardiopulmonary-bypass (CPB). In order to avoid cerebral gas embolisms that can occur during this clampless beating heart surgery, several precautions have been rigorously observed: (a) Patients must be in Trendelenburg position, (b) mean arterial pressure must be maintained around 70-75 mmHg, keeping the aortic valve constantly closed, (c) aspiration at the aortic root must be effective, (d) left atriotomy should be performed with a transitory cross-clamping of the aorta, until the mitral valve is opened with a suction cannula, thus suppressing anterograde LV ejection and eliminating any risk of gas embolism, (e) A soft LV vent cannula should be placed in the centre of the mitral valve prosthesis to prevent LV anterograde ejection as well as to avoid any injury to the LV wall, (f) De-airing of the left heart chambers should be performed under aortic cross-clamping and finally (g) aortic root suction should be maintained until completion of heart filling.

Both patients underwent mitral valve replacement using bileaflet mechanical prosthesis N=° 31, with complete preservation of the subvalvular apparatus. In the first patient, we performed a complete retention of native leaflets using a technique that involved reefing the native leaflets into the valve sutures.

In the second patient, the plication of the anterior leaflet caused excessive traction on the corresponding chordae tendineae and led us to perform another technique of the complete preservation of the subvalvular apparatus. An incision was made along the anterior mitral ring, 2 to 3 mm from the attachment of the leaflet. The anterior leaflet was divided into two parts, anterior and posterior, to which the chordae tendineae from the anterolateral and posteromedial papillary muscles were attached, respectively. The middle area of each segment, devoid of chordal insertion, was excised. The remainder of the separated valve leaflet (the anterior and posterior segments) was shifted and reaffixed to the mitral ring, by the prosthesis sutures, near the anterior and posterior commissures, respectively.

CPB time was 43 and 52 min, respectively, and was easily weaned in both patients without need for inotropic drugs or circulatory support. Mechanical ventilation duration was 3 and 6 hours, respectively, and both patients stayed in intensive care for 24 and 48 hours, respectively. Postoperative echocardiography showed neither valvular tissue in the left ventricular outflow tract nor interference with prosthetic leaflet mobility. The trans-prosthetic gradient was: 4.1 mmHg and 3.7 mmHg, respectively. Troponins at the 6th hour were low (0.036 and 0.054 ng/ml respectively) and continued to fall thereafter. The second patient was returned to the operating room following a postoperative bleeding of biological origin. Both patients had no postoperative neurological disorders and their postoperative length of stay was 9 and 13 days respectively.

The first patient with a preoperative LVEF of 24% underwent cardiac resynchronization therapy 24 months after surgery. After a mean follow-up of 66 months (84 and 48 months, respectively), both patients were asymptomatic, on low-dose of beta-blockers, ACE inhibitors and diuretics. They had no prosthetic valve dysfunction and their LVEF was 42% and 51%, respectively.

3. Discussion

1) Advantages of this technique

(1) Continuous coronary perfusion with normothermic and oxygenated blood provides good myocardial protection,

resulting postoperatively in low myocardial enzyme levels.

(2) Suppression of myocardial ischemia-reperfusion injuries preserves immediate postoperative systolic function, leading to easy CPB weaning and perioperative hemodynamic stability. This will result in a shorter duration of CPB with fewer side effects on the different organs, thus reducing the duration of mechanical ventilation and intensive care.

(3) Avoidance of aortic cross-clamping reduces atheromatic embolism and is mandatory in porcelain aorta.

(4) Complete preservation of the subvalvular apparatus, during MVR, preserves LV systolic function in the long term.

Despite the progress made with the different cardioplegia protocols, myocardial ischemia-reperfusion injury remains unavoidable [8]. Furthermore, it has been shown that cardioplegic arrest impairs cardiac lymphatic drainage, thus generating myocardial oedema that may affect postoperative myocardial function [9].

In contrast, beating heart mitral valve surgery offers more physiological and less aggressive conditions particularly in impaired LV. Matsumoto demonstrated in a randomized trial that this technique significantly reduces troponin levels and the levels of catecholaminergic drugs required, compared to patients operated on with continuous infusion of warm blood cardioplegia [10]. In other experimental studies, a reduction in extracellular fluid accumulation and lactate production and a better preservation of energy reserves were observed when the myocardial protection strategy was based on continuous coronary perfusion with normothermic and normokalemic blood [11, 12]. These results provide the experimental basis for the use of beating heart valve surgery when prolonged periods of myocardial ischemia are expected.

During this beating heart approach, we were impressed by the facility of weaning from CPB and the perioperative hemodynamic stability which avoided the need for inotropic drugs, often necessary in such severe LV dysfunction. This observation has also been made by other authors in patients with a very high operative risk [13, 14].

A non-randomized comparative study in a population with predominantly well-preserved myocardial function found that beating heart mitral surgery significantly reduced the duration of intubation, and the total length of hospital stay, without reducing operative mortality [15]. However, in the category of patients with MR with poor LV function; Ghoch noted that this technique significantly reduces the observed mortality compared to the mortality predicted by the EuroSCORE [16]. Pasic recently published a series of 120 very high-risk surgical patients (mean logistic EuroSCORE: 26.1 ± 20.6%) who underwent beating heart mitral surgery. He noted that despite their significant preoperative co-morbidities, hospital mortality was only 10% on average., 7.5% in patients without cardiogenic shock and only 2.4% in the group of ischemic MR patients with severe LV dysfunction (mean LVEF=23 ± 5.5%) [14]. It is important to note that the same author's team reported in a previous article, an operative mortality exceeding 30% in the group of ischemic MR operated with cardioplegic arrest [17].

It has also been shown that the beating heart approach via a right thoracotomy in redo mitral surgery reduces the duration of mechanical ventilation, as well as the number of blood transfusions and operative mortality, compared to fibrillating heart surgery in moderate hypothermia (28°) [13]. Indeed, electrically induced ventricular fibrillation significantly decreases oxygen delivery to the myocardium and redistributes coronary flow away from the subendocardial regions [13]. Furthermore, avoidance of extensive surgical dissection, no need for aortic cross-clamping and cardioplegia delivery, simplify otherwise difficult and risky procedures.

Zhang noted that the minimally invasive beating heart technique outperformed the conventional technique of median resternotomy with a arrested heart for mitral valve surgery in patients with previous sternotomy and a giant left ventricle, as it reduces the operation time and CPB time, decreases the transfusion ratio and the amount of transfusion, shortens the postoperative ICU stay and length of hospital stay, promote early which resulted in faster patient recovery [18].

In patients who had previous cardiac surgery and are not suitable for aortic clamping, due to periaortic adhesions, severe aortic calcifications and low ejection fraction, robotic-assisted beating heart mitral valve surgery is a feasible and effective technique with favourable short- and medium-term results [19].

2) Disadvantages:

Aortic valve integrity is a prerequisite for a bloodless surgical field in beating heart mitral valve surgery without aortic cross-clamping. The presence of a minor aortic leak can significantly interfere with the exposure and the course of the procedure. Salerno used a trans-septal approach for clampless beating heart mitral valve surgery in 214 patients to reduce aortic insufficiency and improved visualization of the mitral apparatus [20]. To counteract this discomfort, Ricci published a technique for continuous coronary perfusion, combining the retrograde and anterograde routes with aortic cross-clamping, which allowed him to perform beating heart polyvalvular surgery [21].

The main concern of this beating heart approach, without aortic clamping, is the risk of gas embolisms. The scrupulous respect of the above-mentioned precautions, whose objective is to prevent this potential risk, allowed us to avoid this complication in our patients who did not have any postoperative neurological disorders. Two randomized studies, based on intraoperative neurological monitoring (electroencephalogram, bi-spectral index, transcranial Doppler) [22] and postoperative neurocognitive testing [23] found no significant difference in neurologic disorder between beating heart and arrested heart mitral valve surgery. This has also been found in other observational studies [15, 21] of beating heart mitral or polyvalvular surgery.

The important dilation of the LV and the excessive tethering of the sub-valvular apparatus discouraged us to opt for a restrictive annuloplasty, which under these conditions is associated with a high risk of MR recurrence and re-hospitalizations [7]. Thus to avoid these complications and to preserve the long-term LV systolic function, we performed MVR preserving the entire sub-valvular apparatus. Indeed, a meta-analysis [24] confirmed that preservation of the subvalvular apparatus, compared to its complete excision, significantly reduces operative mortality, postoperative low cardiac output and mortality at 5 years after surgery. Furthermore, Yun demonstrated in a randomized study comparing complete versus partial preservation of the subvalvular apparatus (posterior mitral leaflet only), that the first approach is associated with a significant reduction in LV size, LV systolic stress and LV mass, as well as a significantly higher LVEF [25].

Nowadays, micro-invasive-procedures (off-pump, beating-heart) for mitral valve repair are abruptly expanding with the potential to be adopted as a valuable alternative to conventional surgery. Beating-heart chordal implantation via transapical approach is a current feasible, safe and reproducible option in selected patients [26].

3) Possible indications:

(1) Patients considered at high surgical risk or unsuitable for mitral surgery in cardioplegic arrest, such as patients in cardiogenic shock, patients on mechanical ventilation, patients on inotropic support or circulatory support [16], (2) mitral redo surgery [13], (3) MR with severe LV dysfunction [15], (4) porcelain aorta [14].

4. Conclusion

In the context of secondary mitral regurgitation with impaired LV function, beating heart mitral valve replacement without aortic cross-clamping does not increase the risk of neurological disorders. It also eliminates myocardial ischemia/reperfusion injuries, thus preserving immediate postoperative LV systolic function in patients considered to be at very high operative risk after cardioplegic arrest. In the mid-term, complete preservation of the subvalvular apparatus during mitral valve replacement improves left ventricular systolic function in such patients.

Abbreviations

ACE: Angiotensin-converting enzyme.
CPB: Cardiopulmonary-bypass.
EuroSCORE: European system for cardiac operative risk evaluation.
LV: Left ventricle.
LVEDD: Left ventricular end-diastolic diameter.
LVEF: Left ventricle ejection fraction.
LVESD: Left ventricular end-systolic diameter.
MR: Mitral regurgitation.
MVR: Mitral valve replacement.
NYHA: New York Heart Association.

Conflict of Interests

The authors declare that they have no competing interests.

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