General Thoracic and Cardiovascular Surgery
https://doi.org/10.1007/s11748-020-01530-z

ORIGINAL ARTICLE

Outcome of medical therapy, repeat intervention, and mitral valve surgery after failed MitraClip therapy

Takayuki Gyoten[1] · Sören Schenk[1] · Oliver Grimmig[1] · Sören Just[1] · Dirk Fritzsche[1] · Daniel Messroghli[2,3,4]

Received: 23 March 2020 / Accepted: 16 October 2020

Abstract

Objectives Optimal treatment for residual mitral regurgitation (MR) after MitraClip failure is not clearly defined. We report our clinical experience and discuss treatment options.

Methods Between January 2013 and January 2018, 37 patients (75 ± 8.9 years, 46% male) were admitted for symptomatic MR (grade 3.1 ± 0.47) diagnosed after previous MitraClip therapy. Clinical outcome of these patients, who underwent medical therapy alone ($n = 8$, M-group), repeat MitraClip therapy ($n = 8$, reMC group), or mitral valve surgery ($n = 21$, S-group) for residual MR, were retrospectively analyzed.

Results Thirty-day survival was 88% (M-group), 100% (reMC-group), and 76% (S-group). The rate of discharge to home was 88% in the reMC-group, better than 38% in the M-group ($p = 0.051$) and 19% in the S-group ($p < 0.001$). Perioperative non-survivors in the S-group had high surgical risk with median logistic EuroSCORE of 64.6% (interquartile range 57.4%–87.0%); all died from low cardiac output syndrome or multiple organ failure. The main MR pathologies resulted from leaflet tear and tethering in the M-group, tethering in the reMC-group, and degenerative valve and leaflet tear in the S-group. Kaplan–Meier analysis of overall survival at 1 year showed better outcome for patients in the reMC-group (50%, 95% CI 15.2–77.5%) and S-group (47.6%, 95% CI 25.7–66.7%), as compared to those in the M-group (12.5%, 95% CI 0.70–42.3%) (log-rank test $p = 0.108$ and $p = 0.167$, respectively).

Conclusion Medical therapy alone after failed MitraClip therapy resulted in poor 1-year prognosis. In patients without extremely high surgical risk, repeat MitraClip therapy, or surgical revision MIGHT BE CONSIDERED depending on valve pathology and cardiac comorbidities

Keywords Surgical revision · Repeat MitraClip therapy · Medical therapy · MitraClip failure

Introduction

When patients with symptomatic mitral regurgitation (MR) are at high surgical risk, interventional edge-to-edge repair using MitraClip (MC, Abbott Vascular, Santa Clara, CA, USA) is regarded as the first choice of therapy for both degenerative and functional MR [1]. Many studies have shown that MC therapy can be safely performed with a high rate of success (defined as residual MR grade ≦ 2) [1–5]. Nonetheless, in cases without successful reduction of MR, further treatment options including medical therapy alone, redo-MC therapy, and surgical revision for residual MR need to be considered. The optimal choice for such second-line treatment is currently under discussion [6–9]. In real-world situations with patients who were deemed inoperable or at high surgical risk, progressive therapy has been easily abandoned and medication therapy alone seems to be chosen. The objective of this analysis was to assess the clinical outcome of medical therapy alone, repeat MC therapy, and open-heart surgical revision in patients with persistent or recurrent MR after first MC therapy. This article summarizes

✉ Takayuki Gyoten
t.gyoten29@gmail.com

[1] Department of Cardiovascular Surgery, Sana-Herzzentrum Cottbus, Leipziger Strasse 50, 03048 Cottbus, Germany

[2] Department of Internal Medicine—Cardiology, Deutsches Herzzentrum Berlin, Berlin, Germany

[3] Department of Internal Medicine and Cardiology, Universitätsmedizin Berlin, Campus Virchow-Klinikum, Charité, Berlin, Germany

[4] German Center for Cardiovascular Research (DZHK), Partner site Berlin, Berlin, Germany

Published online: 29 October 2020

our experience in patients with unsuccessful MC therapy and discusses treatment strategies for residual MR.

Materials and methods

Study design and follow-up

Upon receiving approval from the Institutional Review Board of the Sana Heart Center, we retrospectively reviewed the records of consecutive patients who, between January 2013 and January 2018, had undergone medical therapy alone, repeat MC therapy, or surgical revision for persistent or recurrent MR after percutaneous MC therapy. Follow-up data of clinical status were obtained from the patients' general practitioners or private cardiologists by phone calls and facsimile and were procured for 100% of the patients. The clinical follow-up was concluded on January 31st 2019 when the last enrolled patient had completed 1 year of follow-up. Patients were classified into three groups: medical therapy alone (M-group), repeat MC therapy (reMC-group), and surgical revision (S-group). Clinical outcomes were compared between the groups. The endpoint was defined as death of any cause.

Prior MitraClip implantation as first therapy

Prior MitraClip therapy was performed due to high age, surgical high risk, as well as adjunctive risk (liver dysfunction, during chemotherapy for malignancy, and frailty). Patient selection for prior MitraClip implantation was based on the German Cardiac Society (DGK) criteria [10].

Selection of therapy

Selection of individual therapy was based on discussions of the interdisciplinary heart team of our center, taking into account age, surgical risk as estimated by logistic EuroSCORE, cardiac and extra-cardiac comorbidities, and mitral valve morphology of the patient. All patients provided written informed consent before undergoing interventional or surgical therapy.

Medical therapy alone

All patients were treated with standard medical therapy based on current guidelines for the treatment of heart failure [11–13].

Interventional procedure

Typical criteria for selecting repeat MC therapy in our hospital were ≦ 2 previously implanted clips, no mitral valve stenosis, and no cardiac comorbidity requiring additional procedures. All interventional procedures with MC were performed by the same experienced interventional cardiologist. All clips (arm length 9 mm) were implanted according to standard practices under general anesthesia with transesophageal echocardiographic and fluoroscopic guidance. Maximal residual MR grade 2 at mean blood pressure of 60 mmHg after the implantation was considered acceptable.

Surgical procedures

All procedures were performed via median sternotomy due to critically ill patients and those who were undergoing redo-surgery. After sternotomy, cardiopulmonary bypass was established through direct cannulation of the ascending aorta and right atrium. After transthoracic aortic cross-clamping, myocardial arrest was induced by antegrade warm blood cardioplegia. The mitral valve was exposed via standard left atriotomy or the transseptal approach, depending on the need for tricuspid valve repair and atrial septal defect closure. The failure characteristics of the implanted clips and the degree of tissue damage to the mitral valve were assessed. The clips were cut using scissors and removed, and standard MV replacement was performed. Surgical MV replacement was performed to reduce the duration of aortic cross-clamping and cardiopulmonary bypass.

Statistical analysis

Data are expressed as mean ± standard deviation or median (range and/or interquartile range) for continuous variables and frequency (percentage) for categorical variables. The baseline characteristics, echocardiography, and clinical outcomes of the patients among all three groups were compared using the analysis of variance (ANOVA) test for continuous, normally distributed data and the Kruskal–Wallis test for non-parametric continuous data. Fisher's exact test was used to compare categorical variables. Survival was derived using the Kaplan–Meier method; comparisons were made using the log-rank test. Differences between any two of the three groups were assessed using the Holm test. Statistical significance was set at $p < 0.05$. All reported p values are two-sided. Statistical analysis was performed by a statistician using SPSS for Windows, version 22.0 (IBM Japan, Tokyo, Japan).

Results

Study population

Between January 2011 and January 2018, 249 patients (age 77 ± 8.1 years; 60% males) were scheduled to undergo

MC edge-to-edge repair for severe MR in our hospital. Of those, 8 patients (3.21%) did not undergo the procedure due to various technical reasons (Fig. 1). In the remaining 241 patients, acute success rate (defined as residual MR ≦ grade 2) was 95.9%. During the study period, 37 patients showed persistent or recurrent severe MR and were enrolled in this study. Of those 37 patients, 8 underwent repeat MC therapy (reMC-group), 8 received medication therapy alone (M-group), and the remaining underwent surgical revision (S-group). In addition to 8 patients from our hospital, 13 further patients were added to the S-group who had surgical revision for failed MC therapy at our hospital having undergone MC therapy at an external hospital [S-group, $n=21$; first MC implantation at our hospital ($n=8$), at other hospitals ($n=13$), as shown in Fig. 1.]

Conservative observation in medication therapy alone (M-group)

In the 8 patients (age 78 ± 6.7 years) in the M-group, echocardiography after first MC therapy with 2.75 ± 1.04 clips per patient showed residual MR (mean grade 3.25 ± 0.46). (Table 1) Six patients (75%) received preoperative treatment including placement of an implantable defibrillator or cardiac resynchronization therapy defibrillator. Causes of MR were leaflet tear in 4 patients (50%) and increasing mitral annular dilatation and tethering in 4 patients (50%) with dilated cardiomyopathy (Table 2). There were no clip detachments or ruptured chords. After discussion by our heart team, conservative therapy was chosen for the following reasons: inoperable (patient with dementia), patient's rejection of subsequent invasive therapy. New York Heart Association (NYHA) functional class at discharge was 3.25 ± 0.46 (Table 3).

Repeat MitraClip therapy (reMC-group)

Eight patients (age 75 ± 10.5 years) with median Logistic EuroSCORE of 35% (IQR; 21–43, range, 14–49) underwent repeat MC implantation for symptomatic MR (3.0 ± 0.53 grade) at a median of 301 days (IQR 255–392, range 143–475) after the first MC therapy. In these patients, functional MR was initially successfully treated with 1.38 ± 0.52 clips at first MC therapy (Table 1). The main etiology of recurrent MR was increasing tethering and ring dilation (63%), and MR grade was significantly reduced (1.75 ± 0.89 vs. 3.0 ± 0.53, $p=0.0016$) with an implanted 1.43 ± 0.53 clips (Table 2). Seven patients (88%) were discharged at a median of 3.0 days ICU stay (IQR 1–6, range 1–30) and 13 d hospital stay (IQR 9–24, range 1–41), without any complications (Table 3). One patient (12%) had residual grade 3 MR due to leaflet tear with a total of three clips and required surgical MV replacement several days later because of unstable hemodynamics.

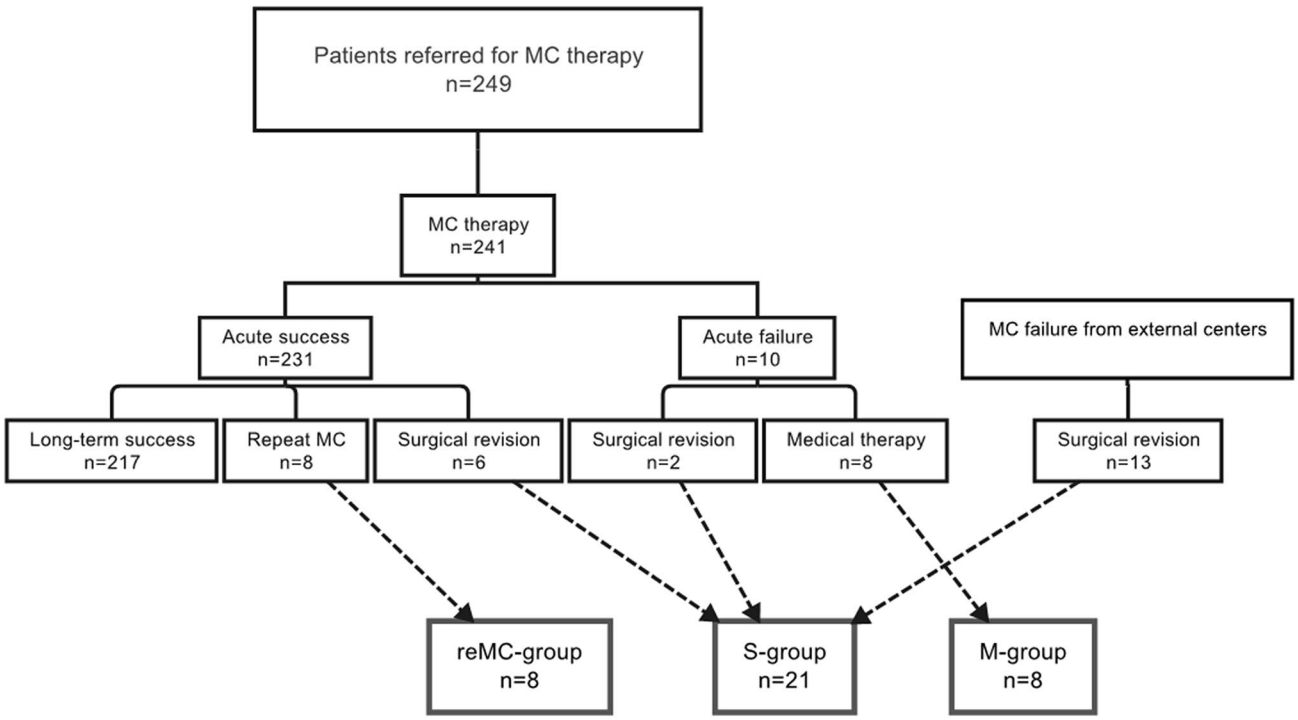

Fig. 1 Flowchart for selection of patients. *MC* MitraClip, *S* surgery, *M* medication

Table 1 Baseline characteristics of three groups; *n* (%) if not otherwise specified

Baseline characteristics	All groups $n=37$	M-group $n=8$	reMC-group $n=8$	S-group $n=21$	*P* value
Age, mean ± SD (years)	75 ± 8.9	78 ± 6.7	75 ± 10.5	74 ± 9.0	0.50
Male gender	17 (46%)	4 (50%)	3 (38%)	10 (48%)	0.91
Functional MR, etiology at first MitraClip therapy	32 (86%)	6 (75%)	8 (100%)	18 (86%)	0.37
Logistic EuroSCORE, mean ± SD	39 ± 23	39 ± 22	34 ± 14	42 ± 27	0.74
Atrial fibrillation	33 (89%)	8 (100%)	7 (88%)	18 (86%)	0.80
Ischemic cardiomyopathy at first MitraClip therapy	5 (14%)	3 (38%)	1 (13%)	1 (4.8%)	0.060
Dilated cardiomyopathy	15 (41%)	3 (38%)	5 (63%)	7 (33%)	0.43
Previous cardiac surgery	8 (22%)	2 (25%)	2 (25%)	4 (19%)	1
Previous implanted clip number	2.2 ± 0.96	2.75 ± 1.04	1.38 ± 0.52	2.33 ± 0.91	0.0094
Previous ICD	11 (30%)	3 (38%)	4 (50%)	4 (19%)	0.23
Previous CRT	19 (51%)	6 (75%)	7 (88%)	6 (29%)	0.0081
NYHA functional class, mean ± SD	3.1 ± 0.35	3.25 ± 0.46	3.13 ± 0.35	3.10 ± 0.30	0.57
*LVEF, mean ± SD	38 ± 16	36.5 ± 19	25 ± 12.8	44 ± 13.5	0.016
*MR grade, mean ± SD	3.1 ± 0.47	3.25 ± 0.46	3.0 ± 0.53	3.0 ± 0.45	0.42
Mean mitral valve gradient, mmHg ± SD	5.0 ± 3.2	4.5 ± 2.6	3.1 ± 1.1	5.9 ± 3.7	0.086

ICD implanted cardioverter defibrillator, *CRT* cardiac resynchronization therapy, *NYHA* New York Heart Association, *LVEF* left-ventricular ejection fraction; MR, mitral regurgitation

*Values of LVEF and MR grade after first failed clipping in M group or before treatment in reMC-group and S-group, respectively

Surgical revision (S-group)

The remaining 21 patients (age 74 ± 9.0 years) with a median logistic EuroSCORE of 40% (IQR 23–59, range 4.53–97) underwent surgical MV replacement for symptomatic MR (3.0 ± 0.45 grade) at a median of 80 days (IQR 46–296, range 1–1496) after the first MC therapy (Table 1). In these patients, 2.33 ± 0.91 clips had been implanted per patient. Causes of MR at the time of surgical revision were leaflet tear in 5 patients (24%), increasing tethering in 5 patients (24%), leaflet degeneration including endocarditis in 4 patients (19%), partial detachment in 4 patients (19%), and technical failure including ruptured chords in 3 patients (14%). The duration of cardiopulmonary bypass and aortic cross-clamping was 118 ± 62 min and 60 ± 25 min, respectively. Concomitant procedures included tricuspid valve repair in 6 patients (29%), ascending aortic replacement in 1 patient (4.8%), and atrial septal defect closure in 9 patients (43%). Redo-open-heart surgery was performed in 8 patients (38%), and emergency or urgent surgery in 10 patients (48%). Intraoperative results are summarized in Table 2.

In total, 6 patients with median logistic EuroSCORE 65% (IQR 57–87, range 35–97) died perioperatively due to multiorgan failure (MOF), low cardiac output syndrome, and liver failure despite intraoperative implantation of extracorporeal membrane oxygenation (ECMO) and intensive medical therapy. Conversely, perioperative survivors (median 29%, IQR 12–47, range 4.53–70) were discharged at median of 3.0 days of ICU stay (IQR 1–6, range 1–30) and 13 days of hospital stay (IQR 9–24, range 1–41), although 2 patients experienced stroke perioperatively. Thoracic echocardiography at discharge showed no residual MR and 6.2 ± 3.1 mmHg mitral valve gradient.

Later clinical outcomes and survival

The median follow-up was 9.2 months (IQR 2.1–34, range 0.033–69). During follow-up, 26 patients (70%) died.

In the M-group, all 8 died during follow-up, with 7 patients living < 12 months after failed MC therapy. 5 patients (63%) died of heart failure, 2 (25%) of progressing renal failure, and 1 (12%) of an unknown cause.

In the reMC-group, the 1-year survival rate was 50%; 4 patients (50%) died from uncontrolled heart failure and 1 died of an unknown cause at 34 months after therapy.

In the S-group, the 1-year survival rate was 48%. One patient (4.8%) died after 10 months due to bladder cancer, while 2 patients (9.5%) died of sepsis at 211 days and pneumonia at 97 days. The cause of death was unknown in 3 patients (14%). During follow-up, there was no prosthesis dysfunction or endocarditis needing redo-surgery.

Figure 2 shows the Kaplan–Meier overall survival analysis in these three groups. The Kaplan–Meier overall survival analysis at 1 year showed better outcome in reMC-group (50%, 95% CI 15.2–77.5%), compared to M-group (12.5%, 95% CI 0.70–42.3%) (log-rank test $p=0.108$). Similarly, The Kaplan–Meier overall survival analysis at 1 year showed better outcome in S-group (47.6%, 95% CI 25.7–66.7%), compared to M-group (log-rank test $p=0.167$) (Fig. 2). However, the Kaplan–Meier overall survival analysis showed

Table 2 Procedural characteristics; *n* (%) if not otherwise specified

Procedural results	M-group $n=8$	reMC-group $n=8$	S-group $n=21$
Elective	*	8 (100%)	11 (52%)
Urgent	*	0 (0%)	7 (33%)
Emergent	*	0 (0%)	3 (14%)
Time between first and second intervention, median, (days)	0	301 (IQR: 255–392)	80 (IQR: 46–296)
MitraClip			
New implanted clip number, mean ± SD	*	1.43 ± 0.53	*
Surgery			
MV replacement	*	*	21 (100%)
ACC, mean ± SD (min)	*	*	60 ± 25
ECC, mean ± SD (min)	*	*	118 ± 62
Redo surgery	*	*	8 (38%)
Concomitant procedures			
AVR	*	*	2 (9.5%)
TVR	*	*	6 (29%)
CABG	*	*	1 (4.8%)
ASD closure		*	9 (43%)
LA ablation	*	*	2 (9.5%)
LAA closure	*	*	1 (4.8%)
AsAo replacement	*	*	1 (4.8%)
Etiology of MR			
Leaflet degeneration	0 (0%)	0 (0%)	*5 (24%)
Partial detachment	0 (0%)	2 (25%)	4 (19%)
Leaflet tear without clip detachment	4 (50%)	1 (13%)	5 (24%)
Increasing MR with ring dilatation	4 (50%)	5 (63%)	4 (19%)
Technical failure	0 (0%)	0 (0%)	3 (14%)

IQR interquartile range, *MV* mitral valve, *ACC* aortic cross-clamping, *ECC* extracorporeal circulation, *AVR* aortic valve replacement, *TVR* tricuspid valve repair, *CABG* cardiopulmonary bypass grafting, *LAA* left atrial appendage, *AsAo* ascending aorta

*This number includes two patients with endocarditis. Elective, routine admission for operation; urgent: patients who have not been electively admitted for operation but who require intervention or surgery; emergency, operation before the beginning of the next working day

no significant difference between reMC-group and S-group (log-rank test, $p=0.73$).

Discussion

We reported the outcome of patients with persistent or recurrent MR after unsuccessful MC therapy, who underwent subsequent medication therapy, repeat MC therapy, or surgical therapy in our hospital. Therefore, we discuss treatment options after unsuccessful MC therapy. Over a 5-year period, 37 patients with persistent or recurrent MR (3 grade and more) after MC therapy were identified. There are two main findings of the current study. First, medical therapy alone after failed MC therapy was associated with very poor prognosis (1-year survival of 13%). Second, the perioperative mortality was higher in patients with surgical revision; yet when surviving the peri-operative stage, surgical revision was associated with no residual MR and survival was comparable to repeat MC therapy.

Our data show that the patients in the M-group had low survival; most patients (88%) died within 1 year (median 5.4 months, 2.0–8.6, range 0.57–9.4) mainly due to uncontrolled heart failure. High-grade residual MR might have been a major driver of this outcome. Patients in the M-group were at high surgical risk (a median of 34, 26–60, range 9.2–69). Discussions of the heart team led us to decide on a conservative approach with medical therapy alone; main reasons for this decision apart from high surgical risk included old age (median 80 years, 74–83, range 66–86), and refusal of further invasive treatment by the patients. Previously, no study has compared these three treatment options; nevertheless, the poor prognosis in the M group is clear, clinicians should pursue further interventional procedures whenever feasible according to the etiology of recurrent MR and the anatomy of the disease.

Table 3 Procedural characteristics

Perioperative results	M-group $n=8$	reMC-group $n=8$	S-group $n=21$	P value
ECMO	*	0 (0%)	1 (4.8%)	*
IABP	*	0 (0%)	2 (9.5%)	*
Re-intubation	*	0 (0%)	1 (4.8%)	*
ICU stay	*	1.13	6.6 ± 9.8	*
Hospital stay	6.3 ± 2.8	5.9 ± 1.3	13 ± 12	0.094
Discharge				
To home	3 (38%)	7 (88%)	4 (19%)	< 0.001
To rehabilitation	5 (63%)	1 (13%) (conversion to surgery)	8 (38%)	0.036
To stroke unit	0 (0%)	0 (0%)	2 (9.5%)	1
In-hospital death	0 (0%)	0 (0%)	6 (28.6%)	0.079
30-day survival	87.5%	100%	71.4%	0.29
LVEF, mean ± SD*	36.5 ± 19	26.5 ± 11	38.3 ± 15	0.209
MR grade, mean ± SD *	3.00 ± 0.00	1.8 ± 0.89	0	< 0.001
Mean mitral valve gradient, mmHg ± SD*	4.5 ± 2.6	4.9 ± 1.8	5.0 ± 2.7	0.912
Medication at discharge				
ACE inhibitor/ARB	6 (75%)	6 (75%)	13 (21%)	0.60
Betablocker	6 (75%)	7 (88%)	13 (21%)	0.83
Mineralocorticoid receptor antagonist	7 (88%)	4 (50%)	8 (38%)	0.23
Loop diuretics	7 (88%)	8 (100%)	15 (71%)	0.52
Digitoxin	1 (13%)	5 (63%)	4 (19%)	0.13

n (%) if not otherwise specified *ECMO* extracorporeal membrane oxygenation, *IABP* intra-aortic balloon pump, *ICU* intensive care unit, *LVEF* left ventricular ejection fraction, *MR* mitral regurgitation, *MV* mitral valve, *ARB* angiotensin receptor blocker, *LVEF* left ventricular ejection fraction

*Data from perioperative non-survivors in S-group ($n = 6$) were excluded

Overall, patients in the reMC-group and the S-group had better survival rates at follow-up. As our data show, reMC was peri-procedurally safer than surgical revision, although the logistic EuroSCORE was not significantly different between reMC- and S-groups ($p = 0.449$). In our results, six patients (29%) in the S group with extremely high surgical risk with median logistic EuroSCORE of 65% (IQR 57–87, range 35–97) died, and three (50%) of the remaining patients needed surgery within 24 h due to unstable circulation (Table 4).

Various studies have proposed that standard MV surgery is the best option in patients with failed MC therapy, except for patients with preoperative cardiogenic shock state or those who have exceeded 30% of EuroSCORE II [6, 14]. In our previous case series, we concluded that surgical revision is feasible, except in patients with cardiogenic shock, septic shock, or liver failure in the preoperative stage [9]. In concordance with these findings, perioperative survivors in the S-group had acceptable mid-term survival, similar to those in the reMC-group. This implies that surgical revision is a feasible option, particularly when the patients are without high surgical risk.

When choosing follow-up therapy subsequent to initial MC therapy, it is necessary to take MR-related etiology and implanted clip number into consideration. According to Kreidel et al., leaflet tear, perforation, or partial clip detachment are anatomical risk factors of repeat MC-failure [8]. In our series, two patients successfully underwent repeat MC therapy after partial clip detachment without any peri-interventional complications and survived longer than 2 years. Studies with larger sample sizes and longer follow-up periods are required to confirm the relation between MR etiology (as an anatomical indication) and the preferable mode of repeat MC intervention.

The clinical impact of elevated gradients after MC therapy has been discussed in some articles [15, 16]. Higher numbers of implanted clips are associated with increased MV gradients, and thus need to be taken into account when considering repeat MC therapy. In our series, clip number significantly increased after repeat MC therapy (pre-interventional clip No., 1.38 ± 0.52 vs. all post-interventional clip No., 2.75 ± 0.89, $p < 0.001$). Mean MV gradient after repeat MC therapy increased compared to the preoperative gradient (4.86 ± 1.81 mmHg vs. 3.06 ± 1.05 mmHg, $p = 0.064$), although MR grade was significantly reduced (1.75 ± 0.89 vs. 3.0 ± 0.53, $p = 0.0016$). Therefore, in case of failed repeat MC therapy, clinicians should assess post-interventional MV stenosis, which may cause deterioration of pulmonary hypertension, atrial fibrillation, and tricuspid regurgitation. MV replacement is suitable for all MR

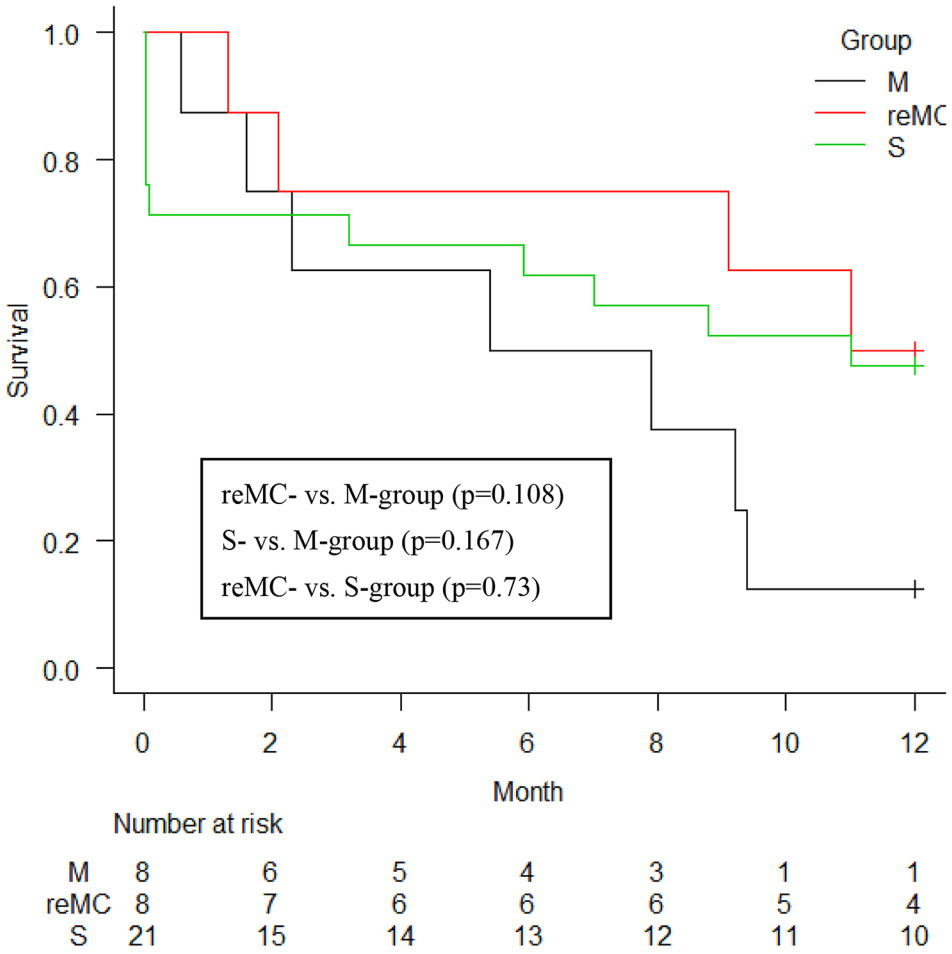

Fig. 2 Clinical outcomes in the three treatment groups. Kaplan–Meier survival curves for death from all causes for reMC-group (red line), M-group (black line), and S-group (green line). One-year outcome was better for reMC-group vs. M-group (log-rank test, $p = 0.108$) and S-group vs. M-group (log-rank test, $p = 0.167$)

etiologies. In the S group, preoperative echocardiography showed a mean MV gradient of 5.94 ± 3.65 mmHg and a mean of 2.33 ± 0.91 implanted clips. After MV replacement, echocardiography in perioperative survivors showed no residual MR and a mean MV gradient of 4.96 ± 2.65 mmHg, which was decreased compared to the preoperative value. Therefore, MV replacement rather than repeat MC therapy seems to be preferable for patients with moderately or severely elevated mean mitral gradients following MC therapy.

We believe that subsequent repeat MC therapy or surgery should be performed, based on individual assessments including mitral valve etiology, cardiac comorbidity, and perioperative surgical risk.

Limitations

Our analysis was done retrospectively at a single center. Therefore, selection bias could not be excluded, and the results of this study should be verified by larger analyses from multi-center datasets.

Conclusion

In patients with failed MitraClip therapy, medical therapy alone was associated with poor prognosis. In patients without extremely high surgical risk, repeat MitraClip therapy or surgical revision might be considered based on valve pathology and cardiac comorbidity.

Acknowledgements None.

Funding None.

Compliance with ethical standards

Conflict of interest The authors declare that they have no competing interests in relationship to this work.

References

1. Feldman T, Foster E, Glower DD, Kar S, Rinaldi MJ, Fail PS, et al. Percutaneous repair or surgery for mitral regurgitation. N Engl J Med. 2011;364:1395–406.
2. Feldman T, Kar S, Elmariah S, Smart SC, Trento A, Siegel RJ, et al. Randomized comparison of percutaneous repair and surgery for mitral regurgitation: 5-year results of EVEREST II. J Am Coll Cardiol. 2015;66:2844–54.
3. Stone GW, Lindenfeld J, Abraham WT, Kar S, Lim DS, Mishell JM, et al. Transcatheter mitral-valve repair in patients with heart failure. N Engl J Med. 2018;379:2307–18.
4. Sorajja P, Vemulapalli S, Feldman T, Mack M, Holmes DR Jr, Stebbins A. Outcomes with transcatheter mitral valve repair in the United States: An STS/ACC TVT registry report. J Am Coll Cardiol. 2017;70:2315–27.
5. Maisano F, Franzen O, Baldus S, Schäfer U, Hausleiter J, Butter C. Percutaneous mitral valve interventions in the real world: early and 1-year results from the ACCESS-EU, a prospective, multi-center, nonrandomized post-approval study of the MitraClip therapy in Europe. J Am Coll Cardiol. 2013;62:1052–61.
6. Geidel S, Wohlmuth P, Schmoeckel M. Survival prediction in patients undergoing open-heart mitral valve operation after previous failed mitraclip procedures. Ann Thorac Surg. 2016;101:952–8.
7. Kreidel F, Alessandrini H, Wohlmuth P, Schmoeckel M, Geidel S. Is surgical or catheter-based interventions an option after an unsuccessful mitral clip? Semin Thorac Cardiovasc Surg. 2018;30:152–7.
8. Kreidel F, Frerker C, Schlüter M, Alessandrini H, Thielsen T, Geidel S. Repeat MitraClip therapy for significant recurrent mitral regurgitation in high surgical risk patients: impact of loss of leaflet insertion. JACC Cardiovasc Interv. 2015;8:1480–9.
9. Gyoten T, Schenk S, Rochor K, Harnath A, Grimmig O, Just S, et al. Surgical revision of failed percutaneous edge-to-edge mitral valve repair: lessons learned. Interact Cardiovasc Thorac Surg. 2019;28:900–7.
10. Boekstegers P, Hausleiter J, Baldus S, et al. Interventionelle behandlung der mitralklappeninsuffizienz mit dem MitraClip®-verfahren: empfehlungen des arbeitskreises interventionelle mitralklappentherapie der arbeitsgemeinschaft interventionelle kardiologie (AGIK) der deutschen gesellschaft für kardi. Kardiologe. 2013;7:91–104.
11. Solomon SD, Rizkala AR, Gong J, Wang W, Anand IS, Ge J, et al. Angiotensin receptor neprilysin inhibition in heart failure with pre trial. JACC Heart Fail. 2017;5:471–82.
12. Ibrahim NE, Song Y, Cannon CP, Doros G, Russo P, Ponirakis A, et al. Alteration of medical therapy in patients with heart failure relative to change in symptom severity. ESC Heart Fail. 2019. https://doi.org/10.1002/ehf2.12480.
13. Emrich IE, Wintrich J, Kindermann I, Böhm M. Evidence-based drug therapy for heart failure-an update. Herz. 2019. https://doi.org/10.1007/s00059-019-4827-2.
14. Elhmidi Y, Voss B, Lange R. Surgical mitral valve intervention following a failed MitraClip procedure. EuroIntervention. 2016;12:Y102–6.
15. Cheng R, Dawkins S, Tat E, Makar M, Hussaini A, Makkar RR, et al. Relation of residual mitral regurgitation despite elevated mitral gradients to risk of heart failure hospitalization after mitraclip repair. Am J Cardiol. 2017;120:1595–600.
16. Patzelt J, Zhang W, Sauter R, Mezger M, Nording H, Ulrich M Elevated mitral valve pressure gradient is predictive of long-term outcome after percutaneous edge-to-edge mitral valve repair in patients with degenerative mitral regurgitation (MR), But Not in Functional MR. J Am Heart Assoc. 2019 8:e011366; doi: 10.1161/JAHA.118.011366.