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Patient–valve mismatch: A comparison of mechanical versus biological prostheses in ischemic mitral patients undergoing chordal-sparing mitral valve replacement

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Abstract

Background

Chordal-sparing mitral valve replacement (MVR) is now preferred over downsized annuloplasty repair in treating chronic severe ischemic mitral regurgitation. However, total leaflet preservation carries the risk of patient–valve mismatch (PVM). The authors aimed to investigate the incidence of PVM among those groups of patients who were treated with either mechanical or biological MVR.

Objective

This study aimed to compare the incidence of PVM in ischemic mitral regurgitation patients undergoing total revascularization together with chordal-sparing MVR with either biological or mechanical prosthesis.

Patients and methods

A controlled prospective study was carried out at the National Heart Institute Cairo, Egypt. 50 patients who underwent total revascularization together with chordal-sparing MVR for chronic severe ischemic mitral regurgitation were studied to determine the incidence of postoperative PVM. A total of 25 patients had received a biological mitral valve, while the other 25 patients had received a mechanical valve; postoperatively, the authors calculated the pressure gradients across the mitral valve of both groups and the effective orifice area that was indexed to the body surface area of the patients. PVM was defined as an indexed effective orifice area of less than or equal to 1.2 cm^2/m^2.

Results

The mean age was 66.32 ± 3.33 years in the biological group and 59.68 ± 2.92 years in the mechanical group. There were nine female patients (36%) in the biological group and seven female patients (28%) in the mechanical group. Aortic cross-clamp time was longer in the biological group, 134.4 ± 8.44 min, with a *P* value of less than 0.001. ICU stay was longer in the biological group 110.4 ± 21.82 h, with a *P* value of 0.035. The indexed effective orifice area showed no significant difference between the two groups. There was a tendency for freedom from PVM in the mechanical group, but this did not reach a significant level ($P = 0.057$).

Conclusion

Mechanical valves are less likely to induce PVM in ischemic mitral patients undergoing chordal-sparing MVR.

Keywords: Biological, ischemic mitral, mechanical, patient–valve mismatch

Introduction

Different mechanisms are involved in the development of ischemic mitral regurgitation following myocardial infarction and dilatation of the left ventricle. Although the mitral valve has a normal structure, the presence of annular dilatation, leaflet tethering, apical and lateral displacement of the papillary muscles, and decreased closing forces can precipitate leaflet

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malcoaptation and various degrees of mitral regurgitation. This functional ischemic mitral regurgitation results from a diseased myocardium rather than a diseased valve and hence treatment is markedly different from primary degenerative mitral regurgitation [1].

The long-standing misperception favoring mitral valve repair over replacement in treating chronic ischemic mitral regurgitation has been challenged in recent years, with increasing evidence of long-term benefits of mitral valve replacement (MVR) in this group of patients [2–5]. Accordingly, chordal-sparing MVR should be considered a reasonable treatment in patients with ischemic mitral regurgitation [6].

The increased recurrence rates of moderate or even severe degrees of mitral regurgitation, which may exceed 50% at long-term follow-up in patients who underwent restrictive annuloplasty to correct ischemic mitral regurgitation with the subsequent progression of left ventricular failure, make chordal-sparing valve replacement an attractive alternative providing more durable treatment for ischemic MR [7].

Although patient–valve mismatch (PVM) is a well-known complication of aortic valve replacement with the subsequent increase in adverse cardiac events and mortality rates [8], this complication has received less attention in mitral position, especially when it comes to ischemic patients undergoing chordal-sparing MVR, with the first case published by Rahimtoola and Murphy [9].

The connection between the indexed effective orifice area (iEOA) and the pressure gradient across the implanted valve in a well-functioning mitral valve prosthesis has been explained by Dumesnil and colleagues [10–12], who reported that PVM results from the too small effective orifice area (EOA) of the valve in relation to the body surface area (BSA) of the patient, causing high-pressure gradients postoperatively [13].

Against this background, we investigated and compared the incidence of PVM among ischemic mitral regurgitation patients who underwent total revascularization surgery together with chordal-sparing MVR with either biological or mechanical prosthesis.

Patients and methods

Between the period of March 2016 and September 2018, this single-center controlled prospective study was carried out at the National Heart Institute, Cairo, Egypt. Fifty patients with ischemic heart disease with associated chronic severe ischemic mitral regurgitation were divided into two groups:

(1) The first group included 25 patients who underwent total revascularization coronary artery bypass grafting surgery together with chordal-sparing MVR using a mechanical prosthetic valve.

(2) The second group included 25 patients who underwent total revascularization coronary artery bypass grafting surgery together with chordal-sparing MVR using a biological mitral valve.

Patients with ischemic mitral regurgitation, of both sexes, age between 18 and 80 years, with ejection fraction more than or equal to 45%, normal anatomical structure of the mitral valve, and patients who agreed to participate in the study were included in this study. Patients with rheumatic mitral valve disease, those who had undergone previous cardiac surgery, patients with acute ischemic mitral regurgitation, coexisting cardiac disease (other valvular lesions, atrial septal defect, and chronic atrial fibrillation), and chronic renal or liver failure, and patients refusing to participate in the study were excluded from this study.

All patients were counseled on the type of mitral prosthesis and the decision on the choice of a biological or a mechanical valve was taken after patient agreement based on age, life expectancy, preference, and indication/contraindication of warfarin therapy.

Chordal-sparing MVR was performed in all included patients with preservation of both anterior and posterior mitral leaflets to preserve left ventricular (LV) function and to decrease the incidence of postoperative LV dilatation and the consequent long-term progressive heart failure. Ethical committee approval was obtained for the study.

Surgical technique

The approach was performed through a standard median sternotomy incision in all patients. This was followed by harvesting of the left internal mammary artery and the saphenous vein graft.

Aortobicaval cannulation was used to initiate cardiopulmonary bypass. All patients received antegrade custodiol cardioplegia through the aortic root to induce cardiac arrest after aortic cross-clamping by administering 20 ml/kg of HTK cardioplegic solution (Custodiol; Koehler Chemi, Alsbach-Hδhnlein, Germany) once over a 10 min duration.

The decision to utilize custodiol cardioplegia was taken to ensure adequate uninterrupted myocardial protection for an already compromised myocardium during this long and demanding complex procedure.

Total revascularization by coronary artery bypass grafting was performed before MVR to easily manipulate the heart, especially if the obtuse marginal branch needed to be grafted. Distal anastomosis was performed first using 7/0 or 8/0 prolene sutures, leaving the proximal anastomosis to be performed after removal of the cross-clamp.

MVR with total preservation of anterior and posterior mitral leaflets was performed through a standard left atriotomy. The anterior mitral leaflet was detached from the annulus, divided into two leaflets with their own chordae, and sutured to the respective commissural annular areas using the procedure described by Okita *et al*. [14].

The posterior leaflet of mitral valve lies between the annulus and the prosthesis. The posterior leaflet remained plicated

between the prosthesis and the annulus of the mitral valve helping to that is the healthy structure of the mitral valve tissue. The mechanical prosthetic valves were kept in the anatomical position of the mitral valve.

The left atriotomy was then closed, the heart was debubbled from air emboli, and the cross-clamp was removed. The bulldog on the internal mammary artery was removed and the proximal anastomosis was performed using 6/0 prolene sutures after side biting the aorta.

Postoperative evaluation of patients

All patients were subjected to transthoracic echocardiography as the method of choice to evaluate prosthetic valve function as adequate doppler velocity recordings can generally be obtained despite acoustic shadowing from valve prosthesis.

A complete echocardiographic examination was performed by an experienced cardiologist including two imaging of the prosthetic valve, measurement of the transprosthetic gradients dimensional and EOA that was indexed to the BSA, and evaluation of left ventricle size and systolic function.

Before the examination, all patients received a beta blocker, with an average resting heart rate of 60 beats per minute. Measurements of the prosthetic velocity and gradients were performed from several windows to minimize angulation between the doppler beam and flow direction.

The pressure gradient was calculated using the simplified Bernoulli equation ($AP = 4 \times V_{Pr}^2$), where V_{Pr} is the velocity of the peak transprosthetic flow jet in meters per second. Prosthetic valve stenosis is generally associated with increased transprosthetic peak flow velocity or mean gradient (mean at least 1.9 m/s, peak 6 mmHg).

The EOA was calculated as $EOA=(CSA_{LVOT}{}'VTI_{LVOT})/VTI_{PrMV}$, where CSA_{LVOT} is the cross-sectional area of the LVOT, which was obtained from diameter measurement just close to the aortic valve from the parasternal long-axis view. The VTI_{LVOT} is the velocity–time integral obtained by pulsed wave doppler in the LVOT and VTI_{PrMV} is the velocity–time integral obtained by continues wave doppler through the mitral prosthesis.

The mitral valve effective orifice area (MEOA) was then indexed to the BSA. The Mosteller formula was used to calculate BSA. The iEOA of the mitral valve was calculated as MEOAI = MEOA/BSA.

PVM was present if the iEOA was less than or equal to 1.2 cm^2/m^2. It was considered moderate if greater than 0.9 and less than or equal to 1.2 cm^2/m^2 and severe if less than or equal to 0.9 cm^2/m^2.

Statistical analysis

Data were collected, revised, coded, and entered into the Statistical Package for the Social Sciences (IBM SPSS) version 20 (SPSS incorporation, Chicago, USA). Qualitative data were presented as number and percentages, while quantitative data with a parametric distribution were presented as mean and SDs. The comparison between two groups with qualitative data was performed using the χ^2 test. Comparisons between two independent groups of quantitative data with a parametric distribution were performed using an independent *t*-test.

Results

Preoperative data

The mean age of the patients in the biological group was 66.32 ± 3.33, while it was 59.68 ± 2.92 in the mechanical group. There were nine female patients (36%) in the biological group and seven female patients (28%) in the mechanical group.

BSA, preoperative New York Heart Association (NYHA) class, and preoperative CCS grade were similar between the two groups; also, the number of diseased vessels was similar, without any significant difference between the two groups. Detailed patient demographics are listed in Table 1.

Operative and postoperative data

Total revascularization was performed in all patients in both groups, with a mean number of grafts of 2.8 ± 0.5 in the biological group and 3.08 ± 0.4 in the mechanical group.

In the biological group, two (8%) patients received a Carpentier–Edwards Perimount Pericardial bioprosthesis, size 25 mm, 20 (80%) patients received size 27 mm, and three (12%) received size 29 mm. In the mechanical group, a mechanical St Jude Medical valve size 25 mm was used in two (8%) patients, size 27 mm in 19 (76%) patients, and size 29 mm in four (16%) patients.

The cardiopulmonary bypass time was 160.88 ± 7.59 min in the biological group and 158.56 ± 6.12 min in the mechanical group, without a significant difference between the two groups, while the aortic cross-clamp time was significantly higher in the biological group, 134.4 ± 8.44 min, in comparison with the mechanical group, 122.04 ± 7.57 min, with a *P* value of less than 0.001.

The duration of mechanical ventilation and total hospital stay were almost similar, with no significant difference between the two groups. The ICU stay was 110.4 ± 21.82 h. in the biological group and 97.84 ± 19.61 h. in the mechanical group, with a *P* value of 0.035 representing a longer ICU stay in the biological group.

The use of postoperative cardiac support was similar between the two groups including the use of IABP, which was used in one patient (4%) in the biological group and two patients (8%) in the mechanical group.

Postoperative NYHA class and CCS grade showed no significant difference between the two groups; also, postoperative complications were similar and showed no significant difference of medical relevance.

In the biological group, postoperative indexed EOA (cm^2/M^2) was greater than 1.2 cm^2/m^2 in five patients, greater than 0.9 and

Table 1 Patient demographics

	Bioprosthetic group	Mechanical group	*P*
	Total (*n*=25)	Total (*n*=25)	
Female sex	9 (36)	7 (28)	0.225
Age in years	66.32±3.33	59.68±2.92	< 0.001*
BSA (M^2)	2.01±0.13	2.07±0.14	0.122
Hypertension	17 (68)	19 (76)	0.528
Diabetes	18 (72)	20 (80)	0.507
Dyslipidemia	18 (72)	20 (80)	0.507
Pre-LVEDD (cm)	5.50±0.33	5.66±0.40	0.129
Pre-LVESD (cm)	3.92±0.47	4.08±0.55	0.274
Pre-EF (%)	55.56±6.25	54.48±6.71	0.558
Degree of MR			
3	3 (12)	5 (20)	0.440
4	22 (88)	20 (80)	
Preoperative NYHA class			
II	5 (20)	8 (32)	
III	18 (72)	15 (60)	0.965
IV	2 (8)	2 (8)	
Preoperative CCS grade			
II	3 (12)	2 (8)	
III	21 (84)	20 (80)	0.542
IV	1 (4)	3 (12)	
Coronary lesions			
LM	8 (32)	8 (32)	
LAD	21 (84)	22 (88)	
D	7 (28)	8 (32)	
LCX	7 (28)	9 (36)	0.952
OM	16 (64)	14 (56)	
RCA	14 (56)	13 (52)	
PDA	6 (24)	10 (40)	
PL	4 (16)	2 (8)	
Number of diseased vessels	3.56±0.50	3.6±0.50	0.778

Values are presented as numbers (%) or mean±SD. BSA, body surface area; CCS, Canadian cardiovascular society; D, diagonal artery; EF, ejection fraction; LAD, left anterior descending artery; LCX, left circumflex artery; LM, left main stem; LVEDD, left ventricular end diastolic diameter; LVESD, left ventricular end systolic diameter; MR, mitral regurgitation; NYHA, New York Heart Association; OM, obtuse marginal artery; PDA, posterior descending artery; PL, posterolateral artery; RCA, right coronary artery. *Significant *P*

less than or equal to 1.2 cm^2/m^2 in 16 patients, and less than or equal to 0.9 cm^2/m^2 in three patients. In the mechanical group, 13 patients had indexed EOA (cm^2/M^2) greater than1.2 cm^2/m^2, nine patients had indexed EOA (cm^2/M^2) greater than 0.9 and less than or equal to 1.2 cm^2/m^2, and two patients had indexed EOA less than or equal to 0.9 cm^2/m^2. The mean indexed EOA (cm^2/M^2) was 1.10 ± 0.16 and 1.14 ± 0.14, respectively, without a significant difference between the two groups.

In terms of 30-day mortality, one patient (4%) died in each group, with no significant difference between the two groups. Other operative and postoperative details are listed in Table 2.

Discussion

In 1978, Rahimtoola was the first to describe PVM as a severe complication of MVR [15].

Various studies have suggested that PVM after MVR may be associated with poor clinical outcomes resembling those of mitral valve stenosis with the subsequent development of late tricuspid regurgitation and persistent pulmonary hypertension [12,16,17]. On the contrary, some studies have reported that PVM has no influence on survival after MVR [18,19].

Despite the presence of huge variations in the rates of PVM, most studies have reported an incidence of 20–70% in mitral position [12,16,20–23] However, most of these studies were carried out on rheumatic patients, who are considered more vulnerable to such complications, especially patients with severe mitral stenosis and fibrosis.

In a retrospective study Akuffu and colleagues investigated 1067 patients who underwent isolated or concomitant MVR in east China for the incidence of PVM. They included patients older than 18 years of age and this was similar to our age group (18–80 years); we excluded younger patients who may have congenital coronary artery lesions and ischemic

Table 2 Operative and postoperative outcomes

	Bioprosthetic group	Mechanical group	*P*
	Total (*n*=25)	Total (*n*=25)	
Number of grafts	2.8±0.5	3.08±0.4	0.033
Size of the replaced valve			
25	2 (8)	2 (8)	
27	20 (80)	19 (76)	0.919
29	3 (12)	4 (16)	
CBP time (min)	160.88±7.59	158.56±6.12	0.169
ACC time (min)	134.4±8.44	122.04±7.57	< 0.001*
Re exploration	1 (4)	2 (8)	0.551
Mediastinal drainage (ml)	580.0±204.12	579.16±266.99	0.990
Duration of mechanical ventilation (h)	20.28±26.22	29.44±30.25	0.173
ICU stay (h)	110.4±21.82	97.84±19.61	0.035*
Total hospital stays (days)	9.0±4.34	11.37±4.53	0.065
Postoperative cardiac support			
Adrenaline	25 (100)	25 (100)	1.000
Levosimendan	3 (12)	4 (16)	0.683
IABP insertion	1 (4)	2 (8)	0.551
Superficial wound infection	2 (8)	1 (4)	0.551
Cerebrovascular events	1 (4)	1 (4)	1.000
MI	1 (4)	2 (8)	0.551
Pneumonia	2 (8)	1 (4)	0.551
Postoperative CCS grade			
I	21 (87.5)	19 (79.17)	0.438
II	3 (12.5)	5 (20.83)	
Postoperative NYHA class			
I	19 (79.17)	15 (62.5)	0.204
II	5 (20.83)	9 (37.5)	
Postoperative LVEDD (cm)	5.52±0.32	5.62±0.34	0.299
Postoperative LVESD (cm)	3.97±0.47	4.09±0.48	0.386
Postoperative EF (%)	52.95±6.86	51.45±6.42	0.438
EOA (cm^2)	2.26±0.24	2.37±0.20	0.091
Maximum pressure gradient (mmHg)	12.83±2.71	12.66±3.03	0.838
Mean pressure gradient (mmHg)	6.29±1.48	6.2±1.6	0.840
Indexed EOA (cm^2/m^2)	1.10±0.16	1.14±0.14	0.361
No mismatch (>1.2 cm^2/m^2)	5 (20.83)	13 (54.17)	
Moderate mismatch (0.9-1.2 cm^2/m^2)	16 (66.67)	9 (37.5)	0.057*
Severe mismatch (<0.9 cm^2/m^2)	3 (12.5)	2 (8.33)	
30-days mortality	1 (4)	1 (4)	1.000

Values are presented as numbers (%) or mean±SD. ACC, aortic cross-clamp; CCS, Canadian cardiovascular society; CPB, cardiopulmonary bypass; EF, ejection fraction; EOA, effective orifice area. IABP, intra-aortic balloon pump; ICU, intensive care unit; LVEDD , left ventricular end diastolic diameter; LVESD, left ventricular end systolic diameter; MI, Myocardial infection; NYHA, New York Heart Association. *Significant P value.

mitral regurgitation. They also concluded that biological valves carry are more likely to lead to development of postoperative PVM in comparison with mechanical valves, without any significant impact on outcomes postoperatively. This was compatible with our results and consistent with our conclusion [24].

However, our findings differ from that of Pasquale Totaro and associates, who studied 92 patients who underwent MVR and received a Carpentier–Edwards stented bioprosthesis. They reported satisfactory postoperative hemodynamic performance in all patients despite the fact that 45% of patients were ischemic mitral patients. This may be attributed to the lack of total leaflet preservation during MVR in their study as they attempted to preserve only the posterior leaflet if possible [25].

In another study, Fino and colleagues studied exercise hemodynamic and functional capacity after MVR in patients with ischemic mitral regurgitation. They analyzed 86 consecutive patients with ischemic mitral regurgitation who underwent either mechanical or biological MVR together with total revascularization. This was very similar to our study in terms of comparing the outcomes of two types of valves in treating ischemic mitral regurgitation patients [26].

Although our study had a smaller patient population, we arrived at the same conclusion, preferring the mechanical valve to treat ischemic mitral patients, rendering the bioprosthesis with worse hemodynamic performance postoperatively. Undoubtedly, the small patient population is considered one of the limiting factors of our study [26].

The surgical technique was similar to total chordal preservation of the whole subvalvular apparatus during MVR. The only difference was in the positioning of the mechanical valve group during insertion; they placed their valves in the anti-anatomical position, while we kept our valves in the anatomical position. Moreover, they did not mention the type of myocardial protection used during their study [26].

The postoperative iEOA was larger in the mechanical group, 1.30 ± 0.2 cm^2/m^2, compared with the biological group, 1.19 ± 0.3 cm^2/m^2. This is similar to our postoperative echocardiographic findings, where the iEOA of the mechanical group was 1.14 ± 0.14 cm^2/m^2 compared with an iEOA of 1.10 ± 0.16 cm^2/m^2 in the biological group [26].

In terms of the postoperative incidence of PVM, they reported that 22% of the patients had moderate mismatch and 9% of the patients had severe mismatch in the mechanical group and 49% of the patients had moderate mismatch and 12% of the patients had severe mismatch in the biological group [26].

This is consistent with our results, with a moderate PVM found in 37.5% of the patients and severe mismatch in 8.33% of the patients in the mechanical group and 66.67% of the patients having moderate mismatch and 12.5% of patients having severe mismatch in the biological group [26].

Interestingly, our results showed that cross-clamp times were significantly longer in the biological group, 134.4 ± 8.44 min, in comparison with the mechanical group, 122.04 ± 7.57 min, with a P value of less than 0.001. This may be attributed to the time consumed during washing of the biological valve with normal saline before insertion. Moreover, the presence of the valve handle throughout the insertion process renders this process more complex than inserting a mechanical valve, especially in patients with a small left atrium.

This was not in agreement with the results of Akuffu and colleagues They investigated the incidence of PVM of the mitral position in their center from 2013 to 2015 and found that the cross-clamp time was shorter only in patients with postoperative PVM. They attributed this to the fact that less time was spent suturing the mitral prosthesis due to the smaller mitral annulus diameter of the PVM patients [24].

Furthermore, Magne *et al*.[21] studied the impact of prosthesis–patient mismatch on survival after MVR, they concluded that severe PVM is considered an independent predictor of mortality following MVR.

In our study, although there was no significant difference between the two groups in the NYHA class, we found that patients with significant PVM had higher grades of NYHA class during the immediate postoperative period. Of course, the short postoperative follow-up period is considered to be one of the limiting factors of the present study. Hence, longer periods of follow-up are needed to clarify the long-term impact of this complication on patient survival.

Finally, our 30-day mortality was identical in both groups, with one patient (4%) dying from each group, without a significant difference between the two groups. This result is better than most of the international studies such as the study of Acker *et al*. [27]. They studied mitral valve repair versus replacement for severe ischemic mitral regurgitation and reported a mortality rate of 17.6% in the replacement group of their study.

Conclusion

We concluded that mechanical valves have better postoperative echocardiographic parameters with lower risk to inducing PVM in ischemic mitral patients undergoing total revascularization together with chordal-sparing MVR when compared to biological valves.

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Conflicts of interest

There are no conflicts of interest.

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