Journal of Artificial Organs (2019) 22:91–97
https://doi.org/10.1007/s10047-018-1076-8

ORIGINAL ARTICLE

Artificial Heart (Clinical)

Effect of concomitant mitral valve procedures for severe mitral regurgitation during left ventricular assist device implantation

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Received: 14 August 2018 / Accepted: 15 October 2018 / Published online: 25 October 2018

Abstract

The effect of performing a concomitant mitral valve procedure (MVP) during continuous-flow left ventricular assist device (CF-LVAD) implantation has been reported for patients with moderate-to-severe mitral regurgitation (MR), but moderate MR is less of a clinical concern for CF-LVAD patients. There is a paucity of reports focusing on patients with severe MR. Thus, the purpose of this study was to analyze the effect of performing a concomitant MVP during CF-LVAD implantation in patients with severe preoperative MR. Between November 2003 and March 2016, 526 patients underwent primary implantation of a CF-LVAD at our center. Patients with severe MR who underwent a concomitant MVP were compared to those who did not in regard to overall survival, perioperative complications, postoperative echocardiography data, bridge-to-transplantation success, and CF-LVAD explantation. Of the 108 patients with severe MR, 26 underwent a concomitant MVP and 82 did not. These groups showed no difference in survival ($p=0.61$). Additionally, the two groups had similar rates of postoperative right heart failure ($p=0.69$) and readmissions ($p=0.42$). The 24-month follow-up echocardiography results were also similar. Furthermore, the groups showed no difference in bridge-to-cardiac transplantation success (30.0% vs 25.0%, $p=0.80$) or CF-LVAD explantation rates (0.0% vs 0.0%. $p=1.0$). Our findings suggest that patients with severe MR who undergo a MVP during CF-LVAD implantation do not have superior outcomes to those who do not. However, assessments of other outcomes may show some benefits to performing concomitant MVPs.

Keywords Heart failure · Mechanical circulatory support · Left ventricular assist device · Mitral regurgitation

Introduction

The use of continuous-flow left ventricular assist devices (CF-LVADs) to treat patients with advanced chronic heart failure has grown exponentially over the past decade [1, 2]. Although these patients often have a dilated left ventricle and significant functional mitral valve regurgitation (MR) [3], the decision of whether to perform a concomitant mitral valve procedure (MVP) during CF-LVAD implantation remains controversial. In patients with dilated cardiomyopathy that leads to severe MR, the valve leaflets and chordae are structurally normal. The valve dysfunction is due to alterations in the shape and dimensions of the ventricle, along with the displacement of one or both papillary muscles. In many of these patients, MR is significantly decreased after CF-LVAD implantation as the result of offloading the left ventricle [4–6]. The current guidelines from the International Society for Heart and Lung Transplantation (ISHLT)

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do not recommend routine surgical procedures for severe MR [2]. Despite these guidelines, several studies have suggested that there are advantages to performing concomitant MVPs [3–5]. However, one limitation of most of these studies was that the study cohort included patients with moderate MR. In many patients with moderate MR, CF-LVAD implantation alone may sufficiently reduce MR through the physiologic effect on left ventricular unloading. Therefore, moderate MR is less of a clinical concern when implanting a CF-LVAD, and inclusion of patients with moderate MR in a study may bias the results. To more precisely determine the effect of performing a concomitant MVP during CF-LVAD implantation, we focused our study on the patients with severe preoperative MR. We compared the patients with severe preoperative MR who underwent a concomitant MVP during CF-LVAD implantation to those who did not in regard to long-term survival, postoperative transthoracic echocardiography findings, rates of postoperative complications, success of bridge to transplantation, and rates of CF-LVAD explantation due to LV recovery.

Methods

This was a single-center, retrospective study. Between November 2003 and March 2016, 526 patients with end-stage heart failure underwent primary implantation of a HeartMate II LVAD ($n=403$) (Thoratec Corp., Pleasanton, CA) or a HVAD ($n=123$) (HeartWare International Inc., Framingham, MA) at our center. At the time of implantation, 108 of these patients had severe MR (the etiology for all of which was functional MR due to dilated cardiomyopathy), and 209 had moderate MR. Our study cohort comprised the 108 patients with severe MR, 26 of whom underwent a concomitant MVP during CF-LVAD implantation. The MVPs performed included Alfieri stitch ($n=23$), mitral valve annuloplasty ($n=2$), and mitral valve replacement ($n=1$). The Alfieri stitch procedures were performed on a beating heart through the left ventricle core using a pledgeted suture. Patient data, including demographics, preoperative characteristics, postoperative complications, echocardiography findings, and overall survival, were collected retrospectively from the Texas Heart Institute (THI)/Baylor College of Medicine clinical LVAD database. Approval to conduct, this review was obtained from our institutional review board.

Postoperative complications were defined as follows. Readmission was defined as return to the hospital within 30 days of discharge from the index admission. Neurological dysfunction was defined as a new neurological deficit with abnormal neuroimaging findings. A neurologist examined the images and classified each case of neurological dysfunction as either ischemic or hemorrhagic. Patients were considered to have gastrointestinal bleeding if they had 1 or more of the following findings: positive stool guaiac test, hematemesis, melena, active bleeding at the time of endoscopy or colonoscopy, or blood within the stomach at endoscopy or colonoscopy. Patients were considered to have an infection if they had one or more of the following symptoms: driveline infection that required surgical treatment, pump infection that required surgical treatment, or sepsis (positive blood cultures). Acute kidney injury was defined using the Risk, Injury, Failure, Loss of kidney function, and End-stage kidney disease (RIFLE) classification system. Right heart failure (RHF) was defined according to the following criteria from the International Mechanically Assisted Circulatory Support (INTERMACS) Registry: (1) need for a right ventricular assist device, inotrope support, or a pulmonary vasodilator (eg, prostaglandin E or inhaled nitric oxide) for a duration of >1 week at any time after LVAD implantation and (2) meeting two of the four following clinical criteria: (1) central venous pressure >18 mmHg or mean right atrial pressure >18 mmHg, (2) cardiac index <2.3 L/min/m^2, (3) ascites or evidence of moderate or worse peripheral edema, or (4) evidence of elevated central venous pressure, as shown by echocardiography (dilated inferior vena cava without collapse) or physical examination (signs of increased jugular venous pressure). Mitral regurgitation was evaluated preoperatively and postoperatively using the official transthoracic echocardiography protocol at our institution. CF-LVAD pump speed (revolutions per minute) was optimized post-implantation by a heart failure cardiologist using a transthoracic echocardiography ramp study.

Statistical analyses were performed with SAS 9.2 software (SAS Institute Inc., Cary, NC). Univariate analysis was used to compare the demographics, operative characteristics, postoperative complication rates, transthoracic echocardiography findings [residual MR, tricuspid valve regurgitation (TR), and LV end-diastolic diameter (LVEDD)], bridging success in bridge-to-transplantation patients, and survival of the patients who underwent a MVP and those who did not. Continuous variables were reported as mean and standard deviation, and were compared with analysis of variance. Categorical variables were reported as number and percentage, and were compared with the chi-square test. The Kaplan–Meier method was used to estimate survival, and a log-rank test was performed to compare overall survival among the patients who did and did not undergo a MVP.

Results

Of the 108 patients who had severe MR at the time of CF-LVAD implantation, 26 underwent a concomitant MVP ($n=2$ in 2005; $n=1$ in 2006; $n=1$ in 2007; $n=2$ in 2009; $n=5$ in 2010; $n=10$ in 2011; $n=2$ in 2012, $n=1$ in 2013; and $n=2$ in 2014). A comparison of the demographic and

perioperative characteristics of the patients who underwent a MVP and those who did not showed that the patients who did undergo a MVP were more likely to receive a HM-II rather than an HVAD ($p < 0.01$) (Table 1). In addition, the MVP group had a lower preoperative white blood cell count ($p = 0.02$).

Kaplan–Meier analysis revealed no significant difference in overall survival after CF-LVAD implantation for the patients who underwent a MVP and those who did not ($p = 0.61$) (Fig. 1).

The patients who did and did not undergo a concomitant MVP during CF-LVAD implantation showed no significant difference in events per patient-year (EPPY) for the postoperative complications assessed (Table 2).

Echocardiography was performed preoperatively, postoperatively, and at 1, 3, 12, and 24 months after CF-LVAD implantation to assess the changes in residual MR, TR, and LVEDD (Table 3). Overall, MR severity decreased dramatically after CF-LVAD implantation in both the patients who underwent a concomitant MVP and those who did not. During the postoperative period (< 2 weeks), the percentage of patients with severe MR decreased to 0.0% in the MVP group and to 5.2% in the non-MVP group, and the two groups showed no difference in the proportion of patients with severe MR ($p = 0.27$) or moderate MR ($p = 0.71$). During the 24-month follow-up period, the two groups showed no significant difference in MR severity. Both the MVP and non-MVP groups showed a gradual decrease in TR severity and a substantial decrease in LVEDD after CF-LVAD implantation, but there was no significant difference between the groups for these parameters during the 24-month follow-up period.

Of the 108 patients with severe MR who underwent CF-LVAD implantation, 58 were indicated as bridge-to-transplantation patients. In this subcohort, heart transplantation was later successfully performed in 3 of 10 patients (30%) who underwent a concomitant MVP during CF-LVAD implantation and in 12 of 48 patients (25%) who did not. A statistical comparison of the bridging success rates of those who underwent a MVP and those who did not showed no difference between the two groups ($p = 0.80$).

None of the patients in the MVP group or in the non-MVP group underwent CF-LVAD explantation due to LV recovery ($p = 1.0$).

Discussion

In this study, we examined whether there was a clinical benefit for patients with severe MR to undergo a concomitant MVP at the time of CF-LVAD implantation for heart failure. Patients who underwent a MVP and those who did not showed no significant difference in postoperative survival, complication rates, or echocardiography findings for TR or LVEDD. In addition, the groups showed no significant difference in bridging success in patients who received the CF-LVAD as a bridge to heart transplantation. None of the patients in either group had the CF-LVAD explanted due to recovery of LV function.

Although CF-LVAD recipients often have moderate-to-severe MR preoperatively, theoretically, if the CF-LVAD is set to the optimal speed, it can unload the volume and pressure of the left ventricle, which could lead to a decrease in LV size and indirectly correct a coexisting mitral valve lesion [4–6]. Therefore, performing a concomitant MVP at the time of CF-LVAD implantation remains controversial.

The 2013 ISHLT guidelines for mechanical circulatory support state that surgical repair or replacement of the mitral valve for MR is not routinely required, unless there is an expectation of ventricular recovery (Class IIb recommendation, Level of evidence C); furthermore, they state that performing a routine MVP for severe MR is not recommended for patients undergoing LVAD implantation (Class III recommendation, Level of evidence C) [7]. Nevertheless, there are multiple reports describing cases in which a concomitant MVP was performed during CF-LVAD implantation in patients with MR, but it is still unknown whether these MVPs are beneficial. Stulak et al. [3] reported that patients with moderate-to-severe MR before CF-LVAD implantation had better survival outcomes than patients with less-than-moderate MR, suggesting that there may be no benefit to addressing significant MR during CF-LVAD implantation. Similarly, Goodwin et al. [8] reported that moderate-to-severe preoperative MR resolved in patients who underwent CF-LVAD implantation. In contrast, Tanaka et al. [9] found that patients who underwent surgical correction of moderate-to-severe MR during CF-LVAD implantation had better midterm hemodynamic and survival outcomes than patients who did not undergo surgical correction. Kitada et al. [10] reported that preoperative posterior displacement of the mitral leaflets was associated with persistent MR after CF-LVAD implantation in their patients, suggesting that certain morphologic features may make MR refractory to simple volume reduction of the left ventricle. Many of these previous studies included patients with moderate MR in their cohort. However, we believe moderate MR and severe MR populations should be analyzed separately because moderate MR could be decreased sufficiently by unloading the left ventricle with a CF-LVAD, making it much less of a clinical concern than treating severe preoperative MR.

In our database, we had records for 317 patients with moderate-to-severe preoperative MR. To more precisely analyze the effects of CF-LVAD implantation on MR, we only included in our study the 108 patients with severe MR. Our data showed no significant difference in long-term survival

Table 1 Characteristics of the patients with severe mitral valve regurgitation who underwent continuous-flow left ventricular assist device implantation

Variables	Full cohort ($n=108$)	No MVP ($n=82$)	MVP ($n=26$)	p value
Age (years)	54.1 ± 14.0	54.3 ± 14.8	53.8 ± 11.0	0.87
Female	30 (27.8)	23 (28.0)	7 (26.9)	0.91
BMI (kg/m^2)	27.0 ± 6.3	26.5 ± 6.0	28.7 ± 6.9	0.14
BSA (m^2)	2.0 ± 0.2	1.9 ± 0.2	2.0 ± 0.3	0.29
Ischemic cardiomyopathy	43 (39.8)	30 (36.6)	13 (50)	0.24
Hypertension	57 (52.8)	43 (52.4)	14 (53.8)	0.90
Diabetes mellitus	19 (35.2)	29 (35.3)	9 (34.6)	0.94
Smoking history	44 (40.7)	32 (39.0)	12 (46.1)	0.58
COPD	15 (13.9)	10 (12.2)	5 (19.2)	0.37
Previous cardiac surgery	37 (34.3)	28 (34.1)	9 (34.6)	0.96
Device type				
INTERMACS profile 1	14 (13.0)	12 (14.6)	2 (7.7)	0.36
INTERMACS profile 2	44 (40.7)	34 (41.5)	10 (38.5)	0.79
INTERMACS profile 3	33 (30.6)	23 (28.0)	10 (38.5)	0.31
INTERMACS profile 4	14 (13.0)	11 (13.4)	3 (11.5)	0.80
HeartMate II	79 (73.1)	54 (65.9)	25 (96.1)	< 0.01
HeartWare HVAD	29 (26.9)	28 (34.1)	1 (3.8)	< 0.01
Laboratory				
Hemoglobin (g/dL)	11.7 ± 2.1	11.7 ± 2.1	11.5 ± 2.0	0.67
WBC (1000/mm^3)	9.6 ± 6.5	10.2 ± 7.2	7.8 ± 2.8	0.02
Platelets (1000/mm^3)	202.6 ± 89.6	203.1 ± 95.4	201.1 ± 69.6	0.91
Sodium (mEq/L)	134.6 ± 5.0	134.7 ± 4.8	134.1 ± 5.4	0.59
Creatinine (mg/dL)	1.5 ± 0.7	1.4 ± 0.7	1.5 ± 0.9	0.77
BUN (mg/dL)	31.7 ± 17.0	32.7 ± 17.9	28.2 ± 13.2	0.18
AST (U/L)	72.3 ± 135.8	67.5 ± 118.7	87.5 ± 181.5	0.60
ALT (U/L)	89.2 ± 224.5	86.3 ± 224.4	98.4 ± 229.0	0.81
Total bilirubin (mg/dL)	1.8 ± 2.3	1.9 ± 2.5	1.6 ± 1.2	0.32
Albumin (g/dL)	3.6 ± 0.6	3.6 ± 0.6	3.6 ± 0.5	0.96
INR	1.3 ± 0.3	1.3 ± 0.3	1.3 ± 0.4	0.61
Echocardiogram				
LVEF (%)	21.4 ± 3.5	21.4 ± 3.8	21.3 ± 2.2	0.91
LVEDD (cm)	7.0 ± 1.1	6.9 ± 1.0	7.4 ± 1.3	0.12
Severe TR	30 (27.8)	25 (30.5)	5 (19.2)	0.26
Severe MR	108 (100)	82 (100)	26 (100)	1.00
Severe AR	2 (1.9)	2 (2.4)	0 (0.0)	0.42
Right heart catheterization				
CI (L/min/m^2)	1.8 ± 0.5	1.8 ± 0.5	1.9 ± 0.6	0.50
CVP (mmHg)	13.2 ± 8.3	12.1 ± 7.3	15.4 ± 10.0	0.22
PAP (mmHg)	37.1 ± 10.5	36.2 ± 9.1	40.0 ± 13.9	0.25
PCWP (mmHg)	26.6 ± 10.1	25.7 ± 9.7	29.9 ± 11.3	0.14
Operative variables				
CPB use	104 (96.3)	78 (95.1)	26 (100.0)	0.25
RVAD use	13 (12.0)	10 (12.2)	3 (11.6)	0.93

Continuous data shown as mean ± standard deviation. Categorical data shown as No. (%)

BMI body mass index, *BSA* body surface area, *COPD* chronic obstructive pulmonary disease, *WBC* white blood cell, *BUN* blood urea nitrogen, *AST* aspartate aminotransferase, *ALT* alanine aminotransferase, *INR* international normalized ratio, *LVEF* left ventricular ejection fraction, *LVEDD* left ventricular end-diastolic diameter, *TR* tricuspid valve regurgitation, *MR* mitral valve regurgitation, *AR* aortic valve regurgitation, *CI* cardiac index, *CVP* central venous pressure, *PAP* pulmonary artery pressure, *PCWP* pulmonary capillary wedge pressure, *CPB* cardiopulmonary bypass, *RVAD* right ventricular assist device

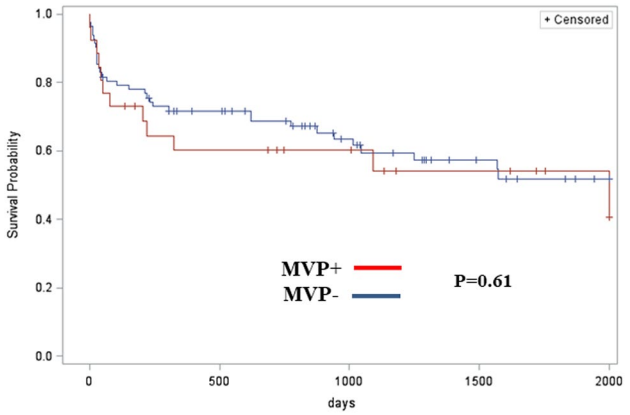

Fig. 1 Survival curves for the patients who underwent a concomitant mitral valve procedure (MVP+) during CF-LVAD implantation and those who did not (MVP−)

between the patients who underwent a MVP at the time of CF-LVAD implantation and those who did not.

Patients who have undergone CF-LVAD implantation have shown significant decreases in LV diameter, annulus size, and severity of MR at 1 month after implantation due to ventricular unloading [4]. Because of these effects, the current ISHLT guidelines do not recommend performing routine MVPs for MR during CF-LVAD implantation.

Recent reports have shown that residual MR after CF-LVAD implantation can have detrimental effects on survival [11] and lead to RHF [12]. To determine whether performing a concomitant MVP reduces residual MR after CF-LVAD implantation, we compared the echocardiography results of the MVP and non-MVP groups. The indications for performing echocardiography were determined by the individual cardiologists during the study period. At 24 months after CF-LVAD implantation, the non-MVP group did not have inferior results, compared to the MVP group. Additionally, our study groups showed no significant difference in the overall survival or the incidence of postoperative RHF or readmission. These findings suggest that concomitant MVPs do not further reduce severe residual MR after CF-LVAD implantation or its associated effects.

It is currently unknown whether performing a MVP during CF-LVAD implantation can improve the success rate of bridge to heart transplantation or the chance for future CF-LVAD explantation. Taghavi et al. [13] have suggested that performing a concomitant MVP during CF-LVAD implantation could permit certain patients to become eligible for heart transplantation. However, Atluri et al. [14] concluded that performing CF-LVAD implantation alone may be sufficient to improve pulmonary hypertension, right ventricular function, and TR, key components in the assessment of heart transplantation candidacy. Yet, in a case reported by Ammirati et al. [15], only limited changes were seen in pulmonary hypertension after CF-LVAD implantation. Consistent with the findings of Atluri et al., our real-world experience showed that there was no significant difference in bridge-to-transplantation success between patients who underwent a MVP and those who did not, suggesting that MVPs may not be necessary. Our study groups also showed no significant difference in the rates of CF-LVAD explantation due to LV recovery.

As mentioned above, previous studies have suggested that there are advantages to performing a concomitant MVP; however, no studies have shown that concomitant MVPs improve long-term survival, which may be one reason why concomitant MVPs remain a controversial topic. In future studies, it may be beneficial to assess the effects of MVPs on daily cardiac output changes. Because one considerable limitation of the current CF-LVADs is that they are stable at a fixed rpm and do not respond to physiological changes in hemodynamics, it may be easier to manage patients who have fewer daily changes in cardiac output. Future studies

Table 2 Incidence of postoperative complications in patients with severe mitral valve regurgitation

Events	No MVP ($n=82$) (total support time = 145.5 years)			MVP ($n=26$) (total support time = 42.0 years)			p value
	Patients	Events	EPPY	Patients	Events	EPPY	
Early readmission	13	23	0.16	4	4	0.10	0.42
Neurological dysfunction	18	22	0.15	7	9	0.21	0.58
Ischemic	10	11	0.08	4	4	0.10	0.81
Hemorrhagic	11	11	0.08	5	5	0.12	0.51
Gastrointestinal bleeding	26	37	0.25	8	10	0.24	0.67
Acute kidney injury	12	–	–	3	–	–	0.67
Right heart failure	32	–	–	9	–	–	0.69
Early right heart failure	18	–	–	8	–	–	0.40
Late right heart failure	15	–	–	3	–	–	0.49

P values represent a comparison of EPPY

MVP mitral valve procedure, *EPPY* events per patient-year

Table 3 Preoperative and follow-up transthoracic echocardiography results

	MR			TR			LVEDD		
	No MVP	MVP	*p* value	No MVP	MVP	*p* value	No MVP	MVP	*p* value
Preoperative	82	26		82	26		6.9 ± 1.0	7.4 ± 1.3	0.11
Trace	0 (0.0)	0 (0.0)	1.00	4 (4.9)	1 (3.8)	0.83			
Mild	0 (0.0)	0 (0.0)	1.00	19 (23.2)	8 (30.8)	0.44			
Moderate	0 (0.0)	0 (0.0)	1.00	34 (41.5)	12 (46.2)	0.67			
Severe	82 (100.0)	26 (100.0)	1.00	25 (30.5)	5 (19.2)	0.26			
Postoperative (< 2 weeks)	77	22		77	22		5.8 ± 1.2	5.6 ± 1.8	0.55
Trace	23 (30.0)	7 (31.8)	0.86	22 (28.6)	8 (36.4)	0.48			
Mild	32 (41.6)	9 (40.9)	0.95	21 (27.3)	7 (31.8)	0.67			
Moderate	18 (23.4)	6 (27.3)	0.71	24 (29.3)	3 (13.6)	0.10			
Severe	4 (5.2)	0 (0.0)	0.27	10 (13.0)	4 (18.2)	0.53			
1 month	63	19		63	19		5.4 ± 1.3	5.5 ± 1.1	0.78
Trace	12 (19.0)	5 (26.3)	0.49	19 (30.2)	4 (21.1)	0.44			
Mild	27 (42.9)	8 (42.1)	0.95	19 (30.2)	9 (47.4)	0.17			
Moderate	19 (30.2)	6 (31.6)	0.91	17 (27.0)	6 (31.6)	0.70			
Severe	5 (7.9)	0 (0.0)	0.20	8 (12.7)	0 (0.0)	0.10			
3 months	42	14		42	14		5.8 ± 1.0	5.7 ± 1.0	0.77
Trace	7 (17.7)	3 (21.4)	0.69	10 (23.8)	3 (21.4)	0.86			
Mild	23 (54.8)	7 (50.0)	0.75	17 (40.5)	6 (42.9)	0.87			
Moderate	8 (19.0)	3 (21.4)	0.85	12 (28.6)	4 (28.6)	1.00			
Severe	4 (9.5)	1 (7.2)	0.78	3 (7.1)	1 (7.1)	1.00			
12 months	44	13		44	13		5.7 ± 0.9	5.5 ± 0.9	0.37
Trace	6 (13.7)	4 (30.8)	0.15	12 (27.3)	6 (46.2)	0.20			
Mild	21 (47.7)	4 (30.8)	0.28	19 (43.2)	4 (30.8)	0.42			
Moderate	14 (31.8)	4 (30.8)	0.94	8 (18,2)	2 (15.4)	0.82			
Severe	3 (6,8)	1 (7.7)	0.91	5 (11.4)	1 (7.7)	0.70			
24 months	42	11		42	11		5.7 ± 1.0	5.0 ± 1.1	0.11
Trace	13 (31.0)	7 (63.6)	0.05	14 (33.3)	4 (36.4)	0.85			
Mild	18 (42.9)	2 (18.2)	0.13	14 (33.3)	4 (36.4)	0.85			
Moderate	10 (23.8)	2 (18.2)	0.69	11 (26.2)	1 (9.1)	0.23			
Severe	1 (2.4)	0 (0.0)	0.61	3 (7.1)	2 (18.2)	0.26			

MR mitral valve regurgitation, *TR* tricuspid valve regurgitation, *LVEDD* left ventricular end-diastolic diameter, *MVP* mitral valve procedure

should also evaluate the effects of concomitant MVPs on exercise tolerance and symptom severity. Finally, the introduction of pressure-sensing artificial intelligence in LVADs may change the MVP debate in the future.

Our study had several limitations. First, it was a single-center, retrospective study. Second, the surgical indications for severe MR were decided by the surgeons and were not consistent during the 13-year study period. Third, we did not have routine postoperative right heart catheterization data for the full study period. Fourth, 25 out of 26 patients who underwent an MVP received a HM-II. This could have potentially affected the results, although it would be more likely if the groups had significantly different outcomes. Fifth, we did not evaluate postoperative quality of life, so we could not exclude the possibility that concomitant MVPs may improve the quality of life of the patients. Quality of life could be assessed in future studies by analyzing scores from instruments such as the EuroQol or the Kansas City Cardiomyopathy Questionnaire, which are included in the INTERMACS database. Last, to address the clinical controversy more precisely, we focused on patients with severe MR and excluded from our analysis the patients with moderate MR, which limited the sample size.

In conclusion, for the outcomes we assessed, the results of the patients with severe MR who underwent a MVP during CF-LVAD implantation were not superior to those of the patients who did not undergo a concomitant MVP. However, future studies designed to assess different outcomes may be able to show a beneficial effect to performing a concomitant MVP during CF-LVAD implantation.

Acknowledgements The authors thank the Department of Biostatistics and Epidemiology at THI for helping us analyze our dataset and the Scientific Publications Department at THI for providing editorial support.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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