Surgical therapy of organic mitral valve disease: Strategy and outcomes

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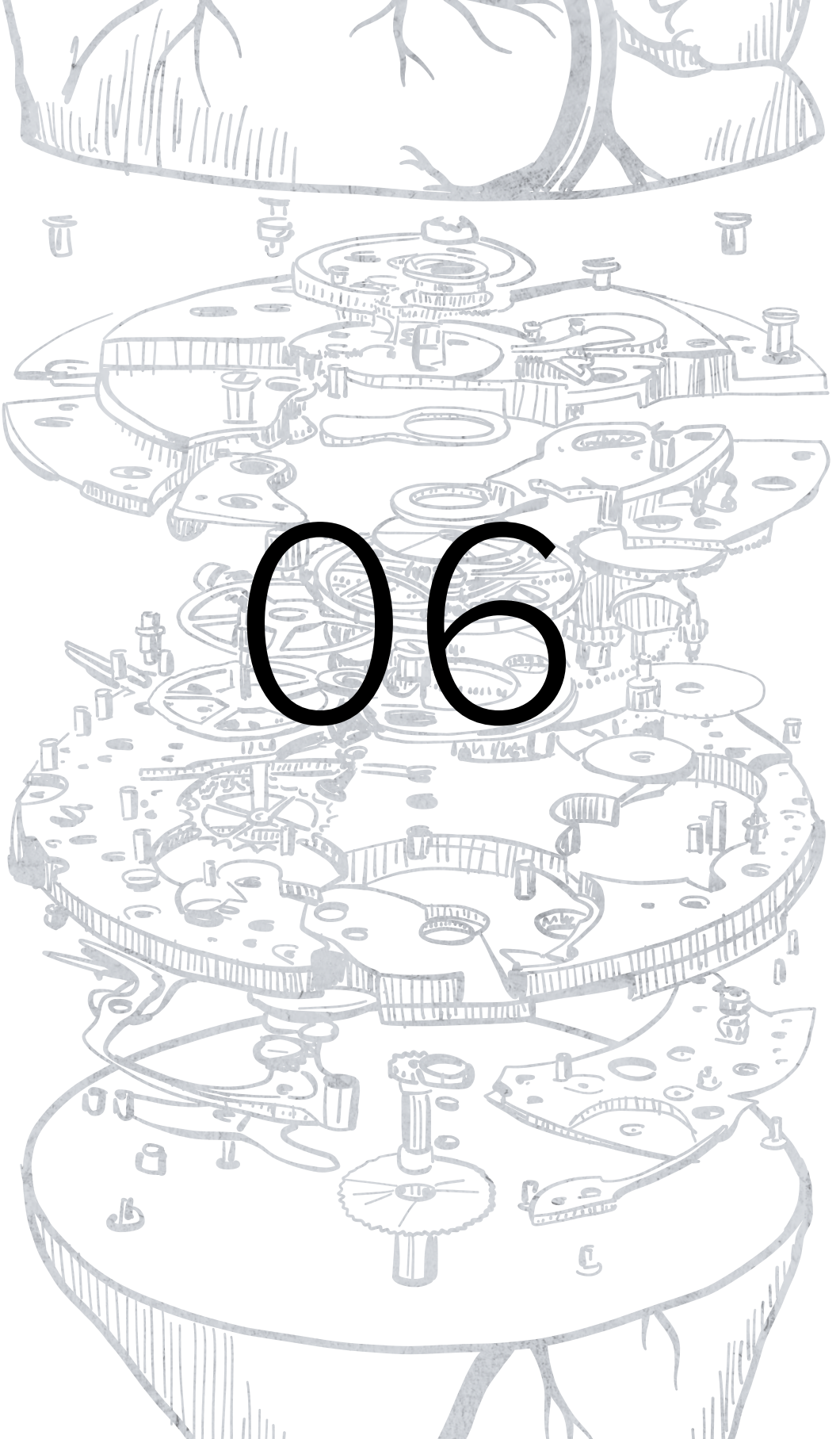
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Papillary muscle head repositioning for commissural prolapse in degenerative mitral valve disease

Anton Tomšič; Robert J.M. Klautz; Thomas J. van Brakel; Nina Ajmone Marsan; Michel I.M. Versteegh; Meindert Palmen

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ABSTRACT

Background. Surgical correction of commissural mitral valve prolapse can be challenging. Several surgical techniques, including commissural closure, leaflet resection with sliding plasty and chordal replacement, remain commonly in use. Conversely, papillary muscle head repositioning remains uncommonly utilized for the treatment of commissural prolapse.

Methods. Between January 2003 and December 2015, 518 patients underwent primary mitral valve repair for severe degenerative mitral valve regurgitation at our institution. Among these, 116 patients had non-isolated commissural prolapse (14 anterolateral, 82 posteromedial, and 20 bicommissural prolapse). Eighty-eight patients underwent papillary muscle head repositioning and presented the study cohort.

Results. Mean patient age was 62.8±12.5 years and 32 (36%) patients were female. Postoperative echocardiography showed no residual mitral regurgitation in all but 1 (1%) patient in whom Grade 2+ regurgitation was seen. The freedom from late reintervention rates at 5 and 10 years were 96.1% (95% CI 91.8%-100%), and 92.7% (95% CI 86.4%-99.0%), respectively. Upon reoperation, no recurrent commissural prolapse was observed. Echocardiographic follow-up demonstrated excellent valve repair durability. The freedom from Grade ≥2+ mitral regurgitation rates at 5 and 10 years were 92.6% (95% CI 86.3%-98.9%) and 86.1% (95% CI 76.7%-95.5%), respectively.

Conclusions. Papillary muscle head repositioning for the treatment of commissural mitral valve prolapse is a reproducible and reliable technique that provides excellent long-term results.

INTRODUCTION

Mitral valve repair for degenerative mitral valve disease provides good early and late outcomes [1]. As a result of widespread utilization of standardized techniques to address specific lesions, the reproducibility and durability of valve repair for degenerative mitral valve disease have improved over time. However, commissural prolapse remains technically challenging and several techniques, including commissural closure, leaflet resection with sliding and chordal replacement, have been described to address this issue [2-8].

When the subvalvular apparatus is preserved and prolapse is a consequence of chordal or papillary muscle elongation, papillary muscle head repositioning presents an alternative to these techniques [9]. Dreyfus et al. originally described this technique and demonstrated its excellent durability [10, 11]. Additionally, the versatility of this technique was described as it can be applied to any prolapsing segment of the mitral valve, provided that the subvalvular apparatus is of sufficient quality. In the setting of commissural prolapse, papillary muscle head repositioning offers the advantage of preserving the largest possible mitral valve orifice area. Surprisingly, based on the current literature, the technique seems largely underutilized [2-7]. To date, data on the early and late results of this technique in the setting of commissural prolapse remain scarce.

The aim of this study was to analyze the results of a papillary muscle head repositioning-oriented approach to commissural prolapse. We analyze (I) the feasibility of papillary muscle head repositioning for commissural prolapse and (II) the early and late clinical and echocardiographic outcomes.

METHODS

Patients

Between January 2003 and December 2015, 518 consecutive patients without a history of previous cardiac surgery underwent mitral valve repair for mitral regurgitation (MR) due to degenerative mitral valve disease at our institution. Commissural prolapse

(limited- involving the commissural scallop only and measuring ≤5mm of leaflet margin; extensive- involving the commissural leaflet and either 1 or both paracommissural areas) was defined as described by Carpentier et al. [12].

One hundred and sixteen patients had non-isolated commissural prolapse- 14 anterolateral, 82 posteromedial, and 20 bicommissural prolapse (total number of commissural lesions= 136). In 11 cases, commissural prolapse was caused by chordae rupture or fibrosis, rendering papillary muscle head repositioning technically not feasible. In the remaining 125 commissural lesions, this was successfully addressed with papillary muscle head repositioning in 102 (82%) cases (**Table I**). Papillary muscle head repositioning was unsuccessfully attempted (residual prolapse) in 2 patients with prolapse of the anterolateral commissure; in both patients, commissural closure was performed instead. Because of anatomical reasons (n=1), calcification or fibrosis of the commissural segment (n=3) or according to surgeon preference (n=17), papillary muscle head repositioning was not attempted and another technique was used. In the latter cases, only limited commissural prolapse (without prolapse of the adjacent parts of the anterior and/or posterior mitral valve leaflet) was present that was suitable for correction by either the magic stitch technique or very limited commissural closure.

TABLE I. Overview of the site of commissural lesion (number of lesions=125) and surgical techniques used to address this for patients (n=105) with an intact subvalvular apparatus.

	Papillary muscle head reposition	Commissural plasty	PTFE neochords implantation	Papillary muscle shortening
Posteromedial commissure (n=73)	63 (86)	6 (8)	2 (3)	2 (3)
Anterolateral commissure (n=12)	6 (50)	5 (42)	1 (8)	0 (0)
Bicommissural (n=20)				
Posteromedial commissure (n=20)	18 (90)	2 (10)	0 (0)	0 (0)
Anterolateral commissure (n=20)	15 (71)	4 (20)	1 (5)	0 (0)
Combined (n=125)	102 (82)	17 (13)	4 (3)	2 (2)

Data are presented as n (%). Abbreviations: PTFE: polytetrafluoroethylene.

Eighty-eight patients in whom papillary muscle head repositioning was performed to address commissural prolapse presented the final study cohort. This includes 5 patients with bicommissural prolapse in whom this technique was combined with a different technique on the contralateral commissure. The preoperative patient characteristics are listed in **Table II**; in the final study cohort, 14 (16%) patients demonstrated limited commissural prolapse only.

TABLE II. Baseline characteristics.

Characteristic	Value (N=88)
Age (years)	62.8±12.5
Female gender	32 (36)
NYHA class	
I	30 (34)
II	43 (49)
III/IV	15 (17)
Atrial fibrillation	38 (43)
Renal impairment	
Moderate (CC 50-85 ml/min)	42 (48)
Severe (CC <50 ml/min)	5 (6)
Hypertension	44 (50)
Chronic lung disease	7 (8)
History of TIA or CVA	5 (6)
Peripheral vascular disease	1 (1)
Diabetes mellitus	4 (5)
Left ventricular end-diastolic diameter (mm)	57.3±7.2
Left ventricular end-systolic diameter (mm)	34.7±6.8
Impaired left ventricular ejection fraction (≤60%)	29 (33)
Range of commissural prolapse	
Extensive commissural prolapse	74 (84)
Limited commissural prolapse	14 (16)

Data are presented as n (%). Abbreviations: CC: creatinine clearance; CVA: cerebrovascular accident; NYHA: New York Heart Association; TIA: transient ischemic attack.

The study was approved by our Institutional Ethics Committee. Preoperative, intraoperative and postoperative data were prospectively collected in our computerized database and retrospectively analyzed. Intraoperative transesophageal and postoperative transthoracic echocardiography was standardly performed by an experienced cardiologist to document the intraoperative and postoperative result of mitral valve repair. Follow-up data were collected through clinical visits at our institution or affiliated clinics and hospitals and through questionnaires to patients.

Study endpoints

Early mortality was defined as mortality within 30-days after the operation or during the index hospitalization. Postoperative mortality and morbidity endpoints were defined according to the joint Society of Thoracic Surgeons, American Association for Thoracic Surgery, and European Association for Cardio-Thoracic Surgery Guidelines [13]. The severity of MR was evaluated using a multi-parametric integrative approach, including qualitative and quantitative assessments as currently recommended [14]. The severity of MR was graded on a 4-grade scale: Grade 1+ (mild), Grade 2+ (moderate), Grade 3+ (moderate-to-severe) and Grade 4+ (severe). The follow-up echocardiograms were re-evaluated by an experienced cardiologist (N.A.M.) for cases in which any significant MR was observed.

Surgical technique

All patients were operated through median sternotomy using standard techniques for extracorporeal circulation with ascending aortic and bicaval cannulation. Intermittent antegrade and retrograde warm blood cardioplegia was used for cardiac protection. The mitral valve was exposed via the trans-septal approach in most patients.

The technique of papillary muscle head repositioning has previously been described by Dreyfus et al. [10, 15]. We have previously shown the technical execution of this technique in patients with commissural prolapse [16]. In short, the papillary muscle head providing chordal support to the prolapsing commissure can be identified by the presence of fan-like chordae terminating at the free edge of the commissural scallop (**Figure 1**). First, the corresponding portion of the muscle head is split vertically. The desired amount of downward displacement towards the apex of the left ventricle corresponds to the height of prolapse determined on surgical analysis. Thereafter, a pericardial pledgeted 4-0 polypropylene U suture is placed in the mobilized papillary muscle head. This is then resutured to the base of the remaining papillary muscle head.

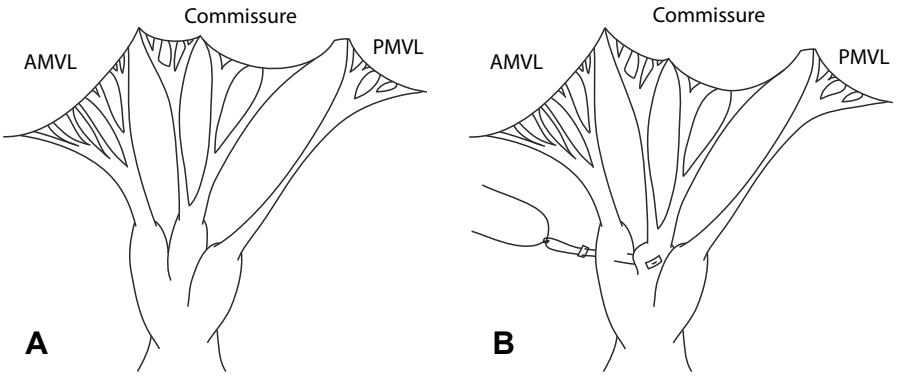

FIGURE 1. Schematic presentation of the papillary muscle head repositioning technique.

Additional mitral valve repair techniques and procedures performed are presented in **Table III**. Posterior mitral valve leaflet prolapse was addressed with quadrangular resection combined with posterior annulus plication (early in our series) or leaflet sliding technique (later in our series). Residual posterior mitral valve leaflet prolapse was addressed with the implantation of neochords. When the extent of excessive tissue was less pronounced, a more limited (triangular) resection and/or implantation of neochords were performed. Anterior mitral valve leaflet prolapse was addressed predominantly with the implantation of neochords. Ring annuloplasty was performed in all cases.

Statistical analysis

Continuous data are presented as mean ± standard deviation for normally distributed data or median and interquartile range (IQR) when not normally distributed. Categorical data are presented as counts and percentages. Survival and freedom from time-related events were estimated using the Kaplan-Meier method. Statistical analysis was performed using the IBM Statistics for Windows, version 23.0 (SPSS, Inc., IBM Corporation, Armonk, NY, USA).

TABLE III. Intraoperative data.

Variable	Value
Commissure (number of lesions=125)	
Papillary muscle head repositioning	120 (96)
Commissural plasty*	4 (3)
PTFE neochords*	1 (1)
Posterior mitral valve leaflet	
Triangular or quadrangular resection	22 (75)
Chordal shortening	1 (1)
Chordal transfer	3 (3)
PTFE neochords	23 (26)
Leaflet sliding	50 (57)
Indentation closure	13 (15)
Anterior mitral valve leaflet	
Triangular resection	1 (1)
Chordal shortening	1 (1)
Chordal transfer	2 (2)
PTFE neochords	45 (51)
Annulus	
Posterior annulus plication	36 (41)
Annular decalcification	9 (10)
Annuloplasty	88 (100)
Annuloplasty	
Physio ring[a]	68 (78)
Physio II ring[a]	16 (18)
Carpentier Classic[a]	1 (1)
Memo 3D[b]	2 (2)
Simulus semi rigid[c]	1 (1)
Annuloplasty ring size (mm)	
24-30	9 (10)
32-36	54 (50)
38-40	25 (40)
Concomitant procedures	
Tricuspid valve repair	53 (60)
Radiofrequency ablation for atrial fibrillation	35 (40)
Coronary artery bypass grafting	18 (21)
Aortic valve or root intervention	5 (6)
Ascending aorta replacement	3 (3)

*Data are presented as n (%). * In 5 patients with bi-commissural prolapse, papillary muscle head repositioning was combine with a different technique on the contralateral commissure. [a] Edwards Lifesciences, Irvine, CA, USA. [b] LivaNova, London, UK. [c] Medtronic, Inc, Minneapolis, MN, USA.*

RESULTS

Early clinical and valve-related results

There were 2 (2.3%) early deaths. The cause of death was multiple organ dysfunction syndrome, which developed as a consequence of severe postoperative distributive shock in 1 patient and periprocedural myocardial infarction resulting in acute biventricular failure in 1 patient.

Postoperative transthoracic echocardiography showed none or trivial MR in 73 (85%), mild (Grade 1+) MR in 12 (14%) and moderate (Grade 2+) MR in 1 (1%) patient. In the latter patient, who refused early reoperation, residual regurgitation was a consequence of posterior mitral valve leaflet restriction. Hemodynamically significant systolic anterior motion of the anterior mitral valve leaflet was absent in all patients.

Late clinical results

The median survival follow-up was 9.7 years (IQR 5.0-11.8) and was 99% complete (1 patient was lost to follow-up because of emigration). There were 18 late deaths. The cumulative actuarial survival rates at 1, 5, and 10 years were 94.3% [95% confidence interval (CI) 89.4%-99.2%], 89.2% (95% CI 82.5%-95.9%), and 74.3% (95% CI 64.1%-84.5%), respectively (**Figure 2**). The cause of death was end-stage heart failure in 1 patient (poor left ventricular function without significant recurrent MR was seen in this patient), intracranial bleeding in 1 patient, sudden unexplained death in 6 patients and ventricular fibrillation in 1 patient. One patient died due to an acute type A aortic dissection, 8 years after the initial operation. The patient underwent an emergent reoperation at another institution and died during the reoperation. The cause of death was not cardiac related in 8.

There were 5 thromboembolic events, 2 cerebrovascular accidents and 3 transient ischemic attacks. Four severe bleeding events occurred, including 1 case of intracranial bleeding resulting in death. In this patient, atrial fibrillation was the indication for long-term oral anticoagulation, and intracranial bleeding occurred at a supra-therapeutic international normalized ratio value. No cases of operated valve endocarditis occurred.

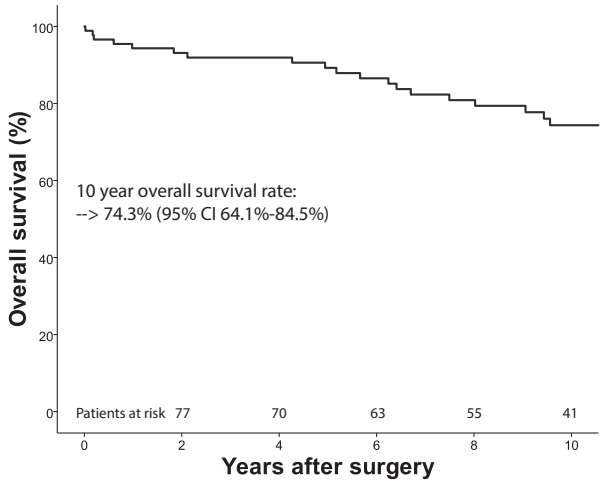

FIGURE 2. Overall survival.

Freedom from reintervention and recurrent mitral regurgitation

Five patients required late mitral valve reintervention during the follow-up period. The freedom from late reintervention rates at 1, 5, and 10 years were 98.7% (95% CI 96.2%-100%), 96.1% (95% CI 91.8%-100%), and 92.7% (95% CI 86.4%-99.0%), respectively (**Figure 3**). The indication for reintervention was recurrent MR in 4 patients and mitral valve stenosis in 1 patient (**Table IV**). Upon reoperation, no cases of recurrent commissural prolapse were documented. However, in 1 patient, in whom recurrent MR was a consequence of a combined *de novo* anterior mitral valve leaflet prolapse and posterior mitral valve leaflet restriction, surgical inspection revealed that posterior mitral valve leaflet restriction was partially caused by traction from the repositioned papillary muscle head. This observation was not encountered in any other patient.

The median echocardiographic follow-up time was 8.7 years (IQR 3.1-10.7) and was available in 91% of patients. Eleven (14%) patients developed recurrent MR during the follow-up period; at last follow-up echocardiography, 4 (5%) patients demonstrated Grade 2+ MR and 7 (9%) patients demonstrated ≥Grade 3+ MR. The freedom from ≥Grade 2+ MR rates at 1, 5, and 10 years were 97.5% (95% CI 94.0%- 100%), 92.6% (95% CI 86.3%- 98.9%), and 86.1% (95% CI 76.7%-95.5%), respectively. The freedom from ≥Grade 3+ MR rates at 1, 5, and 10 years were 98.7% (95% CI 96.2%-100%), 93.8% (95% CI 87.9%-99.7%), and 91.9% (95% CI 84.8%-98.9%), respectively (**Figure 3**). Four of the

7 (57%) patients in whom recurrent, ≥grade 3+ MR was seen underwent mitral valve reoperation. The other 3 (43%) patients were still alive and free from reoperation at the time of last follow-up.

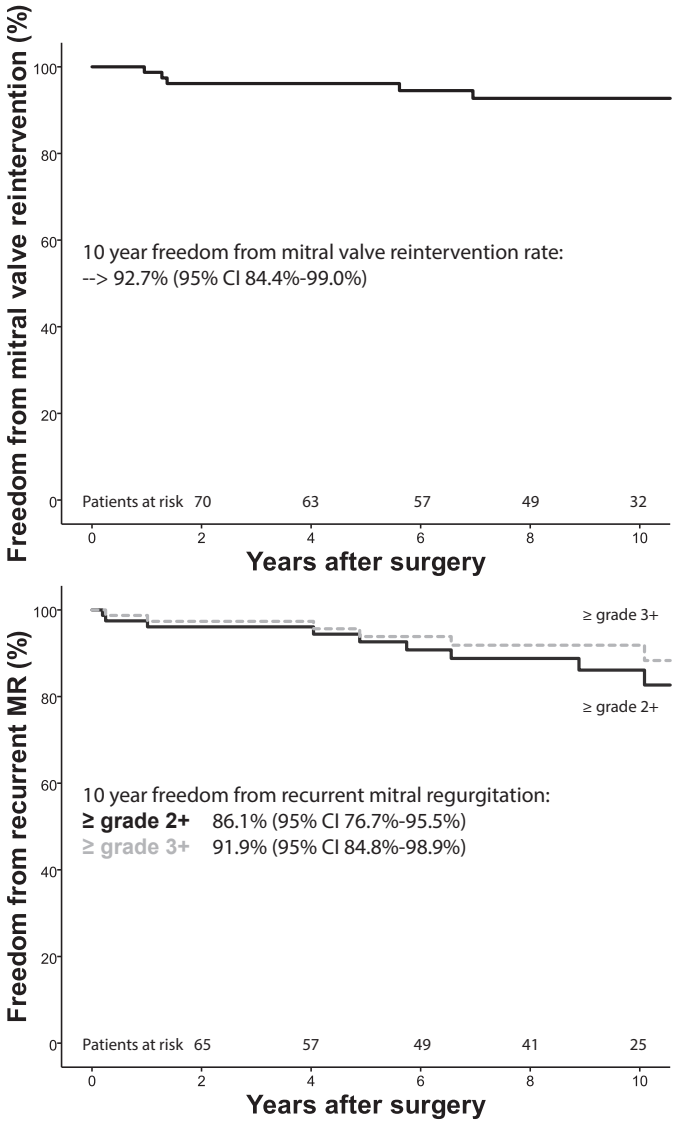

FIGURE 3. **Above:** freedom from late mitral valve reintervention. **Below:** freedom from ≥Grade 2+ and ≥Grade 3+ recurrent mitral regurgitation.

TABLE IV. Details on late reoperation.

	Year of initial surgery	Time to reoperation (years)	Indication for reoperation	Perioperative findings	Procedure performed	Outcome
1	2005	5.6	Recurrent MR	Ring dehiscence	MV re-repair	Survived
2	2005	1.4	Recurrent MR	AMVL restriction + PMVL pseudoprolapse	MV replacement	Survived
3	2005	1.0	Recurrent MR	PMVL restriction	MV replacement	Survived
4	2006	7.0	Recurrent MR	AMVL pseudoprolapse + PMVL restriction (partially a consequence of traction from the repositioned papillary muscle head)	MV replacement	Survived
5	2010	1.3	Mitral valve stenosis	Severe pannus formation	MV re-repair	Survived

Abbreviations: AMVL: anterior mitral valve leaflet; MR: mitral regurgitation; MV: mitral valve; PMVL: posterior mitral valve leaflet

Of the 14 patients with only isolated commissural prolapse, follow-up echocardiography was available in 13 [93%, mean follow-up 6.4 (IQR 3.0-9.5) years]. No recurrent MR was seen in any of these patients. One patient underwent late reoperation due to mitral valve stenosis, developing as a consequence of severe pannus formation.

DISCUSSION

Our data demonstrate that papillary muscle head repositioning presents a reproducible and reliable option for the treatment of commissural prolapse in patients with degenerative mitral valve disease. Furthermore, this technique can be used to address the majority of commissural lesions in these patients.

The technique of papillary muscle head repositioning was originally described by Dreyfus et al [11, 15]. They have compared the results of posterior papillary muscle head repositioning (n=60) against chordal shortening (n=40) in the posterior paramedial and paracommissural area in patients with non-isolated anterior mitral valve leaflet prolapse. At a mean follow-up of 26.4±24.2 months, excellent repair durability with low reoperation rates were reported with the papillary muscle head repositioning technique

[11]. Surprisingly, despite the documented good long-term results and versatility of this technique, this does not seem to be commonly in use to treat commissural lesions [2-5, 8].

We currently utilize papillary muscle head repositioning as the technique of choice for commissural prolapse in degenerative mitral valve disease. Due to evident reasons, this technique cannot be performed when the native chordae are ruptured or otherwise considered unsuitable for a durable repair. In these patients, we tend to address commissural prolapse with either commissural plasty or chordal replacement. In the absence of any of these observations, papillary muscle head repositioning is technically feasible in the vast majority of patients with degenerative mitral valve disease. In our experience, papillary muscle head repositioning was relatively less often performed at the level of the anterolateral commissure when compared to the posteromedial one. This is due to the fact that prolapse is normally less extensive at the level of the anterolateral commissure, making commissural prolapse at the anterolateral commissure repairable with a single magic stitch or very limited commissural closure. Hampered by the retrospective study design, we reason that the demonstrated percentage of patients in whom papillary muscle head repositioning was feasible in our experience is likely underestimated. The technique does necessitate a certain level of expertise, in particular at assessing the amount of leaflet prolapse and corresponding amount of papillary muscle head displacement needed. In our experience, all operations were performed by experienced mitral valve surgeons. Importantly, the technique was reproducible and a steep learning curve was observed even in surgeons previously unfamiliar with this technique.

In degenerative mitral valve disease, commissural prolapse is almost always accompanied by prolapse of the adjacent segments of the anterior and/or posterior mitral valve leaflet, an observation supported by our data and others as well [5, 12]. This prevented us to study the feasibility and durability of papillary muscle head repositioning only in cases of isolated commissural prolapse. However, as such cases are very rare, papillary muscle head repositioning should be seen as a technique complementary to other techniques performed to secure valve competency. Directly addressing the commissural region as a functional whole is an advantage of the papillary muscle head repositioning technique when compared to other techniques.

Previous studies have demonstrated changes in biochemical and mechanical properties of the myxomatous mitral valve chordae [17, 18]. In particular, increased glycosami-

noglycan content is responsible for the characteristic thickened appearance of the degenerated chordae. This also negatively alters their mechanical characteristics, causing them to fail at lower loads than normal mitral valve chordae [17]. As papillary muscle head repositioning includes preservation of these degenerated chordae, concerns on their long-term durability are justified. Clinical and echocardiographic follow-up in our patients demonstrated a low incidence of mitral valve reintervention and recurrent MR. Recurrent commissural prolapse was absent in all patients who underwent late reoperation. This makes us believe that despite impaired mechanical properties, chordae tendinae of degenerated mitral valves are suitable for a long-lasting repair. Our results, therefore, support the durability of the papillary muscle head repositioning technique previously described by Dreyfus et al. [10, 11, 15]. Furthermore, our results provide additional evidence on the long-term durability, reproducibility and versatility of this technique. Upon reoperation, retraction of the posterior mitral valve leaflet occurred secondary to excessive traction from the repositioned papillary muscle head in 1 patient. This could present a consequence of fibrotic changes of the papillary muscle following its mobilization and manipulation. As this was not seen in any other patient, we reason that the risk of developing this complication is low.

Commissural closure has been proposed as a technically non-challenging option to address commissural prolapse [3, 8]. De Bonis et al. previously reported their experience with 125 patients undergoing commissural closure with annuloplasty for isolated commissural prolapse [3]. They demonstrated excellent valve repair durability. Furthermore, follow-up echocardiography demonstrated low mean resting mitral valve gradients and no patients needed mitral valve reintervention for mitral valve stenosis during the follow-up period. On the other hand, others have reported modifications of this technique as recurrent MR can occur due to leaflet tearing [19]. Commissural closure will inevitably distort normal leaflet motion and induce excessive stress on the sutures and mitral valve leaflets. This implies that the technique –while considered technically not challenging- requires a certain level of expertise and might only be suited for cases of limited commissural prolapse. Commissural prolapse, on the other hand, most commonly occurs in combination with prolapse of the anterior and/or posterior mitral valve leaflet and is typically seen in patients with forme fruste or Barlow's disease.

Commissural closure inevitably results in a significant reduction of the circumference of the mitral valve opening area, leading to a 30% to 40% reduction of the mitral valve orifice area and possibly favoring dynamic mitral valve stenosis [8, 9]. Papillary muscle

head repositioning, on the other hand, restores normal leaflet motion, allows for a good surface area of leaflet coaptation, and does not reduce the mitral valve orifice area [9]. This provides a clear advantage over the commissural closure technique. It has previously been demonstrated that annuloplasty itself can cause exercise-induced mitral valve stenosis in cases of low indexed ring orifice area [20]. Efforts to preserve the maximal mitral valve orifice area seem to be justified.

As an alternative to papillary muscle head repositioning, leaflet resection with or without leaflet sliding can be performed to treat commissural prolapse. Shimizu et al. reported their experience with 122 patients with commissural prolapse [5]; leaflet resection was performed in 111 (91%) patients and was accompanied by leaflet sliding in 43 (35%) of these. They demonstrated good long-term valve repair durability with low reoperation and recurrent MR rates. We rarely utilize this technique in the setting of commissural prolapse in degenerative mitral valve disease as it is technically more challenging than other options that provide comparable results. However, in the uncommon cases of annular and leaflet calcification at the height of the commissural region, leaflet resection with sliding or commissural reconstruction might be unavoidable.

In case of ruptured native chordae tendineae, chordal replacement presents a reasonable primary alternative repair technique. This technique has documented good long-term durability and is also suitable as a primary strategy to address commissural prolapse in the setting of degenerative mitral valve disease [21]. In cases of degenerative mitral valve disease (and particularly Barlow's disease where commissural prolapse is most frequently present), the commissure is usually affected as a functional whole and leaflet prolapse expands to the adjacent parts of the anterior and/or posterior leaflet segments. As chordal replacement is targeted at resolving leaflet prolapse of only a limited length of the leaflet free edge, multiple neochords would be needed to address this issue. Therefore, we prefer to utilize papillary muscle head repositioning as a primary treatment strategy in this setting as a single maneuver can effectively resolve the issue. This characteristic also provides an additional benefit over surgical techniques (e.g. small leaflet resection or leaflet foldoplasty) that focus on the commissure only. As another alternative, chordal shortening can be performed in cases where native chordae are intact and considered suitable for a durable valve repair. This technique, however, is technically challenging, making it less attractive than the papillary muscle head repositioning technique [11].

In this study, we have focused only on patients who demonstrated commissural prolapse during echocardiographic and surgical valve analysis. In a small proportion of patients, there were some doubts regarding the extensiveness of changes in the commissural region. Typically very limited prolapse was seen in these patients and papillary muscle head repositioning was not primarily considered or performed. In several of these cases, residual commissural prolapse or billowing was seen on the saline test and addressed with commissural plasty or implantation of neochords as this needs to be resolved to secure optimal repair durability. Papillary muscle head repositioning presents a valuable technique in these cases as well and an aggressive approach to billowing of the commissures seems in our opinion justified.

LIMITATIONS

This is a single-center study with limitations inherent to the study design. Papillary muscle head repositioning was not initially considered in all patients with commissural prolapse. Therefore, the true feasibility of this technique might be underestimated. Not all patients were followed-up prospectively at our institution after undergoing surgery, resulting in differences in the frequency of clinical and echocardiographic follow-up. To overcome this shortcoming, echocardiographic studies in cases where any significant MR was reported were reassessed for regurgitation severity by an experienced cardiologist. We reason that any recurrent commissural prolapse would result in ≥Grade 2+ recurrent MR and thus be detected during follow-up. Due to the low number of patients in whom commissural abnormalities were addressed with repair techniques other than papillary muscle head repositioning, a comparison between both groups was not feasible. The durability of papillary muscle head repositioning seen in our experience is however in line with previous studies on this matter and supports the previously demonstrated good results of this technique.

CONCLUSIONS

Papillary muscle head repositioning is a reproducible technique that can effectively resolve commissural prolapse in in the majority of patients with degenerative mitral valve disease. The technique provides excellent long-term durability and the occurrence of recurrent commissural prolapse is highly unlikely.

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