Twenty-Year Outcome after Mitral Repair Versus Replacement for Severe Degenerative Mitral Regurgitation.

Analysis of a Large, Prospective, Multicenter International Registry

Running title: Lazam et al.; Mitral Valve Repair vs. Replacement

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Abstract

**Background**—Mitral valve (MV) repair is preferred over replacement in clinical guidelines and is an important determinant of the indication for surgery in degenerative mitral regurgitation (MR). Yet, the level of evidence supporting current recommendations is low, and recent data cast doubts on its validity in the current era. Accordingly, the aim of the present study was to analyze very long-term outcome after MV repair and replacement for degenerative MR with a flail leaflet.

**Methods**—MIDA is a multicenter registry enrolling patients with degenerative MR with a flail leaflet in 6 tertiary European and US centers. We analyzed the outcome after MV repair (n=1,709) and replacement (n= 213), overall, by propensity score matching and by inverse probability-of-treatment weighting.

**Results**—At baseline, patients undergoing MV repair were younger, had more comorbidities and were more likely to present with a posterior leaflet prolapse than those undergoing MV replacement. After propensity score matching as well as after inverse probability-of-treatment weighting, the 2 treatments groups were balanced and absolute standardized differences were usually below 10%, indicating adequate match. Operative mortality (defined as a death occurring within 30 days from surgery or during the same hospitalization) was lower after MV repair than after replacement, both in the entire (1.3 vs 4.7%; p<0.001) and in propensity-matched population (0.2% vs 4.4%; p<0.001). During a mean follow-up of 9.2 years, 552 deaths were observed, of which 207 were of cardiovascular origin. Twenty-year survival was better after MV repair than after MV replacement, both in the entire (46% vs 23%, p<0.001) and in matched population (41% vs 24%, p<0.001). Similar superiority of MV repair were obtained in patients’ subsets based on age, sex or any stratification criteria (all p<0.001). MV repair was also associated with reduced incidence of reoperations and valve-related complications.

**Conclusions**—Among patients with degenerative MR with a flail leaflet, referred to mitral surgery, MV repair was associated with lower operative mortality, better long-term survival and fewer valve-related complications compared to MV replacement.

**Key-words:** mitral regurgitation; valve replacement; mitral valve repair
Clinical Perspective

What is new?

• We found that closely matched patients undergoing MV repair for degenerative MR with a flail leaflet have a lower operative mortality, a better long term survival and a similar risk of reoperation when compared to patients undergoing MV replacement.

• We also found that the association between MV repair and improved survival appears to be sustained 20 years following surgery and is observed in all the pre-specified age subgroups.

• Finally, we observed that MV repair is associated with a lower risk of valve-related complications than MV replacement.

What are the clinical implications?

• Our findings suggest that MV repair should be preferred over MV replacement for patients with degenerative MR and a flail leaflet.

• Whenever possible, patients should be referred to surgical centers experienced in performing MV repair.
Introduction

Mitral regurgitation (MR) is the most prevalent valvular disease in the western world.\textsuperscript{1,2} Degenerative MR with mitral prolapse commonly requires surgical correction,\textsuperscript{3} which alleviates grim prognosis of severe regurgitation,\textsuperscript{4-6} and restores normal life expectancy.\textsuperscript{7,8} Mitral valve (MV) repair is preferred to MV replacement and has been increasingly performed, based on comparative studies conducted in the 1980s showing repair superiority for operative mortality,\textsuperscript{9-11} left ventricular function,\textsuperscript{12} valve-related complications and long-term survival.\textsuperscript{13-15} Accordingly, the American and European guidelines recommend MV repair as a Class I indication (when it is expected to be durable) and more recently have additionally recommended to refer patients with severe degenerative MR to centers with expertise in valve repair.\textsuperscript{7,8}

Despite these recommendations, foundational evidence is rather low,\textsuperscript{7,8} and largely derived from non-randomized, single center studies utilizing crude statistical adjustments to control for differences in baseline characteristics between patients’ groups.\textsuperscript{16-20} Moreover, the causes of MR were non-uniform and may have been biased against outcome following valve replacement when repair was not feasible. In addition, these studies were conducted in an era when operative mortality was still high and chordal sparing was not routine, potentially adversely impacting left ventricular geometry and function.\textsuperscript{12} Conversely, in the current era, surgical risk has markedly decreased\textsuperscript{21} and preservation techniques during MV replacement, protective of left ventricular geometry and function, have markedly improved.\textsuperscript{22} Recent data comparing MV repair and replacement failed to demonstrate superiority of repair in specific subgroups, such as elderly patients,\textsuperscript{17,23} women,\textsuperscript{24} patients with endocarditis,\textsuperscript{25} or ischemic MR.\textsuperscript{26} They all have raised a contemporary challenge on valve repair superiority. If MV replacement is non-inferior to MV repair, consequences would be wide-ranging regarding treatment algorithms centered on valve reparability and regarding valve repair as a quality
measure for valve centers. Furthermore in the development of percutaneous techniques, insistence on percutaneous repair could be replaced by an easier and standardized percutaneous valve replacement.

For the purpose of this indispensable repair versus replacement comparison, to obtain promptly data on long-term outcome, we used the large multicenter Mitral regurgitation International DAtabase (MIDA) registry, which was designed to study patients with uniformly classified degenerative MR. Employing state-of-the-art statistical methods to balance risk factors between clinical cohorts, we tested the null hypothesis that valve repair and replacement provide similar short-and long-term outcomes.

Methods
Study design
All participating medical centers provided ethics and institutional review board approval. The study was conducted in accordance with institutional policies, national legal requirements, and the revised Helsinki declaration. The MIDA registry systematically merged the consecutive experience with degenerative MR of 6 tertiary centers: 2 in France (university hospitals in Amiens and Marseille), 2 in Italy (university hospitals in Bologna and Modena), 1 in Belgium (university hospital in Brussels), and 1 in the United States (Mayo Clinic, Rochester, Minnesota). Institutional review board authorizations were obtained before conducting the study. The study was conducted in accordance with the institutional policies and national legal requirements prevailing at the time of patient’s recruitment.

Patient population
Patients were enrolled in the MIDA registry if they had degenerative MR with a flail leaflet detected by a 2-dimensional transthoracic echocardiography between January 1, 1980 and December 31, 2005 and none of the following: ischemic MR; significant concomitant aortic
valve disease, congenital heart diseases, mitral stenosis and prior valve surgery.

The MIDA registry currently includes 2,472 patients. From this initial cohort, 1,922 patients who underwent either MV repair (n=1,709) or MV replacement (n=213) were included in the present analysis. Patients only treated medically (n=538), aged < 18 years (n=2) or with incomplete datasets (n=10) were not considered for inclusion.

**Surgical Procedure**

Surgical methods to repair the MV evolved over the 35-year study period. In the first half of the study, posterior leaflet prolapses were mostly corrected by resection and suture repair of the involved portion of the posterior leaflet, whereas anterior leaflet prolapses were corrected by either chordal shortening, chordal transfer, or commissural annuloplasty. In recent years, fewer and smaller resections of the posterior leaflet were used to correct posterior leaflet prolapses. In both anterior and posterior leaflet prolapses, insertion of artificial Gore-Tex neochordae to resuspend the prolapsing segments progressively became the standard surgical approach. Throughout the study period, leaflet surgery were always supplemented by some form of remodeling annuloplasty, by use of either semi-rigid or rigid rings in the European centers and by use of a flexible posterior annuloplasty bands at the Mayo Clinic.

**Echocardiography**

Transthoracic echocardiograms were performed within routine clinical practice as previously described. The severity of MR was assessed semiquantitatively on a scale from 1 to 4 by Doppler echocardiography. Diagnosis of flail leaflet was based on failure of leaflet coaptation, with rapid systolic movement of the involved leaflet tip within the left atrium.

**Outcomes.**

The primary end-point was all-cause mortality and secondary end-points were operative mortality, and valve-related complications (reoperations, thromboembolism, major bleeding, infective endocarditis). Definitions of these complications have been published previously.
Follow-up

Events were collected through direct review of clinical data, patients’ interview, follow-up letters and questionnaires. Causes of death were adjudicated by review of death certificates, physician and hospital notes, and autopsy reports.

Statistical analysis

All statistical analyses were performed using the SPSS 22, NCSS 2007, R version 3.0.2 (IPW package version 1.0-10) softwares. Continuous variables were expressed as mean±1 SD and compared with a 2-sided Student’s t-tests and categorical variables were summarized as frequency percentages and analyzed by chi-square tests. Long-term survival was computed with the Kaplan-Meier method and compared using the log-rank chi-square test. Cox proportional hazards regression models were used to determine the association between MV repair and outcomes. Subgroup analyses were conducted with the use of tests for interactions in the Cox regression model. A significance level of 0.05 was assumed for all statistical tests.

Propensity score matching

Variables that were associated with survival as indicated in univariate Cox models were used for calculating propensity scores.29,30 The propensity for MV repair was then estimated using a logistic regression model with the response variable being surgery MV repair (yes/no). The covariables used to build the propensity score were age, gender, diabetes, smoking habits, dyslipidemia, arterial hypertension, previous surgery, history of endocarditis, Charlson sum, leaflet involvement, New York Heart Association functional class, left ventricular ejection fraction, concomitant CABG, atrial fibrillation, pulmonary hypertension. A single propensity score was generated for each patient and used to select pairs of patients with matched propensity scores in the two surgery groups (2:1 match) within a caliper of 0.19 standard deviations of the propensity score. For this purpose, we used the greedy, nearest neighbor matching algorithm included in the psmatch routine. Bias reduction and balance between the
groups of patients with MV repair and MV replacement was assessed with standardized
differences of covariates. An absolute standardized difference below 10% indicates a small
imbalance.

**Inverse probability-of-treatment weighting**

Using the same baseline characteristics for the propensity score calculation allowed case-
weight estimation with a logistic regression model to predict the inverse probability of having
a MV repair. The case weights balanced the cohorts for an inverse probability-of-treatment
weighting analysis that included all patients with available data. Weighted t-tests and
weighted chi-square tests were used in the inverse probability-of-treatment weighting
analyses to compare continuous or categorical variables in the surgery groups. Standardized
differences were calculated to compare baseline characteristics in the surgery groups for the
original and the inverse probability-of-treatment weighting adjusted cohort.31

Cox proportional hazard regression models were adjusted for inverse probability
weights32,33 to determine the impact of the type of surgery on survival. Survival models were
further stratified by age groups: <65 years, 65-74 years, >75 years. To account for variation
in medical centers, Cox models were used with center as clusters in the models.34 The
proportional hazards assumption in the Cox models was assessed with Schoenfeld residuals;
the model fit was evaluated with martingale and Cox-Snell residuals. A 2-sided P value of
<0.05 was considered statistically significant. Finally, subgroup analyses were conducted
with the use of for interactions tests in the Cox regression model.

**Results**

**Baseline characteristics**

Baseline characteristics of the overall population and of the subset of propensity score-
matched population are shown in Table 1. Although some baseline differences were noted
between the MV repair and replacement groups before propensity score matching or inverse probability-of-treatment weighting adjustments, the 2 groups were well balanced after matching by propensity score as well as after inverse probability-of-treatment weighting adjustment, and absolute standardized differences were usually below 10%, indicating adequate match (see supplemental Figure 1).

**Operative mortality**

Operative mortality (defined as a death occurring within 30 days from surgery or during the same hospitalization) occurred overall in 33 patients (1.7%) and was lower after MV repair (1.3%, 23/1709) than after MV replacement (4.7%, 10/213, p<0.001). In the propensity matched cohort, operative mortality was also lower in the MV repair (0.2%, 1/410) than in the MV replace group (4.4%, 9/205, p<0.001).

**Long-term survival**

During a mean follow-up of 9.4 years (range 4.4 - 18.1 years) a total of 552 deaths were observed, of which 207 were of cardiovascular origin. Overall survival of the total population was 75% (95%CI, 73%-77%) at 10 years and 43% (95%CI, 37%-48%) at 20 years.

Ten- and 20-year overall survival of the unmatched cohort was also significantly better after MV repair (77% [95%CI,75%-80%] at 10 years and 46% [95%CI, 39%-52%] at 20 years) than after MV replacement (Figure 1A, 57% [95%CI, 49%-64%] at 10 years and 23% [95%CI, 14%-32%] at 20 years, p<0.001). Multivariable Cox model for the overall cohort adjusting for age, left ventricular ejection fraction, Charlson index, New York Heart Association class III-IV, atrial fibrillation, concomitant bypass surgery and previous heart surgery confirmed again that MV repair was associated with higher survival (Table 2).

Propensity score matching of the MV repair and replacement groups yielded 615 patients (2:1 matching). Direct comparison of survival in matched groups (with identical age and comorbidity index) confirmed higher survival after MV repair (76% [95%CI,71%-81%]
at 10 years and 41% [95%CI, 28%-54%] at 20 years) than after MV replacement (57% [95%CI, 49%-65%] at 10 years and 24% [95%CI, 14%-33%] at 20 years, p<0.001) (Figure 1B). Using the inverse probability-of-treatment weighting Cox model, MV repair was again associated with better survival (Table 2). Twenty-year inverse probability-of-treatment weighting-adjusted survival was significantly better after MV repair than after MV replacement (47% [95%CI, 29%-59%] vs 31% [95%CI, 9%-65%], p<0.001, Figure 1C).

**Impact of MV repair on long term survival in different age groups.**

To confirm that the survival advantages associated with MV repair were independent of age, we separated the study population into 3 pre-specified age groups. Post-operative survival was better after MV repair than after MV replacement in each of these age subgroups (Figure 2 A-to-I), both in the overall and the propensity-matched population. In patients ≥75 years, the survival advantage brought about by MV repair was initially modest but increased over time and was overall significant. Multivariable Cox models for each age subgroups adjusting for the same parameters as in the overall population, confirmed that MV repair was associated with better survival irrespective of age. Similar results were obtained using inverse probability-of-treatment weighting Cox models (Table 2).

**Subgroup analyses of long-term survival (Figure 3)**

The survival benefit associated with MV repair was consistently observed in the following subgroups: women versus men, those aged <65 years versus 65-74 years versus ≥75 years, those with isolated posterior leaflet prolapses vs those with either anterior or bi-leaflet prolapses (see supplemental Figure 2), those with and without coronary risk factors, those without guidelines triggers for surgery. The beneficial effects associated with MV repair were also found to be independent of the calendar year of operation (<1995 versus 1995-2000 versus ≥2000).
Freedom from reoperation

During follow-up, 95 MV reoperations were observed of which 78 were indicated for a recurrent significant MR (69 in the MV repair group), 10 for infective endocarditis, 3 for thromboembolism, and 4 for mitral stenosis. Figure 4 shows MV reoperation free survival among the MV repair and replacement groups.

Freedom from recurrent MR

Data on recurrent MR after MV repair was available in 1480 patients. During follow-up, 115 of these patients developed 3+ MR (including 69 patients who needed reoperation). Twenty-year freedom from 3+ MR after MV repair was 88% [95%CI, 86%-90], 85% [95%CI, 82%-88%] and 87% [95%CI, 85%-89%], respectively in the total population, in the matched cohort and in the IPW-adjusted cohort (see supplemental Figure 3).

Freedom from valve related complications

During the follow-up period, 152 embolic events (transient ischemic attacks or strokes) and 47 gastrointestinal bleeding events (all patients receiving warfarin) occurred. Sixteen patients developed infective endocarditis. Twenty-year freedom from valve-related events (ie, stroke, bleeding, and endocarditis) was 83% [95%CI, 80%-86%] after MV repair and 50% [95%CI, 32%-66%, p<0.001] after MV replacement (Figure 5). Similar results were obtained in the matched and inverse probability-of-treatment weighting-adjusted cohorts. Twenty-year freedom from endocarditis was also better after MV repair than after MV replacement (see supplemental Figure 4).

Discussion

The MIDA registry is a prospective, non-interventional, multicenter, international registry that includes all consecutive patients diagnosed in routine practice with degenerative MR with a flail leaflet at 6 tertiary referral centers from Europe and the United States.627 To the
best of our knowledge, it is the largest registry in the world specifically designed to
investigate pure MV regurgitation with a flail mitral leaflet. By enrolling consecutive patients
both in Europe and in the United States, it is also the only one whose results are potentially
applicable to patients from both continents. The present analysis indicates that closely
matched patients undergoing MV repair for degenerative MR with a flail leaflet have a lower
operative mortality, a better long term survival (total mortality decrement of approximately
50%) and a similar risk of reoperation when compared to patients undergoing MV
replacement. Long-term, the results are congruent by all methods used (direct comparison,
propensity score matching, inverse probability weighing). Furthermore, the survival benefit
associated with MV repair appears to be sustained 20 years following surgery and is observed
in all the pre-specified age subgroups.

Current AHA/ACC and ESC guidelines strongly recommend MV repair as the
preferred surgical method to treat severe degenerative MR.7,8 Although the evidence
supporting these recommendations is largely derived from single center observational series,
the observed superiority of MV repair is so strong that the guidelines consider a low
likelihood of achieving a durable repair as a legitimate reason to refer patients to centers with
significant experience in MV repair or to delay surgery until more advanced stages of the
disease.7,8 To date, no randomized trials comparing MV repair and replacement have been
conducted in patients with degenerative MR.7,8 While results of the Cardiothoracic Surgical
Trials Network trial failed to reveal an outcome benefit of MV repair over MV replacement
in patients with ischemic MR, raising more than legitimate concerns as to the objective
superiority of MV repair,26 this condition is a disease of the ventricle and as such, valve
repair is likely not as influential. Several retrospective studies have reported better outcomes
after MV repair than after MV replacement,10,24,35,36 while others failed to demonstrate any
superiority of one over the other approach.17,23-26 These diverging results are most likely
related to the retrospective nature of these studies, the small number of patients included, the mixing of patients with MR of various etiologies, the potential for referral biases in single center studies and the lack of appropriate statistical analyses to compensate for the absence of randomization. Our study is thus unique, not only because of its large sample size and its multicenter design, but also because it exclusively concentrated on the outcome of patients with degenerative MR with a flail leaflet. We also used state-of-the-art statistical methods to minimize the consequences of the lack of randomization, taking advantage of our large sample size and employing both propensity score matching and inverse probability-of-treatment weighting to obtain comparable treatment cohorts. Inverse probability-of-treatment weighting allows working with the entire cohort by weighing patients according to mismatched characteristics and thereby avoiding loss of power. Using this approach, we obtained well-balanced treatment groups, allowing comparison of long-term outcomes in both treatment arms and eventually confirming the beneficial effects associated with MV repair. The results are self-explanatory and strongly support the use of MV repair to treat patients with severe degenerative MR with a flail leaflet.

The present study also shows that MV repair can be undertaken with low operative mortality and morbidity, and good long-term survival. It also shows that the survival advantage resulting from MV repair over replacement is independent of age. However, in patients ≥75 years old, the survival advantage associated with MV repair increased progressively after surgery, suggesting that patients symptomatic but with short life expectancy for other reasons may also be treated by valve replacement. These results somewhat differ from those of previous investigators who did not observe a similar time lag in the benefits from MV repair, possibly because enrolling patients with different baseline characteristics. Finally, the present study shows that the survival advantage associated with MV repair is independent of the year of surgery, thus suggesting little effect of learning.
curve, as well as independent of the presence or absence of guideline triggers, which suggests that, even in the sickest patients, MV repair outperforms MV replacement despite longer bypass et cross-clamp times.

**Study limitations**

This study has some limitations which should be acknowledged. First, despite the prospective nature of the MIDA registry, the completeness of our follow-up data and the use of sophisticated statistical methods to reduced biases, our patients were not randomized between MV repair and replacement and the number of patients undergoing replacement was significantly smaller. Accordingly, we cannot exclude the possibility that unaccounted confounding factors contributed to our results. A prospective randomized trial would undoubtedly provide a more definite demonstration of the superiority of mitral reconstruction. However, at this point in the history of mitral surgery, the present study provides solid scientific evidence while waiting for such a trial to be performed. Second, the time frame of our study was very long (35 years), which implies that the surgical techniques as well as the criteria to quantify MR severity have changed over the years. Although this allowed long-term results to be reported, it also forced us to lump together outcomes of patients with different baseline characteristics or treated by different surgical techniques. The observation that MV repair outperformed MV replacement independently of the year of surgery is quite reassuring in this regard. It indeed suggests that the good results of MV repair are largely independent of the surgical techniques used as long as a competent MV is obtained at the end of surgery. Finally, the MIDA registry involves mostly high-volume surgical centers with expertise in mitral valve evaluation and repair. Whether centers less specialized or with lower surgical volume may provide similar outcome cannot be ascertained. While at present it is essential to factor into practice the benefits of mitral repair in specialized centers in all subsets of patients with flail leaflets, it will be important to verify
using collaborative studies that similar benefits can be obtained in less specialized centers, in
the future.

Conclusions

Data from the international MIDA registry demonstrate that in patients with severe
degenerative MR with a flail leaflet, MV repair is associated with lower operative mortality
and better long-term survival compared to MV replacement. The benefits of MV repair were
confirmed in every age subgroups and independently from the era of the operation. These
data support current recommendations and substantiate the contention that, when feasible,
MV repair should be the preferred treatment of severe degenerative MR and should remain a
central condition of treatment algorithms and quality measure of valve centers.37

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Grazia

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Disclosures

None
References


Table 1. Baseline Characteristics by Treatment Cohort

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<th>Characteristic</th>
<th>Overall population</th>
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<th>Inverse Probability-of-treatment Weighting Cohort</th>
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<td>Repair (n=1,709)</td>
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<td>Demographics</td>
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**Table 2.** Patient outcomes from cohort Cox regression models

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<td>0.48 [0.33-0.70]</td>
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Figure Legends

**Figure 1.** Kaplan-Meier survival curves comparing 20-year overall postoperative survival among patients undergoing MV repair (solid line) or MV replacement (dashed line). Panel A shows survival in the overall population, Panel B in the propensity score matched cohorts and Panel C in the IPW-adjusted cohorts. Numbers at bottom indicate patients at risk.

**Figure 2.** Kaplan-Meier survival curves comparing 20-year overall postoperative survival among patients undergoing MV repair (solid line) or MV replacement (dashed line). Graphs are horizontally stratified according to age groups (< 65 years, 65-74 years and ≥ 75 years). Graphs on the left hand side show survival in the overall population. Those on the center show survival in the propensity matched cohorts. Finally, graphs on the right hand side show survival in the IPW-adjusted cohort. Numbers at bottom indicate patients at risk.

**Figure 3.** Hazard ratios for all-cause mortality according to demographic and clinical characteristics. The horizontal lines indicate 95 percent confidence intervals.

**Figure 4.** Kaplan-Meier survival curves comparing 20-year freedom from mitral reoperation among patients undergoing MV repair (solid line) or MV replacement (dashed line). Panel A shows survival in the overall population, Panel B in the propensity score matched cohorts and Panel C in the IPW-adjusted cohorts. Numbers at bottom indicate patients at risk.
Figure 5. Kaplan-Meier survival curves comparing 20-year freedom from valve related complications (thromboembolism, endocarditis or major bleeding) among patients undergoing MV repair (solid line) or MV replacement (dashed line). Panel A shows survival in the overall population, Panel B in the propensity score matched cohorts and Panel C in the IPW-adjusted cohorts. Numbers at bottom indicate patients at risk.
Overall population

Overall survival (%)

Time (years)

MV repair vs. MV replacement

MV repair: 1709, 1458, 680, 202, 33
MV replacement: 213, 154, 74, 31, 10

p < 0.001
Overall population - < 65 years

Overall survival (%)

Time (years)

MV repair

MV replacement

MV repair 758 701 356 128
MV replacement 73 60 40 22

p<0.001
Matched cohorts - < 65 years

Overall survival (%)

MV repair
MV replacement

Time (years)

MV repair
MV replacement

162
71
146
59
77
39
24
21

p=0.009
IPW-adjusted cohorts - < 65 years

Overall survival (%)

Time (years)

MV repair

MV replacement

p < 0.001

MV repair: 742, 686, 349, 127, 28
MV replacement: 72, 59, 39, 22, 10
Overall population - 65-74 years

Overall survival (%)

Time (years)

MV repair
MV replacement

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p=0.001
Matched cohorts - 65-74 years

Overall survival (%)

MV repair

MV replacement

Time (years)

MV repair 145 129 61 13
MV replacement 79 56 27 8

p=0.001
Overall population - ≥ 75 years

Overall survival (%)

Time (years)

MV repair
MV replacement

p<0.001

MV repair: 387, 278, 85, 59
MV replacement: 58, 38, 7
IPW-adjusted cohorts - ≥ 75 years

Overall survival (%)

Time (years)

MV repair

MV replacement

p = 0.003

MV repair 379

MV replacement 57

273

84

38

7

15

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Hazard ratio
Matched cohorts

Freedom from reoperation (%)

- MV repair
- MV replacement

Time (years)

MV repair: 410, 313, 150, 48
MV replacement: 205, 139, 58, 25

p = 0.51
IPW-adjusted cohorts

Freedom from reoperation (%)

Time (years)

MV repair 1709
MV replacement 213

MV repair 1370
MV replacement 143

MV repair 620
MV replacement 61

MV repair 177
MV replacement 25

p = 0.98
Freedom from valve-related complications (%)
Matched population

Freedom from valve-related complications (%) vs Time (years)

- MV repair
- MV replacement

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<th>Time (years)</th>
<th>MV repair</th>
<th>MV replacement</th>
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p = 0.001
Twenty-Year Outcome after Mitral Repair Versus Replacement for Severe Degenerative Mitral Regurgitation. Analysis of a Large, Prospective, Multicenter International Registry.
Siham Lazam, Jean-Louis Vanoverschelde, Christophe Tribouilloy, Francesco Grigioni, Rakesh M. Suri, Jean-Francois Avierinos, Christophe de Meester, Andrea Barbieri, Dan Rusinaru, Antonio Russo, Agnès A. Pasquet, Hector I. Michelena, Marianne Huebner, Joseph Maalouf, Marie-Annick Clavel, Catherine Szymanski and Maurice E. Enriquez-Sarano
On behalf of the MIDA investigators

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**Supplemental figure 1:** Absolute standardize differences comparing covariate values for patients undergoing MV repair and those undergoing MV replacement before and after propensity score matching (left panel) and before and after IPW adjustment (right panel).

**Matched cohort**

**IPW cohort**

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**Supplemental figure 2:** Kaplan-Meier survival curves comparing 15-year overall postoperative survival among patients undergoing MV repair (solid line) or MV replacement (dashed line). Upper row: patients with anterior or bileaflet prolapse; lower row patients with posterior leaflet. Numbers at bottom indicate patients at risk.
**Supplemental figure 3:** Kaplan-Meier survival curves showing 20-year freedom from 3+ recurrent MR among patients undergoing MV repair. Numbers at bottom indicate patients at risk.

**Supplemental figure 4:** Kaplan-Meier survival curves comparing 20-year freedom from endocarditis among patients undergoing MV repair (solid line) or MV replacement (dashed line). Numbers at bottom indicate patients at risk.