Original Article

# Midterm outcomes of minimally invasive mitral valve surgery in a heterogeneous valve pathology cohort: respect or resect?

**Laina Passos[1], Thierry Aymard[1], Patric Biaggi[1], Mohammed Morjan[2], Maximilian Y. Emmert[3,4], Juerg Gruenenfelder[1], Diana Reser[1]**

[1]Heart Clinic Hirslanden, Zuerich, Switzerland; [2]Clinic for Cardiovascular Surgery, Heart Center Duisburg, Duisburg, Germany; [3]Deutsches Herzzentrum der Charite (DHZC), Department of Cardiothoracic and Vascular Surgery, Berlin, Germany; [4]Charité-Universitätsmedizin Berlin, Berlin, Germany

*Contributions:* (I) Conception and design: L Passos, T Aymard, J Gruenenfelder, D Reser; (II) Administrative support: All authors; (III) Provision of study materials or patients: L Passos, T Aymard, P Biaggi, J Gruenenfelder, D Reser; (IV) Collection and assembly of data: L Passos, D Reser; (V) Data analysis and interpretation: L Passos, D Reser; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

*Correspondence to:* Laina Passos, MD. Heart Clinic Hirslanden, Witellikerstrasse 40, 8032 Zürich, Switzerland.
Email: laina.bramazan@hotmail.com.

**Background:** Minimally invasive mitral valve surgery (MIV) through a right lateral thoracotomy has become the standard of care at specialized centers and might soon will be the only acceptable surgical treatment option in the future era of interventional procedures. The aim of our study was to analyze the outcomes of our MIV-specialized, single-center, mixed valve pathology cohort with regard to morbidity, mortality and midterm outcomes comparing two different repair techniques (respect versus resect).

**Methods:** Baseline and operative variables, postoperative outcomes and follow-up information about survival, valve competence and freedom from reoperation were retrospectively collected and analyzed. The repair cohort was divided into three groups (resection, neo-chordae and both) and compared for outcomes.

**Results:** Between July 22nd 2013 and May 31st 2022 a total of 278 consecutive patients underwent MIV. Out of those, we identified 165 eligible patients for the three repair groups: 82 patients (29.5%) had "resection", 66 "neo-chordae" (23.7%) and 17 "both" (6.1%). All preoperative variables were comparable between the groups. The predominant valve pathology of the entire cohort was degenerative disease with 20.5% Barlow's, 20.5% bi-leaflet and 32.4% double segment pathology. Bypass time was 164±47, cross-clamp time 106±36 minutes. All valves planned for repair (85.6%) were successfully repaired except for 13 resulting in a repair rate of 94.5%. Only 1 patient (0.4%) had to be converted to clamshell and 2 (0.7%) needed rethoracotomy for bleeding. Mean intensive care unit (ICU) stay was 1.8 days and hospital stay 10.6±1.3 days. In-hospital mortality was 1.1% and the incidence of stroke (1.8%). All in-hospital outcomes were comparable between the groups. Follow up was complete in 86.2% (n=237) for a mean of 3.7±0.8, up to 9 years. Five-year survival was 92.6% (P=0.5) and freedom from re-intervention 96.5% (P=0.1). All but 10 patients had mitral regurgitation less than grade 2 (95.8%, P=0.2) and all but two had less than New York Heart Association (NYHA) II (99.2%, P=0.1).

**Conclusions:** Despite a heterogeneous cohort with mixed valve pathologies, there is a high reconstruction rate, low short- and midterm morbidity, mortality and need for re-intervention with comparable outcomes of the resect and respect technique in a specialized MIV center.

**Keywords:** Minimally invasive mitral surgery; leaflet resection; neo-chordae

Submitted Dec 12, 2022. Accepted for publication Mar 03, 2023. Published online Jun 20, 2023.
doi: 10.21037/jtd-22-1796
**View this article at:** https://dx.doi.org/10.21037/jtd-22-1796

## Introduction

Minimally invasive mitral valve surgery (MIV) through a right lateral thoracotomy has become a standardized routine intervention in specialized centres worldwide. It was first described by Carpentier in 1996, facilitated by Chitwood in 1997 and commercialized by Mohr in 1998 by introducing a port-access technology, which improved visualization and reduced cross-clamp and cardio pulmonary bypass (CPB) times (1-3). Since then, MIV shows excellent long-term outcomes with faster recovery and equal repair rates, even in propensity-matched studies and meta-analyses when compared to sternotomy (4-7).

Amongst the many of the mitral valve repair techniques, the most reproducible and therefore most commonly used is leaflet resection ("resect") and/or the application of neo-chordae ("respect"). The former, which is an anatomical reconstruction, was pioneered by Carpentier and became the gold standard for mitral valve repair due to its excellent long-term results since 1983 (8). However, there are reports about impaired left ventricular function, reduced annular area, poor valve mobility and increased tissue stress with this technique (9).

Tirone David pioneered the neo-chordal technique with polytetrafluoroethylene (PTFE) sutures. It restores the geometry and movement of the valve and ventricle, provides a large orifice area, maximizes the coaptation line and decreases tissue stress. This method soon became an alternative to "resect" with also excellent long-term results (10-13).

In MIV, both repair techniques have their drawbacks: it is time consuming to resect and difficult to determine the correct length of an implanted neo-chordae. Therefore, Mohr and von Oppell developed the "Leipzig Loop Technique" to facilitate MIV with the use of premeasured chordae (14). However, there are reports about recurring prolapse with severe regurgitation, systolic anterior motion and neo-chordal rupture with this technique (15,16).

Since posterior mitral leaflet (PML) prolapse is the most common lesion and relatively simple to repair, most of the above mentioned studies report excellent long-term outcomes of this patient population with either the respect or resect technique (12,13,17,18). But it is quite different with anterior mitral leaflet (AML) and bileaflet mitral leaflet (BML) prolapse, which require a more complex repair and usually have less good results (11,12,17,19).

We are a MIV specialized centre and our patient population is heterogeneous with only 1/3 PML cases and we use respect and resect techniques depending on the valve pathology only. Therefore, the aim of our study was to analyse the outcomes of our real-world, single-centre MIV cohort with regard to morbidity, mortality and midterm outcomes comparing respect versus resect. We present this article in accordance with the STROBE reporting checklist (available at https://jtd.amegroups.com/article/view/10.21037/jtd-22-1796/rc).

### Highlight box

**Key findings**

- Our study of minimally invasive mitral valve surgery shows that different repair techniques result in comparable outcomes in a mixed leaflet pathology cohort, if they are applied depending on the valve pathology, resulting in a high reconstruction rate with low short- and midterm morbidity, mortality and need for re-intervention.

**What is known and what is new?**

- The respect and resect repair techniques are known to have excellent long-term outcomes described in highly selected P2 leaflet pathology cohorts.
- Our study shows that these outcomes can also be achieved in a mixed pathology all-comers real-world cohort, if the repair techniques are used depending on the valve pathology.

**What is the implication, and what should change now?**

- We believe that the reported excellent long-term outcomes of minimally invasive mitral valve repair might renders it the only remaining surgical competitor to the countless emerging interventional mitral valve solutions in the near future because of its superior results, even in elderly patients.

## Methods

The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the local institutional ethics committee board (Kantonale Ethikkommission Zürich) (No. 2017-01895) and individual consent was obtained from every patient included in this study. Using our institutional database, medical records of referring cardiologists and by calling the patients personally, we obtained retrospectively patient baseline and operative variables, in-hospital outcomes (30 days postoperatively) and follow-up information about survival, valve competence and freedom from reoperation.

Being specialized in MIV, we only consider a few contraindications for this approach, which are the following: grade III–IV sclerosis of the ascending or descending aorta, severe mitral annular calcifications, suspected adhesions in

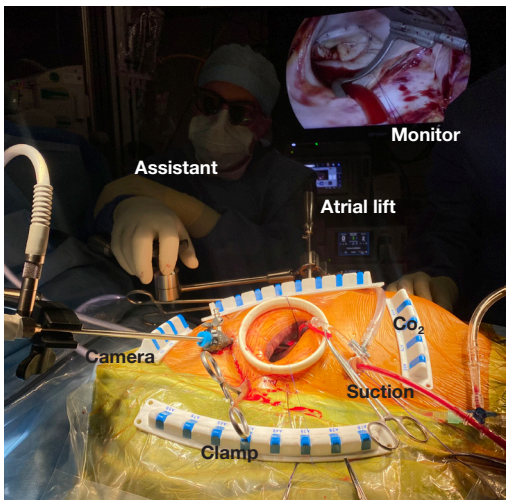


**Figure 1** Intraoperative setting: video assisted minimally invasive mitral valve surgery.

the right hemithorax (previous irradiation or right sided thoracic surgery) or severe coronary disease with acute or chronic ischemic mitral regurgitation, which requires concomitant bypass surgery through sternotomy,

The surgical technique has already been described previously and is just mentioned here briefly (20): CPB is established by percutaneous or surgical transfemoral cannulation using the Seldinger technique. *Figure 1* shows our operative setting: thoracotomy is performed in the 4$^{th}$ intercostal space using only a soft tissue retractor to minimize rib spreading in order to decrease postoperative pain. Caudally of the incision we place a port for the sucker and continuous $CO_2$ insufflation. Cranially, a port is placed for the camera. Transthoracic cross clamping (Chitwood clamp) is performed through an axillary stab incision and the patient is cooled to 34 ℃. Single shot antegrade cristalloide cardioplegia (Custodiol, Brettschneider) is given through a long aortic root cannula, which is also used as a vent for de-airing. Valve surgery is performed both under direct vision through the thoracotomy and by observing the monitor behind the assistant in front of the surgeon. An atrial lift retractor is applied parasternally with special care not to injure the mammary artery.

As a standard of care, we use an annuloplasty ring for annular stabilization in all cases (Physio II, Edwards Lifesciences, Irvine, CA, USA). In the presence of excess tissue in width (P2), we perform a small triangular resection in order to avoid tension or immobilization of the posterior leaflet and to allow a high coaptation line. In the absence of excess tissue and especially in the presence of flail leaflets, we use single Goretex sutures as Neochordae (Gore, Newark, Delaware, USA). The number of the sutures depends on the extent of the prolapsed tissue and normally ranges between two and four (they are applied to any posterior or anterior segments if necessary). If the valve does not present with too much excess tissue, the ring is implanted first and then evaluated for the need for further techniques. Besides "resection" and "neo-chordae", we use sliding plasty (P2), commissuroplasty (single suture), cleft-closure (any segments with single suture) and Alfieri-Stich, which can either be applied alone or in combination with the other above mentioned repair techniques. In addition to the mitral valve procedure, tricuspid valve repair, persistent foramen ovale (PFO) or atrial septal defect (ASD) closure, left atrial appendage closure (suture or clip) and cryoablation were performed when indicated.

All repair patients received warfarin for 3 months. Before discharge, all patients had an echocardiogram to evaluate the result of surgery. Regurgitation grade was defined as none, mild, moderate or severe (grade 0–4). After discharge the patients were followed by their referring cardiologists including clinical and echocardiographic assessment after 3 months, 1 year and annually thereafter. For follow-up, every patient and cardiologist were contacted by phone and email to obtain clinical and echocardiographic data. We closed the follow-up on May 31$^{st}$ 2022. At discharge there was 100% complete echocardiographic follow up, after 3 months 86.7%, at one year 79% and thereafter 87.8%.

### *Statistical analysis*

All statistical analyses were performed using R version 4.2.1 (The R Foundation for Statistical Computing). Categorical variables are presented as frequencies with percentages and compared between groups using Fisher's exact test. Continuous variables are presented as means with standard deviation (SD) and compared between groups using analysis of variance. Groups are compared using Kruskal-Wallis test. Overall survival and freedom from re-intervention are presented using Kaplan-Meier curves and compared using the log-rank test. Estimators at 5 years are presented with 95% confidence interval (CI). Two-sided P values less than 0.05 are considered statistically significant. In case of significant differences between the techniques, post-hoc comparisons between single techniques were performed using a Bonferroni correction to evaluate the pair of groups with significant difference (P<0.017 is considered

**Table 1** Baseline characteristics of the total cohort and the three repair groups

| | Total cohort | Resection | Chordae | Both | P |
|---|---|---|---|---|---|
| Number of patients | 278 | 82 | 66 | 17 | – |
| Age (years) | 65±12 | 60.9±12.5 | 63.5±11.6 | 58.2±14.5 | 0.20 |
| Euroscore II | 1.6±1 | 1.25±0.93 | 1.19±0.65 | 1.03±0.42 | 0.54 |
| Male patients | 164 (58.9) | 63 | 43 | 13 | 0.28 |
| Hypertension | 85 (30.6) | 22 | 12 | 4 | 0.47 |
| NYHA class (III/IV) | 61 (21.9) | 15 | 6 | 2 | 0.29 |
| LVEF (%) | 63±7.1 | 64.1±6.3 | 63.1±5.3 | 64.2±5.5 | 0.57 |
| Atrial fibrillation | 45 (16.2) | 9 | 6 | 1 | 0.93 |
| Coronary heart disease | 45 (16.2) | 8 | 9 | 2 | 0.72 |
| Previous PCI | 17 (6.1) | 4 | 2 | 0 | 0.84 |
| Previous stroke | 11 (4.0) | 4 | 0 | 0 | 0.21 |
| COPD | 9 (3.2) | 2 | 3 | 1 | 0.56 |
| Peripheral vascular disease | 5 (1.8) | 2 | 0 | 0 | 0.60 |
| Previous cardiac surgery | 3 (1.1) | 0 | 0 | 0 | – |

Mean with standard deviation or number of patients with percentage. NYHA, New York Heart Association; LVEF, left ventricular ejection fraction; PCI, percutaneous coronary intervention; COPD, chronic obstructive pulmonary disease.

significant). Continuous variables are presented as mean ± SD or median with range. Kaplan-Meier curves were used to analyse overall survival and freedom reoperation.

## Results

Between July 22nd 2013 and May 31st 2022, a total of 278 consecutive elective patients underwent video-assisted MIV through a right lateral mini-thoracotomy at our clinic performed by four surgeons (they have long overcome their learning curves in MIV, which took place in previous hospitals). In order to compare the outcomes of the three different repair techniques (respect versus resect), we defined three groups: resection (n=82), neo-chordae (n=66) and both (n=17).

*Table 1* shows the baseline characteristics: the preoperative variables of the repair groups were comparable. The total cohort presents with a mean age of 65±12 years, a median Euroscore II of 4 (0–13) and predominantly male patients (58.9%). Sixty-one (21.9%) were symptomatic with New York Heart Association (NYHA) functional class III/IV despite of a normal mean ejection fraction of 63%±7.1%, one third had hypertension (30.6%) and 16.2% had documented atrial fibrillation. Further comorbidities included coronary heart disease (16.2%) treated with percutaneous coronary intervention (PCI) (6.1%), previous stroke (4.0%), chronic obstructive pulmonary disease (COPD) (3.2%) and peripheral vascular disease (1.8%). Three patients (1.1%) had previous cardiac surgery (n=2 with previous mitral valve reconstruction years ago, n=1 with bypass surgery plus aortic valve replacement).

*Table 2* shows the valve pathology: all variables of the repair groups were comparable. The total cohort presented with mainly degenerative mitral valve disease (96.4%) with regurgitation (97.1%). One fifth of the patients had Barlow's disease (20.5%). The incidence of single segment pathology was 37.4%, of double segment pathology 32.4% and antero-posterior pathology 20.5%. Less than one third of the patients had posterior pathology only (28.4%). Annular calcification was present in 16.5%. Concomitant moderate tricuspid regurgitation occurred in 9.4% and severe regurgitation in 5.8% of the patients.

*Table 3* shows the intraoperative outcomes, which were also comparable between the repair groups. Overall, there was no intra-operative mortality. Mean cardiopulmonary bypass time was 164±47 minutes, cross-clamp time 106±36 minutes. One patient (0.4%) had to be converted to Clamshell due to bad exposure of the

**Table 2** Valve pathology of the total cohort and the three repair groups

| | Total cohort | Resection | Chordae | Both | P value |
|---|---|---|---|---|---|
| Mitral disease etiology | 278 (100.0) | 82 | 66 | 17 | – |
| Degenerative | 268 (96.4) | 82 | 65 | 17 | 0.50 |
| Functional | 8 (2.9) | 0 | 0 | 0 | – |
| Mixed | 2 (0.72) | 0 | 1 | 0 | 0.50 |
| Mitral endocarditis | | | | | |
| Acute | 2 (0.72) | 2 | 0 | 0 | 0.60 |
| Chronic | 3 (1.1) | 0 | 0 | 0 | – |
| Mitral regurgitation | 270 (97.1) | 82 | 66 | 17 | – |
| Mitral stenosis | 5 (1.8) | 0 | 0 | 0 | – |
| Regurgitation and stenosis | 3 (1.1) | 0 | 0 | 0 | – |
| Barlow's disease | 57 (20.5) | 14 | 12 | 4 | 0.80 |
| Flail leaflet | 123 (44.2) | 53 | 34 | 10 | 0.28 |
| Single segment pathology | 104 (37.4) | 38 | 32 | 9 | 0.90 |
| Double segment pathology | 90 (32.4) | 25 | 20 | 4 | 0.93 |
| Posterior leaflet pathology | 79 (28.4) | 26 | 24 | 9 | 0.24 |
| Antero-posterior pathology | 57 (20.5) | 13 | 12 | 3 | 0.95 |
| Commissural pathology | 23 (8.3) | 2 | 7 | 1 | 0.12 |
| Annular calcification | 46 (16.5) | 6 | 9 | 1 | 0.47 |
| Tricuspid valve regurgitation | | | | | |
| Moderate | 26 (9.4) | 5 | 6 | 0 | 0.53 |
| Severe | 16 (5.8) | 2 | 1 | 0 | 1 |

Number of patients with percentage.

valve (resection group). There was no need for conversion to sternotomy. Forty patients (14.4%) were planned for straight forward valve replacement due to advanced age, extensive calcification, sclerosis or infectious destruction of the leaflets. Out of 238 patients (85.6%), which were planned for mitral repair, 225 could be successfully repaired (</= mitral regurgitation grade 1 in the intraoperative transesophageal echocardiography) resulting in a 94.5% repair rate. Leaflet resection was performed in 99 patients (44.0%), neo-chordae in 83 (36.9%), combined resection and neo-chordae in 17 (7.6%). Further reconstruction techniques included sliding-plasty in 5.8%, cleft closure (41.7%) and commissuroplasty (12.0%). Four patients received an Alfieri stitch (1.4%). There was significantly less cleft-closures in the resection group compared to the chordae and both groups (P=0.03). A total of 13 patients (5.4%) had a failed repair and needed valve replacement as bailout procedure. Five patients from the resection group (5.7%), 1 from the chordae group (1.5%) and 3 from the both-group (15%) which was significantly different and worst for the both-group (P=0.045). Concomitant tricuspid valve repair was performed in 12.6%, cryo-ablation in 4.0%, left atrial appendage closure in 16.2% and patent foramen closure in 9.0%. Fifty-three patients (19%) received a valve replacement mostly with a biological prosthesis (n=50).

In-hospital outcomes are shown in *Table 4* and did not show any significant difference between the repair groups. Overall mean intensive care unit (ICU) stay was 1.8 days with a range of 1–32 days. Mean postop ejection fraction was 57%±8% and mitral gradient 3.1±0.4 mmHg. Five patients suffered a permanent stroke (1.8%, one in each group). There was three in-hospital deaths (1.1%): on post

 

**Table 3** Operative outcomes of the total cohort and the three repair groups

| | Total cohort | Resection | Chordae | Both | P |
|---|---|---|---|---|---|
| Bypass time (minutes) | 164±47 | 160±44 | 159±30 | 177±52 | 0.24 |
| Cross-clamp time (minutes) | 106±36 | 104±30 | 107±24 | 115±74 | 0.35 |
| Conversion | 1 (0.4) | 1 | 0 | 0 | 1 |
| To sternotomy | 0 | 0 | 0 | 0 | – |
| To clamshell | 1 (0.4) | 1 | 0 | 0 | 1 |
| Planned valve repair | 238 (85.6) | 87 (36.4) | 67 [28] | 20 (8.3) | – |
| Successful valve repair | 225 (94.5) | 82 (94.3) | 66 (98.5) | 17 (85.0) | 0.045 |
| Bonferroni correction | – | * | * | – | 0.23 |
| Bonferroni correction | – | * | – | * | 0.16 |
| Bonferroni correction | – | – | * | * | 0.03 |
| Leaflet resection | 99 (44.0) | 82 | 0 | 17 | – |
| Neochordae | 83 (36.9) | 0 | 66 | 17 | – |
| Resection + chordae | 17 (7.6) | 0 | 0 | 17 | – |
| Sliding plasty | 12 (5.3) | 11 | 0 | 1 | 0.002 |
| Cleft closure | 124 (41.7) | 39 | 44 | 12 | 0.03 |
| Bonferroni correction | – | * | * | – | 0.03 |
| Bonferroni correction | – | * | – | * | 0.11 |
| Bonferroni correction | – | – | * | * | 1 |
| Commissuroplasty | 27 (12.0) | 3 | 7 | 2 | 0.11 |
| Ring size (mm) | 34.3±4.8 | 34.3±1.9 | 34.7±2.6 | 35.5±2.7 | 0.13 |
| Valve replacement | 53 [19] | 5 | 1 | 3 | 0.045 |
| Mechanical | 3 (1.1) | – | – | – | – |
| Biological | 50 (18.0) | 5 | 1 | 3 | – |
| Tricuspid valve repair | 35 (12.6) | 5 | 4 | 0 | 0.7 |
| Cryoablation | 11 (4.0) | 1 | 1 | 0 | 1 |
| Left atrial appendage closure | 45 (16.2) | | | | |
| Clip | 20 (7.2) | 5 | 2 | 1 | 0.5 |
| Suture | 25 (9.0) | 3 | 6 | 0 | 0.26 |
| Foramen ovale closure | 25 (9.0) | 9 | 4 | 2 | 0.5 |

Mean with standard deviation or number of patients with percentage. In the case of significant P values (<0.05) while comparing all three groups, Bonferroni correction was performed to evaluate the pair of groups with significant difference (P<0.017 is considered significant). *, compared groups.

op day three and five due to cardiogenic shock despite extracorporeal membrane oxygenator (ECMO) implant (both in the resection group) and on day 30 due to severe pulmonary edema. Mean hospital stay was 10.6±1.3 days. One patient from the Chordae group had to be re-operated during hospital stay due to severe residual mitral regurgitation (MR) on day nine. Seven patients had a mitral regurgitation grade >2 (2.5%) at discharge (two in the

**Table 4** In-hospital outcomes of the total cohort and the three repair groups

| | Total cohort | Resection | Chordae | Both | P |
|---|---|---|---|---|---|
| In-hospital mortality | 3 (1.1) | 2 | 0 | 0 | 0.6 |
| Permanent stroke | 5 (1.8) | 1 | 1 | 1 | 0.4 |
| Tamponade | 1 (0.36) | 1 | 0 | 0 | 1 |
| Rethoracotomy | 2 (0.72) | 1 | 1 | 0 | 1 |
| Wound infection thorax | 0 | 0 | 0 | 0 | – |
| Groin seroma | 1 (0.36) | 0 | 0 | 0 | – |
| Intensive care stay (days) | 1.8 (1–32) | 1.6 (1–13) | 1.4 (1–7) | 1.7 (1–6) | 0.9 |
| Hospital stay (days) | 10.6±1.3 | 9.7±2.9 | 9.7±2.2 | 9.8±1.7 | 0.9 |
| Pacemaker implantation | 20 (7.2) | 1 | 2 | 0 | 0.7 |
| Post-op ECMO | 3 (1.1) | 1 | 0 | 0 | 0.3 |
| Need for re-operation | 1 (0.36) | 0 | 1 | 0 | 0.3 |
| LVEF postop (%) | 57±8 | 55±8 | 52±6 | 57±7 | 0.6 |
| Mitral regurgitation >2 | 7 (2.5) | 2 | 2 | 1 | 0.6 |
| Mitral gradient (mmHg) | 3.1±0.4 | 3.1±1.2 | 2.7±1.2 | 3±1 | 0.2 |

Mean with standard deviation, median with range or number of patients with percentage. ECMO, extracorporeal membrane oxygenator; LVEF, left ventricular ejection fraction.

resection and chordae group and one in the both group). Twenty patients needed a pacemaker implant (7.2%): 10 after mitral valve replacement and 10 with concomitant tricuspid repair. Both patients from the chordae group requiring a pacemaker had concomitant tricuspid repair.

Data from the follow up are shown in *Table 5* and did not show any difference comparing the repair groups. Overall mean follow up time was 3.7±0.8 years. Four patients (1.5%) refused to participate in the follow up and another four were lost mainly due to moving abroad. Follow up of the 275 survivors was completed in 237 patients (86.2%) by our referring cardiologists until May 31st 2022 (up to 9 years). Thirty patients (10.8%) were waiting for a follow up appointment.

Only four patients (1.7%) suffered from NYHA III/IV at 3 months, which further decreased over time (1.3% at 1 year and 0.8% after). Mitral regurgitation less than grade 2 could be confirmed in 95.8% of the followed up patients (n=227) and was constant over time. There was no relevant mitral stenosis. These outcomes were comparable between the groups.

*Figure 2* shows the calculated 5-year survival of 92.6% (95% CI: 87.1–98.4%) of the entire cohort and the three different repair groups which was comparable (P=0.5). There were 9 late deaths (3.8%): 1 cardiac, 4 non-cardiac (3 in the resection, 1 in the chordae group) and 4 unknown causes (1 in the chordae group). There was no cerebrovascular event or stroke. These outcomes were also comparable between the groups.

*Figure 3* shows freedom from re-intervention of 96.5% (95% CI: 93.0–100%) of the entire cohort and the three different repair groups which was also comparable (P=0.1). Eight patients (3.4%) needed a re-intervention for recurrence of mitral regurgitation grade >3, 2 due to endocarditis, 1 due to systolic anterior motion (SAM) and 5 due to recurrent prolapse. Two received a Mitra-Clip and one could be re-repaired. These outcomes were also comparable between the groups.

## Discussion

Our study shows that in a specialized MIV center, despite a heterogeneous, all-comers, real-world patient cohort with mixed valve pathologies, there is a high successful reconstruction rate with low morbidity and mortality, excellent midterm survival and low need for re-intervention with comparable results for respect and resect techniques.

There is still an ongoing debate about the durability of

 

**Table 5** Follow up outcomes of the total cohort and the three repair groups

| | Total cohort | Resection | Chordae | Both | P |
|---|---|---|---|---|---|
| Survivors | 275 | 80 | 66 | 17 | – |
| Patients lost to follow up | 4 (1.5) | 2 (2.5) | 2 (3.0) | 0 | 0.8 |
| Patients did not consent | 4 (1.5) | 2 (2.5) | 0 | 0 | 0.6 |
| Waiting for follow up | 30 (10.8) | 9 (11.2) | 7 (10.6) | 1 (5.9) | 1 |
| Patients followed up | 237 (86.2) | 7 (83.8) | 56 (84.8) | 16 (94.1) | 1 |
| Stroke | 0 | 0 | 0 | 0 | – |
| Mortality | 9 (3.8) | | | | |
| Cardiac cause | 1 (0.4) | 0 | 0 | 0 | – |
| Non-cardiac cause | 4 (1.7) | 2 (2.5) | 0 | 0 | 0.6 |
| Unknown cause | 4 (1.7) | 1 (1.3) | 2 (3.0) | 0 | 0.7 |
| Reintervention | 8 (3.4) | 0 | 3 (1.3) | 1 (0.4) | 0.1 |
| Endocarditis | 2 (0.8) | 0 | 0 | 0 | – |
| SAM | 1 (0.4) | 0 | 1 (0.4) | 0 | 0.5 |
| Recurrent prolapse | 5 (2.1) | 0 | 2 (0.8) | 1 (0.4) | 0.08 |
| NYHA III/IV | | | | | |
| 3 months | 4 (1.7) | 1 (0.4) | 0 | 1 (0.4) | 0.2 |
| 1 year | 3 (1.3) | 0 | 0 | 1 (0.4) | 0.1 |
| >1 year | 2 (0.8) | 0 | 0 | 0 | – |
| Mitral regurgitation > grade 2 | | | | | |
| 3 months | 10 (4.2) | 2 (0.8) | 4 (1.7) | 0 | 0.5 |
| 1 year | 10 (4.2) | 2 (0.8) | 4 (1.7) | 2 (0.8) | 0.2 |
| >1 year | 10 (4.2) | 2 (0.8) | 3 (1.3) | 3 (1.3) | 0.2 |
| Mitral gradient (mmHg) | | | | | |
| 3 months | 2.8±0.3 | 2.6±1.1 | 2.2±1.1 | 2.5±0.6 | 0.2 |
| 1 year | 2.8±0.3 | 2.6±1.5 | 2.4±1.4 | 2.2±0.6 | 0.6 |
| >1 year | 2.8±0.3 | 2.5±1 | 2.6±1.5 | 2.2±1.1 | 0.7 |

Number of patients with percentage, mean with standard deviation. SAM, systolic anterior motion; NYHA, New York Heart Association.

respect versus resect. In a randomized controlled trial of PML patients, Falk *et al.* showed similar results up to 1 year comparing resection and loops (13). In our study we were unable to find short- or mid-term differences between the two techniques either (even in a heterogeneous cohort) and therefore we are convinced that they should not be applied depending on the incision but on the valve pathology only. In the case of excessive tissue, it should be resected (predominantly in PML) and otherwise respected with chordae (predominantly AML, BML), which has already been emphasized earlier (15,21,22). In complex valve pathologies there might be the need to apply both or even further techniques (sliding plasty, commissuroplasty, cleft closure, chordae transfer, etc.).

It is known from the literature that mitral valve patients are a low risk patient population and therefore, when performed in specialized centres, MIV mitral repair is very safe with low in-hospital mortality and morbidity, which results in low need for re-intervention and a survival comparable to the general population (12,13,17,21). Our

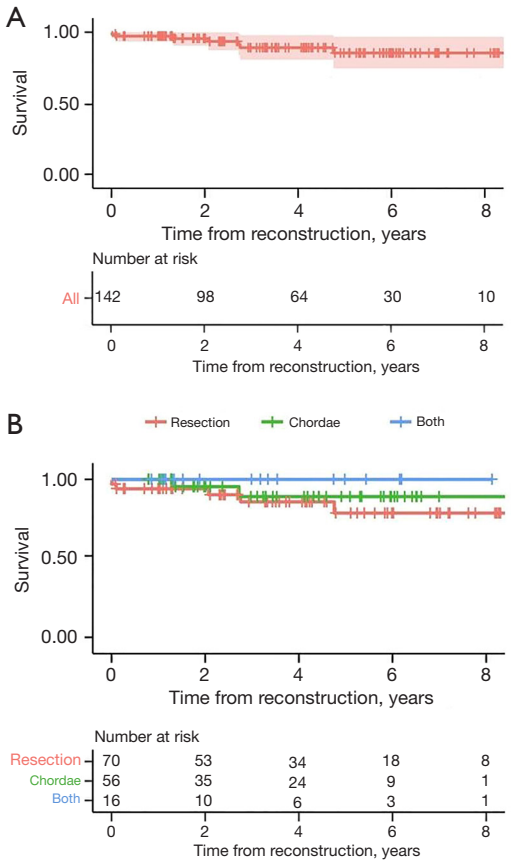


**Figure 2** Five-year survival of 92.6% (95% CI: 87.1–98.4%) of the entire cohort (A) and the three different repair groups (B), which did not show any significance (P=0.5). Resection 89.7% (95% CI: 80.9–99.4%), chordae 94.7% (95% CI: 87.8–100%), both (no death). CI, confidence interval.

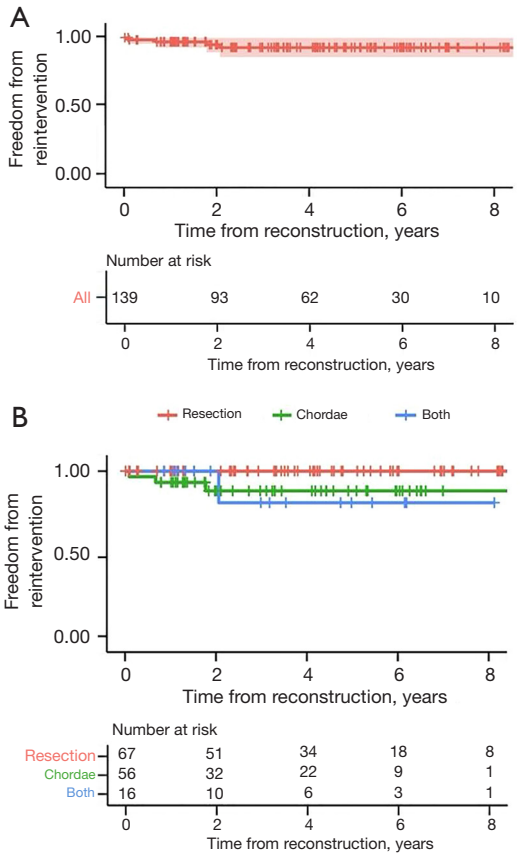


**Figure 3** Freedom from re-intervention of 96.5% (95% CI: 93.0–100.0%) of the entire cohort (A) and the three different repair groups (B), which did not show any significance (P=0.1). Resection (no re-intervention), chordae 93.7% (95% CI: 87–100%), both 90% (95% CI: 72.2–100%). CI, confidence interval.

study also includes low-risk patients and it can approve these excellent outcomes, which can also be explained by the fact that the surgeons have long overcome their learning curves in MIV, which took place in previous hospitals. We also believe that the excellent outcomes of MIV are the result of the good exposure of the valve trough a right lateral thoracotomy in contrary to sternotomy (6).

However, there is a reported difference in outcome within the mitral patient population, which depends on the valve pathology: the literature shows excellent long-term outcomes of PML patients and less good results for AML and BML (11,12,17,19). In our heterogeneous cohort with a high percentage of mixed valve pathologies [comparable to other studies: (11,15)], we were unable to show an increased overall short- or midterm mortality and morbidity and the outcomes were also comparable between the repair techniques (9,18).

Our CPB and cross clamp times are comparable or lower than in other studies despite of the high percentage of mixed valve pathologies and concomitant tricuspid surgery and we did not have any conversion to sternotomy, only one to clamshell (9,12). This might also be the result of the specialized expertise of the performing surgeons past their learning curves. Some studies report increased cross-clamp times in the chordae group, which however does not seem to translate into negative outcomes (18,21).

Our high successful repair rate of 94.5% of a heterogeneous cohort can also compete with other studies, which range between 90–100% depending on the valve pathology (9,12,13).

We report a median ICU stay of 1.8 days. Although it is comparable to other studies (18), we believe that it should

be lower. Unfortunately, we do not have an intermediate care unit yet. This was especially negative during the pandemic because we had to postpone many surgeries due to lack of ICU beds. However, the low-risk MIV population should encourage all centers in the future to establish a fast track standard operating procedure (SOP) with extubation in the operating room (OR) and transfer directly to the intermediate care unit.

Our in-hospital mortality (1.1%), stroke rate (1.8%) and rethoracotomy rate (0.7%) are low and comparable to other studies ranging between 0–5.7% (9,12,13,18,21).

We had one patient with severe MR who was successfully re-operated on day nine (chordae group), which is comparable to other studies (15). Seven patients (2.5%) had MR > grade 2 at discharge, which was comparable between the groups. Pfannmueller *et al.* reports more MR at discharge in the resection group compared to the loop-group (owing to the smaller coaptation area), which resulted in better survival but comparable freedom from re-intervention (21).

The mean hospital stay of 10.6 days (no difference between the groups) is unfortunately longer than we aim for because theoretically our patients could already be discharged on day seven. The reason for this delay is the lack of free rehab places. However, our hospital stay is comparable to other studies with up to 12.9 days (12,15).

Our midterm survival of 92.6% is comparable or better than in other studies ranging between 66–85% up to 18 years with worse outcomes for AML and BML and comparable for respect and resect (11,12,15,18). Pfannmueller *et al.* could show significantly better long-term survival in the loop group and independent predictors for cardiac mortality included repair technique, left ventricular ejection fraction (LVEF), age, infarction and female gender (21). David described age, hypertension and LVEF as risk factors for death in the long-term (11).

Our freedom from re-intervention of 96.5% is high and also comparable to other studies ranging between 90% and 96% with AML being the only independent predictor of reoperation (11,12,15,21). This finding makes us confident that re-intervention rate will remain low in the long-term because it has been described that the incidence mainly occurs at a mean of 15 months (23). In our cohort, 95.8% of the valves were competent (< grade 2 regurgitation) at the follow up closing date May 31$^{st}$ 2022 (up to 9 years). A propensity matched study described left ventricular end systolic diameter (LVESD) as an independent risk factor for recurrent severe regurgitation (18). David *et al.* could show that after 18 years, recurrent moderate or severe MR occurs in one third of the patients due to progressive degenerative disease and that LVEF <40% increases the risk (11).

We report only 4 patients in NYHA function class III/IV after 3 months (1.7%), 3 after 1 year (1.3%) and 2 after that (0.8%) although we found 10 patients with >2 grade mitral regurgitation (comparable between the groups). This is similar or superior to other studies, which describe up to 11% in long-term follow up (9,11,13).

A recent meta-analysis reports the use of larger annuloplasty rings to prevent SAM in the chordae group resulting in a lower postoperative gradient, better LVEF and decreased incidence of re-intervention (9). Our findings were comparable between the groups and the randomized controlled trial (RCT) of Falk *et al.* was also unable to show a long-term benefit of the loop-technique in this regard (13).

We believe that the reported excellent long-term outcomes of MIV might renders it the only remaining surgical competitor to the countless emerging interventional mitral valve solutions in the near future because of its superior results, even in elderly patients (24,25).

Our study has the following limitations: it is retrospective observational, single-centre, low-volume and uncontrolled, which allows for potential biases. Our centre is specialized in MIV, which makes this approach the standard of care for isolated or combined valve disease and therefore we were unable to include a control group operated through full sternotomy to allow further comparison. Therefore, these outcomes might only be reproducible in specialized MIV centres. Furthermore, the patient cohort consisted of low risk patients. Some very few patients were lost to follow up. The follow up echocardiograms were not performed by a core-lab, but by different institutions (referring cardiologists), which also allows for interpretational biases. We would not recommend a randomized controlled study to compare the different repair techniques because we believe that the choice depends on the presenting valve pathology and not the incision.

## Conclusions

Despite a rather low volume at a specialized MIV center and a heterogeneous real-world cohort of all-comers with mixed leaflet pathologies, our findings show a high reconstruction rate while using different repair techniques, low short- and midterm morbidity, mortality and need for re-intervention with comparable outcomes of resect versus respect.

## Acknowledgments

We would like to thank Prof. Burkhardt Seifert (retired

 

from the Division of Biostatistics of the University of Zürich) who provided us with the statistical analyses.
*Funding:* None.

## Footnote

*Reporting Checklist*: The authors have completed the STROBE reporting checklist. Available at https://jtd.amegroups.com/article/view/10.21037/jtd-22-1796/rc

*Data Sharing Statement*: Available at https://jtd.amegroups.com/article/view/10.21037/jtd-22-1796/dss

*Peer Review File*: Available at https://jtd.amegroups.com/article/view/10.21037/jtd-22-1796/prf

*Conflicts of Interest*: All authors have completed the ICMJE uniform disclosure form (available at https://jtd.amegroups.com/article/view/10.21037/jtd-22-1796/coif). The authors have no conflicts of interest to declare.

*Ethical Statement*: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the local institutional ethics committee board (Kantonale Ethikkommission Zürich) (No. 2017-01895) and individual consent was obtained from every patient included in this study.



## References

1. Carpentier A, Loulmet D, Carpentier A, et al. Open heart operation under videosurgery and minithoracotomy. First case (mitral valvuloplasty) operated with success. C R Acad Sci III 1996;319:219-23.
2. Chitwood WR Jr, Elbeery JR, Chapman WH, et al. Video-assisted minimally invasive mitral valve surgery: the "micro-mitral" operation. J Thorac Cardiovasc Surg 1997;113:413-4.
3. Mohr FW, Falk V, Diegeler A, et al. Minimally invasive port-access mitral valve surgery. J Thorac Cardiovasc Surg 1998;115:567-76.
4. Cheng DC, Martin J, Lal A, et al. Minimally invasive versus conventional open mitral valve surgery: a meta-analysis and systematic review. Innovations (Phila) 2011;6:84-103.
5. Davierwala PM, Seeburger J, Pfannmueller B, et al. Minimally invasive mitral valve surgery: "The Leipzig experience". Ann Cardiothorac Surg 2013;2:744-50. Erratum in: Ann Cardiothorac Surg 2014;3:436.
6. Goldstone AB, Atluri P, Szeto WY, et al. Minimally invasive approach provides at least equivalent results for surgical correction of mitral regurgitation: a propensity-matched comparison. J Thorac Cardiovasc Surg 2013;145:748-56.
7. Sündermann SH, Sromicki J, Rodriguez Cetina Biefer H, et al. Mitral valve surgery: right lateral minithoracotomy or sternotomy? A systematic review and meta-analysis. J Thorac Cardiovasc Surg 2014;148:1989-95.e4.
8. Carpentier A. Cardiac valve surgery—the "French correction". J Thorac Cardiovasc Surg 1983;86:323-37.
9. Mazine A, Friedrich JO, Nedadur R, et al. Systematic review and meta-analysis of chordal replacement versus leaflet resection for posterior mitral leaflet prolapse. J Thorac Cardiovasc Surg 2018;155:120-8.e10.
10. David TE. Replacement of chordae tendineae with expanded polytetrafluoroethylene sutures. J Card Surg 1989;4:286-90.
11. David TE, David CM, Lafreniere-Roula M, et al. Long-term outcomes of chordal replacement with expanded polytetrafluoroethylene sutures to repair mitral leaflet prolapse. J Thorac Cardiovasc Surg 2020;160:385-94.e1.
12. Seeburger J, Borger MA, Doll N, et al. Comparison of outcomes of minimally invasive mitral valve surgery for posterior, anterior and bileaflet prolapse. Eur J Cardiothorac Surg 2009;36:532-8.
13. Falk V, Seeburger J, Czesla M, et al. How does the use of polytetrafluoroethylene neochordae for posterior mitral valve prolapse (loop technique) compare with leaflet resection? A prospective randomized trial. J Thorac Cardiovasc Surg 2008;136:1205; discussion 1205-6.
14. von Oppell UO, Mohr FW. Chordal replacement for both minimally invasive and conventional mitral valve surgery

 

using premeasured Gore-Tex loops. Ann Thorac Surg 2000;70:2166-8.
15. Dreyfus GD, Dulguerov F, Marcacci C, et al. "Respect when you can, resect when you should": A realistic approach to posterior leaflet mitral valve repair. J Thorac Cardiovasc Surg 2018;156:1856-66.e3.
16. Bortolotti U, Celiento M, Pratali S, et al. Recurrent mitral regurgitation due to ruptured artificial chordae: case report and review of the literature. J Heart Valve Dis 2012;21:440-3.
17. Mohty D, Orszulak TA, Schaff HV, et al. Very long-term survival and durability of mitral valve repair for mitral valve prolapse. Circulation 2001;104:I1-7.
18. Ma J, Liu J, Wei P, et al. Quadrangular resection versus chordal replacement for degenerative posterior mitral leaflet prolapse. Ann Transl Med 2021;9:60.
19. Flameng W, Herijgers P, Bogaerts K. Recurrence of mitral valve regurgitation after mitral valve repair in degenerative valve disease. Circulation 2003;107:1609-13.
20. Reser D, van Hemelrijck M, Pavicevic J, et al. Repair rate and durability of video assisted minimally invasive mitral valve surgery. J Card Surg 2014;29:766-71.
21. Pfannmueller B, Misfeld M, Verevkin A, et al. Loop neochord versus leaflet resection techniques for minimally invasive mitral valve repair: long-term results. Eur J Cardiothorac Surg 2021;59:180-6.
22. Perier P, Hohenberger W, Lakew F, et al. Toward a new paradigm for the reconstruction of posterior leaflet prolapse: midterm results of the "respect rather than resect" approach. Ann Thorac Surg 2008;86:718-25.
23. Kudo M, Yozu R, Kokaji K, et al. Feasibility of mitral valve repair using the loop technique. Ann Thorac Cardiovasc Surg 2007;13:21-6.
24. Holzhey DM, Shi W, Borger MA, et al. Minimally invasive versus sternotomy approach for mitral valve surgery in patients greater than 70 years old: a propensity-matched comparison. Ann Thorac Surg 2011;91:401-5.
25. Külling M, Corti R, Noll G, et al. Heart team approach in treatment of mitral regurgitation: patient selection and outcome. Open Heart 2020;7:e001280.

**Cite this article as:** Passos L, Aymard T, Biaggi P, Morjan M, Emmert MY, Gruenenfelder J, Reser D. Midterm outcomes of minimally invasive mitral valve surgery in a heterogeneous valve pathology cohort: respect or resect? J Thorac Dis 2023;15(6):3013-3024. doi: 10.21037/jtd-22-1796