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Case Report

Clampless Beating Heart Mitral Valve Replacement in Dilated Cardiomyopathy

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Abstract

Patients with secondary mitral regurgitation (SMR), the majority of which is ischemic, often have atherosclerotic ascending aorta and left ventricular (LV) dysfunction. In these patients, restrictive mitral annuloplasty is associated with a high rate of MR recurrence, aortic cross-clamping increases the stroke rate, and cardioplegic arrest increases postoperative low cardiac output syndrome. To avoid these complications, beating heart mitral valve replacement without aortic cross-clamping has been proposed. Here, we describe two male patients, aged 71 and 54 years, with severe SMR and low left ventricle ejection fraction (LVEF) (24% and 30%, respectively). Beating-heart mitral valve replacement with total chordal sparing was performed without aortic cross-clamping through a full sternotomy. Weaning from cardiopulmonary bypass was easily achieved without use of inotropes. The duration of mechanical ventilation (3 and 6 hours, respectively) and intensive care (24 and 48 hours, respectively) was short. Neither patient presented with postoperative neurological disorders. After a mean follow-up of 66 months, both patients were asymptomatic, without prosthetic valve dysfunction, and their LVEF reached 42% and 51%, respectively. This cases study indicates that for patients with SMR with impaired LV function who are at high risk for cardioplegic arrest, clampless beating heart mitral valve replacement with total preservation of the subvalvular apparatus could reduce stroke incidence, preserve peri-operative LVEF, and allow reverse LV remodeling.

Introduction

In the era of transcatheter edge-to-edge repair, surgical indications for secondary mitral regurgitation (SMR) with 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.[2] A randomized trial showed that in patients with SMR, mitral valve replacement (MVR), with cardioplegic arrest, significantly reduced the incidence of MR recurrence, heart failure, and rehospitalization in comparison to restrictive annuloplasty.[3]

Despite the efficacy and safety of various cardioplegia protocols, none has achieved general consensus. Many of these protocols result in ischemia-reperfusion injuries that are often associated with non-negligible morbidity and mortality, particularly in cases of LV dysfunction.[4] This has led to a renewed interest in beating heart MVR,[5] which offers physiological myocardial protection. Moreover, a meta-analysis[6] comparing coronary artery bypass grafting (CABG) with and without manipulation of the ascending aorta showed that when anaortic off-pump CABG (OPCAB) was compared with on-pump CABG, the rate of stroke was 0.38% vs. 1.87% ($p < 0.0001$) and when anaortic OPCAB was compared with OPCAB using a side-clamp the rate of stroke was 0.31% vs. 1.35% ($p = 0.003$). These findings clearly demonstrate that avoiding aortic manipulation may decrease the rate of peri-operative stroke.

To improve early and late outcomes of surgery in SMR with LV dysfunction, we performed clampless beating heart MVR in two patients.

All procedures performed in this case study involving human participants, were in accordance with the ethical standards of the Faculty of Medicine of Algiers and with the 1964 Helsinki declaration and its later amendments. Written and informed consent for publication was obtained from patients, and consent for publication of this case report was obtained from both patients.

Keywords: Mitral valve insufficiency; Dilated cardiomyopathy; Stroke; Low cardiac output..

Abbreviations: ACE, angiotensin-converting enzyme; CABG, coronary artery bypass grafting; CPB, cardiopulmonary-bypass; CRT, cardiac resynchronization therapy; EuroSCORE, European System for Cardiac Operative Risk Evaluation; GDMT, guideline-directed médical therapy; 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; OPCAB, off-pump coronary artery bypass grafting; SMR, secondary mitral regurgitation; TEER, transcatheter edge-to-edge repair.

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Table 1. Baseline characteristics of patients

	Patient 1	Patient 2
Sex	Male	Male
Age (year)	71	54
Type 2 diabètes	+	+
Former smoker	+	+
Hypercholesterolemia.	+	+
Hospitalizations for heart failure	03	01
GDMT for heart failure	+	+
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	No significant coronary disease	No significant coronary disease

GDMT, guideline-directed medical therapy; 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.

The CARE guideline was observed during the drafting of this case report.

Case presentation

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

Two male patients, aged 71 and 54 years old, respectively, had been previously hospitalized for heart failure. On admission, they were at New York Heart Association (NYHA) stage IV and III, respectively, and both had chronic 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. Both patients received pre-operative guideline-directed medical therapy (GDMT) for heart failure including: Amiodarone, Angiotensin II receptor blocker, Furosemide, and Aldosterone antagonists. Neither patient benefited from pre-operatively cardiac resynchronization therapy (CRT) or cardioversion (Table 1).

In the context of the non-availability of the Mitra-clip in our country and the insistence of patients to undergo surgery, we opted for this technique.

Surgical technique

Both patients were operated on using full sternotomy with aorto-bicaval cannulation. To avoid cerebral gas embolisms that can occur during this clampless beating heart surgery, several precautions were rigorously observed: (a) Patients were in Trendelenburg position, (b) mean arterial pressure was maintained around 70–75 mmHg, keeping the aortic valve constantly closed, (c) aspiration at the aortic root was effective, (d) a soft LV vent cannula was placed in the center of the mitral valve prosthesis to prevent LV antegrade ejection as well as to avoid any injury to the LV wall, and (e) aortic root suction was maintained until completion of heart filling.

Both patients underwent MVR using bileaflet mechanical prosthesis N = °31, with complete preservation of the subvalvular apparatus. Cardiopulmonary-bypass (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 LV outflow tract (Fig. 1) nor interference with prosthetic leaflet mobility. The trans-prosthetic gradient was 4.1 mmHg and 3.7 mmHg, respectively. Troponin levels after 6 hours were low (0.036 and 0.054 ng/ml, respectively) and continued to fall thereafter. Neither patient had postoperative neurological disorders and their postoperative length of stay was 9 and 13 days respectively. The first patient with a pre-operative LVEF of 24% underwent CRT 24 months after surgery. After a mean follow-up of 66 months (84 and 48 months, respectively), both patients were at stage II of dyspnea according to the NYHA classification, and received a low dose of beta-blockers, ACE inhibitors, and diuretics. Their LVEF was 42% and 51%, respectively (Table 2).

Discussion

GDMT including CRT and myocardial revascularization should be the first line of treatment for a patient with heart failure and SMR. Importantly, we learned from the MITRA-FR trial and the COAPT trial that MR can decrease from 32.5% to 46.9% in patients treated with GDMT alone. However, it has also been shown that GMDT alone is not sufficient in more than 50% of patients, especially if there is advanced LV remodeling. The two patients presented in

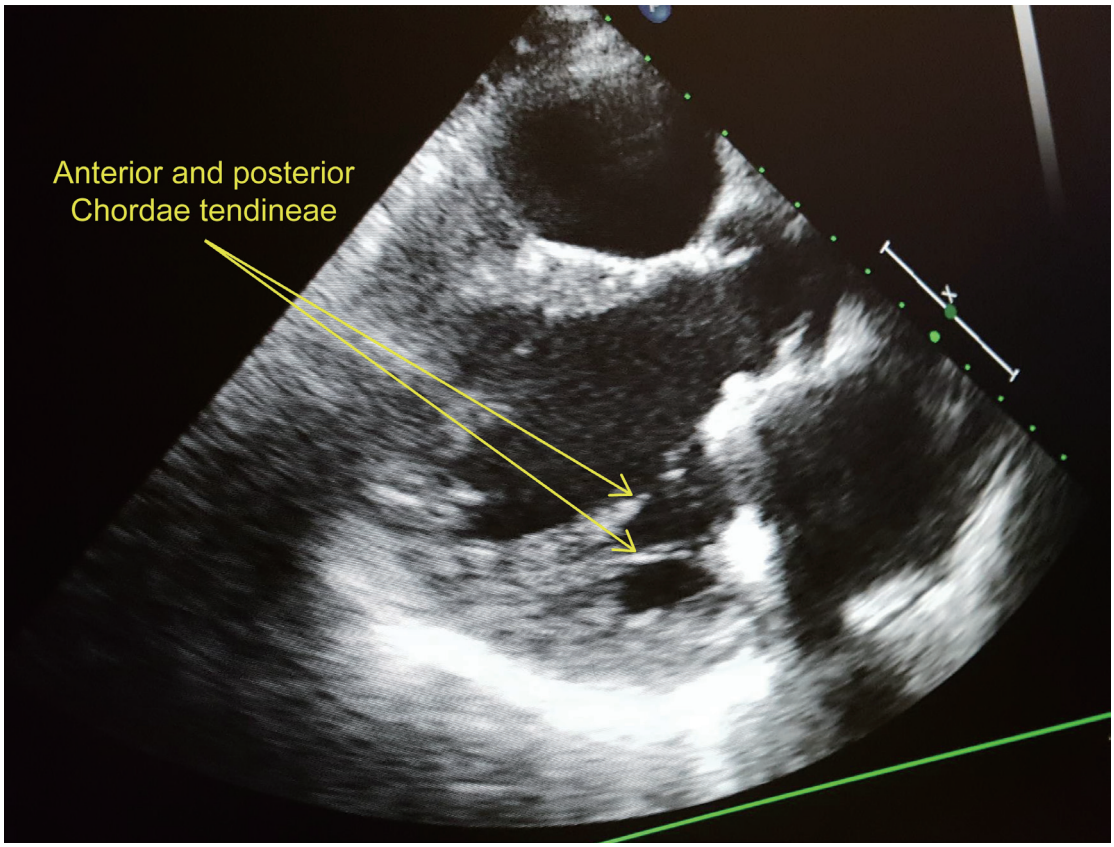

Fig. 1. Postoperative echocardiography. Preservation of the entire subvalvular apparatus did not interfere with the left ventricular outflow tract.

this case study were GDMT "non-responders" and were therefore recommended for surgical treatment.

Advantages of surgical technique

1. Continuous coronary perfusion with normothermic and oxygenated blood provides good myocardial protection, resulting in postoperative low cardiac enzyme levels.
2. Suppression of myocardial ischemia-reperfusion injuries preserves immediate postoperative systolic function, leading to easy CPB weaning and peri-operative hemodynamic stability. This will result in a shorter duration of CPB with fewer side effects and less organ damage, thus reducing the duration of mechanical ventilation and intensive care.
3. Avoidance of aortic cross-clamping reduces atheromatic embolism and is mandatory in a porcelain aorta.

Complete preservation of the subvalvular apparatus during MVR preserves long-term LV systolic function.

Despite the progress made with the different cardioplegia protocols, myocardial ischemia-reperfusion injury remains unavoidable Furthermore, it has been shown that cardioplegic arrest impairs cardiac lymphatic drainage, thus generating myocardial edema that may affect postoperative myocardial function.[7]

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

Table 2. Characteristics of patients after a mean follow-up of 66 months

	Patient 1	Patient 2
Follow-up (Months)	84	48
Dyspnea (NYHA)	II	II
MR grade	0	0
Atrial fibrillation	+	+
Medical treatment	Beta-blocker; ACE inhibitor; Diuretics	Beta-blocker; ACE inhibitor; Furosemide
LVEF	42%.	51%
Prosthetic valve dysfunction	None	None

ACE, angiotensin-converting enzyme; LVEF, left ventricular ejection fraction; MR, mitral regurgitation; NYHA, New York Heart Association.

Table 3. Comparison of the advantages and disadvantages of clampless beating heart mitral valve replacement with total preservation of the subvalvular apparatus in dilated cardiomyopathy

Advantages	Disadvantages
Suppression of myocardial ischemia-reperfusion injuries.	Retraction of the atrial wall during the trans-atrial approach often caused aortic insufficiency. However, this concern is mitigated by the trans-septal approach.
Better myocardial protection with low postoperative myocardial enzyme level.	Relatively blood-filled field.
Preserves immediate postoperative left ventricle systolic function.	Limited surgical precision due to difficult exposure, in small atria and redo operations.
Less use of circulatory support and high doses of inotropes.	Risk of air embolization.
Shorter duration of CPB with fewer side effects on the different organs.	Limited ability to perform complex mitral valve repair procedures.
Reduces the duration of mechanical ventilation and intensive care.	Longer learning curve.
Reduces atheromatic embolism.	
Favors long-term reverse remodeling of the left ventricle.	

CPB, cardiopulmonary-bypass.

technique significantly reduces troponin levels and the levels of catecholaminergic drugs required, compared to patients operated on with continuous infusion of warm blood cardioplegia.[8] In other experimental study, reduced 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.[9] These results provide an experimental basis for the use of beating heart valve surgery when prolonged periods of myocardial ischemia are expected.

During this beating heart approach, there was a remarkable weaning from CPB and peri-operative hemodynamic stability, which avoided the need for inotropic drugs that are often necessary for treating severe LV dysfunction. This observation is consistent with other studies involving patients who demonstrated high operative risks.[10,11]

In patients with SMR and poor LV function, Ghoch noted that this technique significantly reduced the observed mortality compared to the mortality predicted by the EuroSCORE.[12] Pasic published a series involving 120 very high-risk surgical patients who underwent beating heart mitral surgery. That study noted that despite their significant pre-operative co-morbidities, hospital mortality was only 2.4% in patients with ischemic MR and severe LV dysfunction.[11] It is important to note, however, that the same research team previously reported an operative mortality exceeding 30% in patients with ischemic MR operated with cardioplegic arrest.[13]

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 blood transfusions and operative mortality, compared to fibrillating heart surgery.[10] Indeed, electrically induced ventricular fibrillation significantly decreases oxygen delivery to the myocardium and redistributes coronary flow away from the subendocardial regions.[10] Zhang noted that the minimally invasive beating heart technique outperformed the conventional technique of median resternotomy with an arrested heart for mitral valve surgery in patients with previous sternotomy and a giant LV, as it reduces CPB time, decreases the amount of transfusion, and shortens time in the intensive care unit and hospital stay (Table 3).[14]

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. For this reason, Salerno used a trans-septal approach to reduce aortic insufficiency and improve mitral valve exposure.[15]

The main concern of this clampless beating heart approach is the risk of gas embolisms. Rigorous attention to these above-mentioned precautions allowed us to avoid this complication in our patients. A randomized study, based on intra-operative neurological monitoring (electroencephalogram, bi-spectral index, transcranial Doppler)[16] found no significant difference in neurologic disorders between beating heart and arrested heart mitral valve surgery.

To prevent stroke due to aortic manipulations, we avoided aortic cross-clamping.[6] It should be noted, however, that beating heart surgery can be performed with aortic cross-clamping combined with continuous perfusion of the aortic root with oxygenated and normothermic blood.

The important dilatation of the LV and the excessive tethering of the subvalvular apparatus discouraged us to utilize a restrictive annuloplasty, which under these conditions is associated with a high risk of MR recurrence and rehospitalization.[3] Thus, to avoid these complications and to preserve the long-term LV systolic function, we performed MVR preserving the entire subvalvular apparatus. Indeed, Yun demonstrated in a randomized study comparing complete versus partial preservation of the subvalvular apparatus, 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 (Table 3).[17]

Possible indications

The following are possible indications of this technique: (1) pa-

tients considered at high surgical risk or who are unsuitable for mitral surgery in cardioplegic arrest, such as patients on mechanical ventilation, patients on inotropic support or circulatory support,[11] (2) mitral redo surgery,[10] (3) SMR with severe LV dysfunction,[12] and (4) porcelain aorta.[11]

To date, transcatheter edge-to-edge repair (TEER) is indicated to treat severe symptomatic SMR in patients who have prohibitive surgical risk and favorable anatomy after a multidisciplinary evaluation.[1]

Gyoten[18] compared patients with SMR treated either with surgical MV repair or with Mitra-Clip and found that, after propensity-score matching, freedom from cardiac death and freedom from rehospitalization at 1 and 3 years were higher after surgical MV repair.

Future directions

For patients who had previous cardiac surgery and who are not suitable for aortic clamping, robotic-assisted beating heart mitral valve surgery has been shown to be a feasible and effective technique with favorable short and mid-term results.[19] Currently, beating-heart chordal implantation via transapical approach is a current feasible, safe, and reproducible option for selected patients.[20]

Limitations and strengths

The strengths of this case report are related to the efficacy and safety of the technique, which has obtained good results in patients at very high operative risk, whose outcomes with restrictive annuloplasty and cardioplegic arrest are known to be poor and have led to weak recommendations for surgery according to international guidelines for SMR with heart failure. The limitations associated with this case report are the small cohort of patients and the lack of comparison with patients with the same baseline characteristics who were operated on using the conventional technique.

Conclusion

Clampless beating heart MVR with total preservation of the subvalvular apparatus reduces stroke and preserves perioperative LV systolic function in SMR with LV dysfunction in patients who are considered at very high risk for surgery with cardioplegic arrest. This results in easy weaning from CPB, low postoperative cardiac enzyme levels, shorter duration of mechanical ventilation, and less time spent in intensive care. Total preservation of the subvalvular apparatus is crucial in these patients as it allows reverse LV remodeling in the mid-term.

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Conflict of interest

The authors have no conflict of interests to declare.

Author contributions

Conception, data collection, and writing of the original draft (AB); literature review (AB and KK); methodology (AB and YD); resources (AEN).

Ethical statement

All procedures performed in this case study involving human participants, were in accordance with the ethical standards of the Faculty of Medicine of Algiers and with the 1964 Helsinki declaration and its later amendments. Written and informed consent for publication was obtained from the patient.

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