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Single-center five-year outcomes after interventional edge-to-edge repair of the mitral valve

Long-term outcome after MitraClip

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Abstract

Background: The MitraClip procedure was established as a therapeutic alternative to mitral valve surgery for symptomatic patients with severe mitral regurgitation (MR) at prohibitive surgical risk. In this study, the aim was to evaluate 5-year outcomes after MitraClip.

Methods: Consecutive patients undergoing the MitraClip system were prospectively included. All patients underwent clinical follow-up and transthoracic echocardiography.

Results: Two hundred sixty-five patients (age: 81.4 ± 8.1 years, 46.7% female, logistic EuroSCORE: 19.7 ± 16.7%) with symptomatic MR (60.5% secondary MR [sMR]). Although high procedural success of 91.3% was found, patients with primary MR (pMR) had a higher rate of procedural failure (sMR: 3.1%, pMR: 8.6%; p = 0.04). Five years after the MitraClip procedure, the majority of patients presented with reduced symptoms and improved functional capacity (functional NYHA class: p = 0.0001; 6 minutes walking test: p = 0.04). Sustained MR reduction (≤ grade 2) was found in 74% of patients, and right ventricular (RV) function was significantly increased (p = 0.03). Systolic pulmonary artery pressure (sPAP) was significantly reduced during follow-up only in sMR patients (p = 0.05, p = 0.3). Despite a pronounced clinical and echocardiographical amelioration and low interventional failure, 5-year mortality was significantly higher in patients with sMR (p = 0.05). The baseline level of creatinine (HR: 0.695), sPAP (HR: 0.96) and mean mitral valve gradient (MVG) (HR: 0.82) were found to be independent predictors for poor functional outcome and mortality.

Conclusions: Transcatheter mitral valve repair with the MitraClip system showed low complication rates and sustained MR reduction with improved RV function and sPAP 5 years after the procedure was found in all patients, predominantly in patients with sMR. Despite pronounced functional amelioration with low procedure failure, sMR patients had higher 5-year mortality and worse outcomes. Baseline creatinine, MVG, and sPAP were found to be independent predictors of poor functional outcomes and 5-year mortality.
Key words: MitraClip, transcatheter mitral valve repair, long-term outcomes, mitral regurgitation

INTRODUCTION

Mitral regurgitation (MR) is the second most frequent valve disease, with an increasing prevalence in elderly (> 75 years) patients, and is related to reduced functional capacity and impaired quality of life. Transcatheter mitral valve repair (TMVR) with the MitraClip system (Abbot Vascular, Inc., Santa Clara, California) is a therapeutic alternative to mitral valve (MV) surgery in symptomatic patients with moderate to severe MR at prohibitive surgical risk [1–3]. TMVR with the MitraClip procedure can be successfully performed in patients with secondary MR (sMR) and primary MR (pMR) if mitral valve (MV) anatomy is suitable [4]. Its clinical efficacy and safety have been proven in a large number of patients [4–6].

Acute procedural success rates are reported to be up to 99% and are followed by symptomatic improvement in about 80% of cases [7].

A high baseline systolic pulmonary artery pressure (sPAP), a mean elevated baseline mitral valve gradient (MVG), concomitant chronic kidney disease, anemia, peripheral artery disease, and tricuspid regurgitation have been previously reported as independent predictors of poor short-term outcomes after MitraClip procedures [8, 9, 11].

Although more than 70,000 patients have undergone MitraClip procedures to date, data on long-term outcome and durability of MR reduction are limited, and parameters predicting adverse long-term outcomes are not well defined.

The objectives of the present study were to evaluate functional and echocardiographic long-term outcomes 5 years subsequent to transcatheter edge-to-edge mitral valve repair with the MitraClip procedure in a single high-volume center and assess predictors of poor outcomes.

METHODS

Patients and endpoints

In this single-center study, consecutive patients undergoing TMVR with the MitraClip system were prospectively included. From February 2011 to February 2014 symptomatic (functional New York Heart Association [NYHA] class > II), and surgical high-risk patients with moderate-to-severe MR were evaluated for TMVR. All patients underwent TMVR following heart team judgement according to surgical high-risk (EuroSCORE II > 6%).

All patients underwent clinical and echocardiographic examinations before and 5 years after the MitraClip procedure.

According to Mitral Valve Academic Research Consortium (MVARC) definitions, the primary endpoint was defined as all-cause mortality [24]. The secondary endpoint was an improvement in functional capacity: functional NYHA class at follow-up was < II; 25% amelioration in exercise capacity (six-minute walking test [6MWT]).

The study was authorized by the local ethics committee and in accordance with the Declaration of Helsinki. All patients signed written, informed consent before study inclusion.

Echocardiography and follow-up assessment

Echocardiographic assessment before and after TMVR was done following current recommendations and guidelines which included a comprehensive echocardiography [4, 12]. The severity of MR was graded using the radius of proximal isovelocity surface area (PISA radius), effective regurgitant orifice area (EROA), as well as vena contracta (VC) width and regurgitant volume. EROA and regurgitation volume were calculated using the semi-quantitative PISA-method [13]. The echocardiographic studies were performed with a commercially available echocardiographic system (iE 33, Philips Medical Systems, Andover, Massachusetts) and echocardiography probes (X5-1, X7-2t) allowing acquisition of two- (2D) and three-dimensional (3D) data sets. sPAP was estimated from Doppler-based peak tricuspid regurgitation velocity according to use of modified Bernoulli equation (Delta-pressure: 4 × velocity) to approximate differences of pressure between right ventricle and atrium.

The echocardiographer who performed follow-up evaluation was blinded to procedural outcomes and patient characteristics. Trained personnel carried out clinical follow-up evaluation, unattended by the interventionalists or procedural echocardiographer.

Interventional edge-to-edge repair of MR

Procedural details of TMVR with the MitraClip system have been described previously [14, 15]. During the MitraClip procedure, acute changes of MR severity were assessed by intraprocedural transesophageal echocardiography as supposed by Foster and Wunderlich [16, 17]. Acute procedural success was defined as a reduction of MR by at least one grade having a residual MR < 2+. The number of clips required for procedural success was left to the discretion of the treating physician. Before clip release, echocardiography was performed to exclude clinically relevant MV stenosis (mean valve gradient [MVG] > 5 mmHg).

Statistical analysis

Normal distribution of continuous variables was examined using the Kolmogorov–Smirnov test. Continuous data were expressed as mean values ± standard deviation. The Student two-sample t-test or Man-Whitney-U test was performed to compare continuous variables. The Fisher exact test or χ^2 test was used to compare categorical data. Two-tailed p-values were considered to be significant if ranging below 0.05. Univariate analysis was performed to assess the impact of etiology of MR on clinical outcomes. The predictors of 5-year mortality were estimated employing the Cox proportional regression analysis. Survival and cumulative incidence of re-do in groups were compared using the log-rank test and were estimated with the Kaplan–Meier curve. The regression and receiver operating characteristic (ROC) analysis were performed to determine independent predictors with cut-off values of functional outcomes and mortality.

Statistics were performed using SPSS for Windows (PASW statistic, Version 20.0.0.0, SPSS Inc., Chicago, Illinois, USA).

RESULTS

Baseline data and procedural outcomes

Two hundred sixty-five consecutive, surgically high-risk patients (81.4 ± 8.1 years, 46.7% female, Logistic EuroSCORE: 19.7 ± 16.7%, 60.5% sMR) underwent TMVR with the MitraClip system, and the majority of patients (88%, n = 233) completed a 5-year follow-up including physical, laboratory and echocardiographical examinations. Patients lost to follow-up (n = 32) were contacted concerning life quality, complaints and hospitalization via telephone.

The baseline characteristics are presented in Table 1. There were no differences between the groups in demographic baseline characteristics. However, at baseline, patients with sMR presented worse functional capacity (6MWT: 253.3 ± 107.7 m vs. 267.1 ± 160.2 m; p = 0.2; NYHA > III 44.2% vs. 13.8%; p = 0.06) compared to patients with pMR.

The procedure was successfully performed in 242 (91.3%) patients with implantation of more than one clip in 32% of cases. Six MitraClip procedures were aborted due to relevant MV stenosis (MVG > 5 mmHg) after clip closure. Four of those patients were treated for pMR. 13 procedures were aborted due to irreducible MR.

Of note, there was no procedural-related mortality, ten patients (23.8%) had minor bleeding, and one patient had pericardial tamponade, which could be effectively treated with pericardiocentesis. All acute complications could be successfully managed before discharge. Overall, interventional failure rates were low, however, patients with pMR showed statistically significant higher interventional failure rates (pMR: 8.6%, sMR: 3.1%; p = 0.04).

During 5-year follow-up 3 patients underwent surgery for recurrent MR (pMR: 1,9%, sMR: 0.6%; p = 0.3), 16 patients required a second clipping (sMR: 6.8%, pMR: 4.7%, p = 0.5) and 4 patients were treated with additional catheter-based approaches (Carillon®, Cardiac Dimension, Kirkland, The USA; Cardioband®, Edwards Lifesciences, United Kingdom) due to recurrent severe MR and decompensated heart failure (sMR: 1.8%, pMR: 0.9%, p = 0.6) (**Supplementary materials, Suppl. Fig. 4**).

Echocardiographic measures at baseline and five-year follow-up

Concerning baseline echocardiographic characteristics, there were no significant differences between sMR and pMR in MR defining parameters and sPAP. Patients with sMR had larger baseline LV volumes (LVEDV: 165.3 ± 62.6 mL, 135.8 ± 49.2 mL; p = 0.03; LVESV: 106.4 ± 53.3 mL, 59.3 ± 36.6 mL; p = 0.001) and significantly impaired baseline left ventricle (LV) systolic function (38.3 ± 14.1%, 58.1 ± 15%; p = 0.0001). Patients with sMR showed impaired right ventricle (RV) function at baseline as well (TAPSE: 1.7 ± 0.4 cm, 2 ± 0.2 cm; p = 0.09) (Table 2).

At 5-year follow-up a sustained reduction of MR (MR ≤ 2) was found in 74% of patients (sMR: 77%, pMR: 71.5%; p = 0.9). There were no significant changes in LV volumes ($LVEDV_{sMR}$: 162.4 ± 56.7 mL, 154.5 ± 66.9 mL; p = 0.5; $LVEDV_{pMR}$: 127.8 ± 47.3 mL, 116.6 ± 26.4 mL; p = 0.3; $LVESV_{sMR}$: 105.2 ± 45.5 mL, 99.6 ± 57.8 mL; p = 0.6; $LVESV_{pMR}$: 56.2 ± 34.5 mL, 51.6 ± 20.2 mL; p = 0.5). Left ventricular ejection fraction (LVEF) was not significantly changed 5 years after the MitraClip procedure (EF_{sMR} 36.9 ± 12.6%, 38.7 ± 13.6%, p = 0.5; EF_{pMR} 58.1 ± 12.2%, 58.4 ± 9.7%, p = 0.9). In sMR patients, sPAP was significantly reduced at follow-up (50 ± 17.4 mmHg, 39.3 ± 17.3 mmHg, p = 0.05), however, not significantly in pMR patients (49.4 ± 18.3 mmHg; 41.6 ± 18.7 mmHg, p = 0.3) (Table 3). RV function increased significantly just in patients with sMR (1.7 ± 0.4 cm, 1.9 ± 0.4 cm, p = 0.03; 2 ± 0.2 cm, 2.1 ± 0.4 cm, p = 0.5). MVG significantly increased after MitraClip procedures (1.4 ± 0.8 mmHg, 3.5 ± 2.9 mmHg; p = 0.001) without incidence of clinically relevant MV stenosis.

Clinical outcomes and predictors of outcome

At 5-year follow-up the majority of patients (65.4%) presented with improved heart failure related symptoms (functional NYHA class ≤ II) and improved exercise tolerance (6MWT: 243.8 ± 121.3 m, 298.1 ± 118.6 m; p = 0.04). The functional capacity at follow-up did not differ between the groups (NYHA > II sMR: 34.6%, pMR 33.3%; p = 0.6) (Fig. 2). However, functional amelioration was more pronounced in sMR patients as assessed by functional NYHA class (sMR: 3.5 ± 0.5, 2.1 ± 0.9, p = 0.0001; pMR: 3.2 ± 0.4, 2.2 ± 1; p = 0.04) and 6MWT (sMR: 235.3 ± 107.7 m, 305.3 ± 123.1 m; p = 0.03; pMR: 267.1 ± 160.2 m, 278.6 ± 111.9 m; p = 0.8). Decreased levels of N-terminal pro-B-type natriuretic peptide were documented in both groups (sMR: 7635.3 ± 13639.8 pg/mL, 3943.4 ± 4190.5 pg/mL; p = 0.01; pMR: 7157.2 ± 10920 pg/mL, 4313.7 ± 7574.8 pg/mL; p = 0.02) (Table 3).

All-cause mortality was 16% at 5-year follow-up and was significantly higher in patients with sMR (sMR: 19%, pMR: 10%; p = 0.05) (**Supplementary materials, Table 1, Fig. 3**).

According to ROC analysis baseline sPAP > 45 mmHg, baseline MVG > 1.5 mmHg and baseline level of creatinine > 2 mg/dL were found to be independent predictors for all-cause mortality at 5-year follow-up. Furthermore, baseline level of creatinine (cut-off value:1.33 mg/dL; HR: 0.695), baseline sPAP (cut-off value: 50 mmHg; HR: 0.96) and baseline MVG (cut-off value: 1.4 mmHg; HR: 0.82) were used as independent predictors for poor functional outcomes at 5-year follow-up (**Supplementary materials, Figs. 1, 2**).

DISCUSSION

The main findings of the present study are as follows: (1) Acute procedural failure was higher in pMR patients. (2) A majority of patients (74%) showed sustained MR reduction, increased RV function and reduced sPAP at 5-year follow-up. (3) Despite pronounced clinical and echocardiographic amelioration at follow-up and lower interventional failure rates, all-cause 5-year mortality was significantly higher in sMR patients. Baseline levels of creatinine

> 2 mg/dL, MVG > 1.5 mmHg and sPAP > 50 mmHg were independent predictors of the 5-year mortality and poor functional outcomes.

Survival and re-intervention rates

Mortality after TMVR with the MitraClip device has been evaluated previously in different studies. Toggweiler et al. [18] found in 75 patients, a patient mortality of 4% at 30 days, 9% at 1 year and 25% (sMR: 28%, pMR 18%) at 2 years after the MitraClip procedure. Comparable data were presented in 304 patients by Capodanno et al. [19] (4% at 30 days, 11% at 1-year, and 19% at 2-years). The EVEREST II study found a 20% 5-year mortality without statistical difference between MR etiologies [6].

In line with those studies, sustained MR reduction was found with improved functional capacity and quality of life 5 years after the MitraClip procedure. Although the patients in the present study were considerably older (mean age: 81 years), they had sMR more often and were in higher baseline functional NYHA classes, long-term mortality rates (16%) were comparable to the cited studies. In contrast to EVEREST II, higher mortality in patients with sMR was found despite noticeable improvement of functional capacity at follow-up. Of note, in the early EVEREST studies, echocardiographic feasibility criteria were far more restrictive, and the majority of patients were treated for pMR, which might account for different acute and long-term procedural success rates.

Higher all-cause mortality at follow-up in sMR patients was found, and might be explained by the advanced age of sMR patients, a more impaired baseline LV and RV function compared to pMR patients. Similar findings were presented in the COAPT (Cardiovascular Assessment of the MitraClip Percutaneous Therapy for Heart Failure Patients with Functional Mitral Regurgitation) trial. In this trial, Stone et al. found 29.1% 2-year mortality in 302 patients with sMR despite being younger patients, was relevantly higher than the present collective. This might be explained through the present findings "predictors of mortality" such as impaired baseline renal function (creatinine clearance < 51 mL/min), advanced systolic heart failure (LVEF 31%), and elevated RV systolic pressure (> 44 mmHg) [25].

Buzzatti et al. [26] showed higher 5-year mortality (about 50%) with good mid-term results including reduction of MR and improved symptoms in 339 patients with relevant MR. In line with current results, they found pronouncedly worse outcomes and higher mortality in patients with secondary MR associated with worse LV remodelling and function.

Predictors of adverse outcome

Azzalini et al. [22] showed that an impaired LV function was associated with increased mortality in 77 patients with sMR one year after the MitraClip procedure. This finding is in line with the present data. A higher 5-year mortality in sMR patients with reduced baseline LV function was found (EF < 40%) compared to pMR patients with a baseline LVEF > 55%.

Another independent marker for secondary endpoint was the baseline level of creatinine (> 2 mg/dL) in the current study. This finding is supported by a study from Ohno et al. [23]. They found a significant adverse effect of concomitant chronic kidney disease on MR reduction, functional capacity (functional NYHA class), survival and frequency of re-repair in 214 patients with severe MR 1 year after the MitraClip procedure.

Toggweiler [9] (baseline MVG > 3 mmHg) and Neuss et al. (post-procedural MVG > 5 mmHg) showed a devastating impact of higher MVG on clinical outcomes and procedural success [18]. In concordance with those results, baseline MVG (> 1.5 mmHg) as an independent predictor for both primary and secondary endpoints at 5-year follow-up was found in the present study.

Moreover, Matsumoto et al. [11] found that pre-existing pulmonary hypertension was a strong predictor of higher all-cause mortality 12 months after the MitraClip procedure. The Association between worse outcomes and advanced heart disease and symptoms have been presented by Buzzatti et al. [26] in more than 300 patients with relevant MR at 5-year follow-up. The cited study validates present findings; elevated baseline sPAP values are an independent predictor of (> 45 mmHg) adverse outcomes and (> 50 mmHg) all-cause mortality at 5-year follow-up.

Limitations of the study

This single-center retrospective study has several limitations. Data was reported from a single-center experience, and all echocardiographic analyses were not verified by an independent core lab. Furthermore, the 5-year follow-up was sufficiently completed in 233 (88%) patients. Because of this, the present results should be proven in multi-center studies with a larger patient collective.

CONCLUSIONS

Transcatheter mitral valve repair with MitraClip procedure was found to be safe, cause sustained MR reduction, and increase RV function during 5 years subsequent to the procedure. Despite pronounced functional and echocardiographical amelioration and lower procedural failure, sMR patients showed a higher all-cause 5-year mortality compared to patients with pMR. Elevated baseline creatinine, baseline levels of MVG and baseline sPAP were associated with poor functional outcome and high all-cause 5-year mortality.

Conflict of interest: None declared

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Table 1. Baseline demographical characteristics

	All patients (n = 265)	**sMR (n = 160)**	**pMR (n = 105)**	**P**
Gender (female)	46.7%	40.9%	56.7%	0.1
Age [years]	81.4 ± 8.1	79.1 ± 8.7	84.6 ± 5.7	0.1
BMI [kg/m^2]	25.4 ± 4.2	26 ± 4.6	24.5 ± 3.4	0.1
EuroScore [%]	19.7 ± 16.7	21.4 ± 17.5	16.9 ± 15.2	0.3
NYHA ≥ II	100%	100%	100%	1
NYHA III	68.1%	55.8%	86.2%	
NYHA IV	31.9%	44.2%	13.8%	0.06
Chronic heart failure	70.7%	81.4%	66.7%	0.1
Coronary heart diesease	71.4%	75.9%	65%	0.3
Arterial hypertension	66.7%	70.5%	61.3%	0.3
History of stroke	4%	2.3%	6.5%	0.4
Peripheral artery diesease	10.7%	11.4%	9.7%	0.6
Diabetes mellitus	34.7%	45.5%	29.4%	0.09
Hyperlipidemia	36%	45.5%	31.6%	0.1
Nicotine	24%	25%	22.6%	0.5
Creatinine [mg/dL]	1.5 ± 0.8	1.6 ± 0.9	1.4 ± 0.7	0.2

sMR — secondary mitral regurgitation; pMR — primary mitral regurgitation; BMI — body mass index; NYHA — New York Heart Association functional classification

Table 2: Baseline echocardiographical characteristics

	All patients (n=265)	sMR (n = 160)	pMR (n = 105)	P
LVEDV [mL]	154.4 ± 59	165.3 ± 62.6	135.8 ± 49.2	0.03
LVESV [mL]	87.3 ± 52.4	106.4 ± 53.3	59.3 ± 36.6	0.0001
LVEF [%]	46.3 ± 17.4	38.3 ± 14.1	58.1 ± 15	0.0001
sPAP [mmHg]	47.5 ± 15	46.2 ± 15.7	50 ± 14	0.4
MV gradient [mmHg]	1.6 ± 0.9	1.4 ± 0.8	1.8 ± 1	0.03
MR	3.2 ± 0.4	3.1 ± 0.3	3.4 ± 0.5	0.1
MR grade III	79.7%	90.9%	63.3%	0.02
MR grade IV	18.9%	6.8%	36.7%	0.03
E/A ratio	2.4 ± 1	2.6 ± 1.2	2.2 ± 0.8	0.2
PISA radius [cm]	0.9 ± 0.2	0.8 ± 0.2	0.9 ± 0.3	0.2
VC width [cm]	1.4 ± 4.4	1.5 ± 5.3	1.2 ± 2.3	0.7
EROA [cm^2]	0.6 ± 0.3	0.5 ± 0.1	0.6 ± 0.4	0.3
Regurgitation volume [mL]	54.4 ± 16	53.2 ± 16	56.3 ± 16.2	0.4
Tricuspid regurgitation	2.1 ± 0.8	2.1 ± 0.8	2 ± 0.8	0.6
TAPSE [cm]	1.8 ± 0.4	1.7 ± 0.4	2 ± 0.2	0.09

sMR — secondary mitral regurgitation; pMR — primary mitral regurgitation; LVEDV — left ventricular end-diastolic volume; LVESV — left ventricular end-systolic volume; LVEF — left ventricular ejection fraction; MV — mitral valve: MR — mitral regurgitation; PISA — proximal isovelocity surface area; VC — vena contracta; EROA — effective regurgitant orifice area; TAPSE — tricuspid annular systolic excursion

Table 3. Echocardiographical and clinical outcomes at follow-up

	Baseline	Follow-up	P
LVEDV [mL]	150 ± 55.5	140.9 ± 58.4	0.3
sMR	162.4 ± 56.7	154.5 ± 66.9	0.5
pMR	127.8 ± 47.3	116.5 ± 26.4	0.3
LVESV [mL]	87.6 ± 47.7	82.4 ± 52.8	0.4
sMR	105.2 ± 45.5	99.6 ± 57.8	0.6
pMR	56.2 ± 34.5	51.6 ± 20.2	0.5
LVEF [%]	44.5 ± 16.1	45.8 ± 15.5	0.5
sMR	36.9 ± 12.6	38.7 ± 13.6	0.5
pMR	58.1 ± 12.2	58.4 ± 9.7	0.9
IVSDD [cm]	1.2 ± 0.3	1 ± 0.2	0.04
sMR	1.2 ± 0.3	1 ± 0.2	0.04
pMR	1.3 ± 0.3	1.2 ± 0.3	0.3
MR	3.1 ± 0.4	1.7 ± 0.5	0.0001
sMR	3 ± 0.3	1.6 ± 0.5	0.0001
pMR	3.4 ± 0.5	2 ± 0.4	0.0001

MR ≤ II [%]	0	97.4	0.0001
sMR	0	100	0.0001
pMR	0	92.9	0.0001
MR > II [%]	100	2.6	0.0001
sMR	100	0	0.0001
pMR	100	7.1	0.0001
Mitral gradient [mmHg]	1.4 ± 0.8	3.5 ± 2.9	0.0001
sMR	1.4 ± 0.8	2.8 ± 1.3	0.0001
pMR	1.5 ± 0.9	4.8 ± 4.5	0.02
TAPSE [cm]	1.8 ± 0.3	1.9 ± 0.4	0.008
sMR:	1.7 ± 0.4	1.9 ± 0.4	0.03
pMR:	2 ± 0.2	2.1 ± 0.4	0.5
sPAP [mmHg]	49.7 ± 17.3	40.7 ± 17.5	0.02
sMR	50 ± 17.4	39.3 ± 17.3	0.05
pMR	49.4 ± 18.3	41.6 ± 18.7	0.3
Functional NYHA class	3.4 ± 0.5	2.2 ± 0.9	0.0001
sMR	3.5 ± 0.5	2.1 ± 0.9	0.0001
pMR	3.2 ± 0.4	2.2 ± 1	0.004
6MWT [m]	243.8 ± 121.3	298.1 ± 118.6	0.04
sMR	235.3 ± 107.7	305.3 ± 123.1	0.03
pMR	267.1 ± 160.2	278.6 ± 111.9	0.8
NT-proBNP [pg/mL]	5987.3 ± 9989.3	4614.7 ± 5596.6	0.5
sMR	3844.7 ± 3099.4	4581.1 ± 4356.1	0.2
pMR	10510.6 ± 16770.4	4685.8 ± 7939.8	0.4

sMR — secondary mitral regurgitation; pMR — primary mitral regurgitation; LVEDV — left ventricular end-diastolic volume; LVESV — left ventricular end-systolic volume; LVEF — left ventricular ejection fraction; IVSDD — diastolic interventricular septum diameter; MR — mitral regurgitation; TAPSE — tricuspid annular systolic excursion; sPAP — systolic pulmonary artery pressure; NYHA — New York Heart Association; 6MWT — 6 minute walk test; NTpro-BNP — N-terminal pro-B-type natriuretic peptide

Figure 1. Changes in functional New York Heart Association (NYHA) class; pMR — primary mitral regurgitation; sMR — secondary mitral regurgitation.

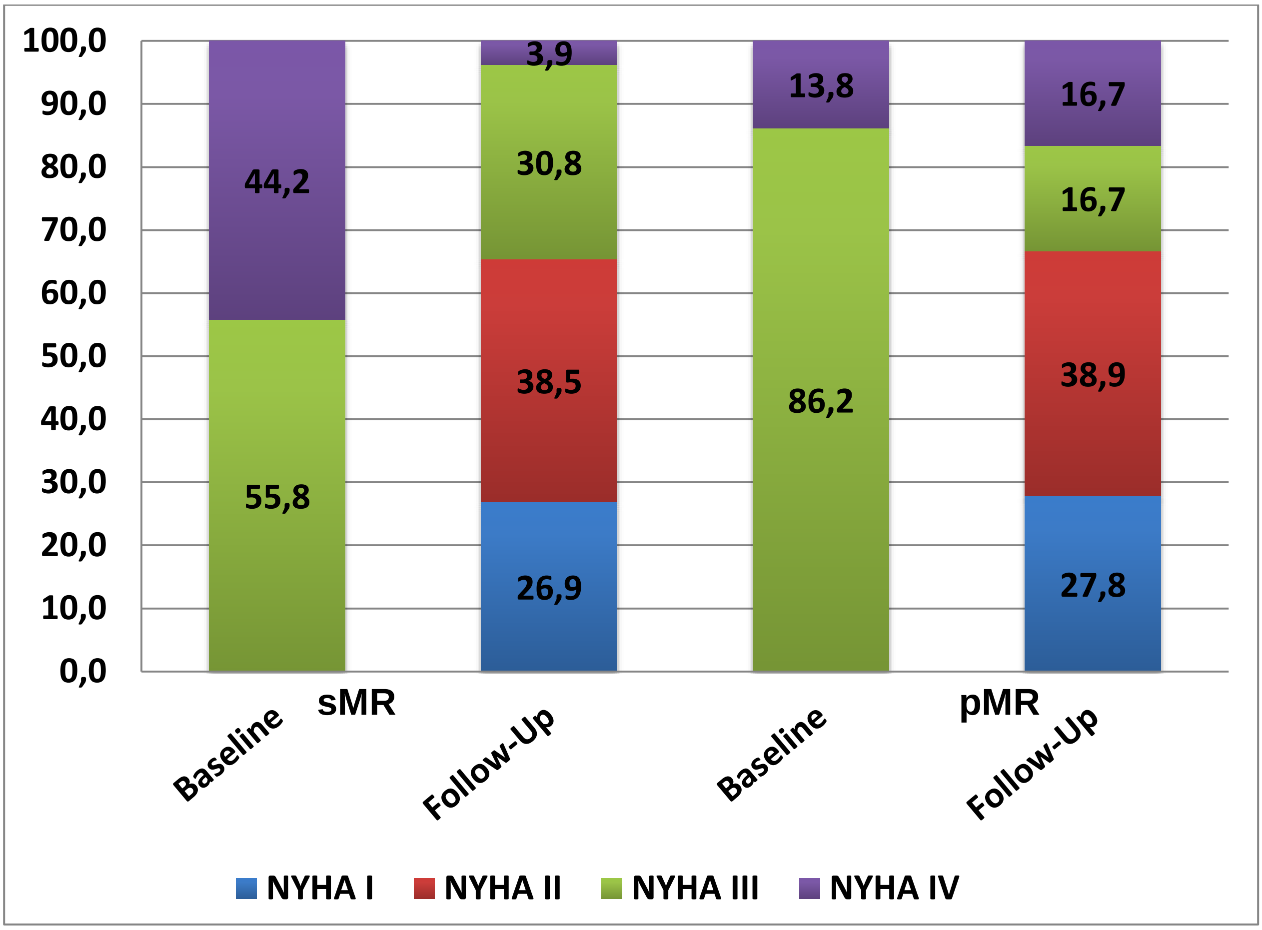

Figure 2: Reduction of mitral regurgitation (MR) at 5-year follow-up; pMR — primary mitral regurgitation; sMR — secondary mitral regurgitation.