2772-9931
https://doi.org/10.1016/j.atssr.2025.05.019

Valve: Short Report

Evolution of Minimally Invasive Mitral Valve Repair: 30-Year Experience From a High-Volume Center

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ABSTRACT

BACKGROUND Minimally invasive mitral valve repair (MVr) is a reproducible, widely adopted, and routinely performed surgical procedure. It is often performed in combination with tricuspid valve (TV) surgery. However, evidence on long-term results and their evolution over time is limited. This study evaluated whether outcomes of isolated minimally invasive MVr or minimally invasive MVr with concomitant TV surgery have improved over the last decades.

METHODS All patients undergoing minimally invasive MVr between 1996 and 2023 were included and split into 5 periods depending on the year of surgery (period 1, 1996–2001; period 2, 2002–2007; period 3, 2008–2013; period 4, 2014–2019; period 5, 2020–2023). The primary study outcome was 10-year survival during different periods. A subanalysis was performed for patients undergoing concomitant TV surgery.

RESULTS A total of 5559 patients with a median age of 59 years (interquartile range, 50–68 years) were included. Among them, 66.0% (n = 3217) of these patients were male, and 12.4% (n = 687) underwent combined MVr and TV surgery. The 30-day mortality steadily improved, ranging from 0.3% in period 5 to 1.1% in period 1. The 10-year estimated survival ranged from 68.1% in period 1 to 83.7% in period 4 (log-rank $P < .0001$). The estimated 1- and 10-year survival in patients with concomitant TV surgery steadily improved, with the lowest survival in period 1 (1-year, 62.3%; 10-year, 8.9%) and the highest survival in period 4 (1-year, 92.5%; 10-year, 62.7%).

CONCLUSIONS Minimally invasive MVr surgery, isolated or in combination with TV surgery, is a safe and reproducible surgical approach with low complication rates, infrequent conversion to sternotomy, and excellent early and long-term survival.

(Ann Thorac Surg Short Reports 2025;3:1040–1044)

Minimally invasive mitral valve repair (MVr) surgery has been widely adopted worldwide over the last decades, thus making it available to a broader patient population. This technique is reproducible, and if performed routinely, it is safe and has the same

Accepted for publication May 27, 2025.

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surgical results as a median sternotomy, besides the known benefits of minimally invasive surgery.[1] Although the complexity of cardiac surgery continuously increases, surgeons are forced to adopt the least invasive and most effective strategies in managing mitral valve (MV) disease to offer patients the best treatment options while remaining competitive. Evidence on the long-term results of minimally invasive MVr surgery and the evolution of outcomes since adopting minimally invasive MVr surgery is limited. This study aimed to present a 3-decade experience, report temporal trends, and compare early and 10-year survival during different study periods after minimally invasive MVr surgery. We hypothesize that outcomes after minimally invasive MVr surgery have continuously improved.

IN SHORT

- Minimally invasive MVr is safe and reproducible with low complication and 30-day mortality rates.
- The outcomes of both minimally invasive isolated MVr and MVr with concomitant TV surgery have continuously improved over the last decades.

PATIENTS AND METHODS

The study was approved by the ethics committee of the University of Leipzig, Leipzig, Germany (Institutional Review Board No. 476/19-ek, November 19, 2019). Because it was a retrospective study, individual informed patient consent was waived. The data were acquired through our institutional database and analyzed retrospectively. We included all patients who were undergoing minimally invasive MVr surgery, including patients with concomitant tricuspid valve (TV) surgery, ablation for atrial fibrillation, and atrial septal closure at our institution between March 1996 and December 2023. Exclusion criteria were age $\leq$18 years and concomitant surgical procedures other than those stated under the inclusion criteria.

To compare temporal trends between different periods, the whole cohort was divided into 5 periods: period 1, 1996 to 2001; period 2, 2002 to 2007; period 3, 2008 to 2013; period 4, 2014 to 2019; and period 5, 2020 to 2023. All patients underwent minimally invasive surgery following our standard protocol, which was previously published.[2]

The primary study outcomes were early survival and 10-year survival after minimally invasive MVr during the different periods. A subgroup analysis was performed to analyze survival in patients undergoing MV surgery with concomitant TV surgery.

All statistical analyses were performed using R Statistical Software (version 4.3.2, R Core Team). Categorical variables were expressed as frequencies and percentages and were compared using the χ^2 or Fisher exact test, depending on expected frequencies. Continuous normally distributed variables were expressed as mean (SD), and nonnormally distributed variables were expressed as median (interquartile range). Variables were compared using an unpaired Student *t* test, analysis of variance, and the Kruskal-Wallis test. We conducted a Kaplan-Meier survival analysis to estimate survival, and periods were compared using the log-rank test. The distribution was evaluated using the Shapiro-Wilks test. *P* values $<$.05 were considered significant.

RESULTS

A total of 5559 patients were included, with 431 (8.8 %) in period 1, 1291 (26.5%) patients in period 2, 1685 (34.6%) in period 3, 1018 (20.9%) patients in period 4, and 447 (9.2%) patients in period 5; all 5559 patients underwent minimally invasive MVr without concomitant TV surgery. A total of 687 (12.4%) patients underwent combined MVr and TV surgery, with the highest number of combined procedures in period 3 (n = 344; 17.0%) and the lowest in period 1 (n = 15; 3.4%). The baseline patient characteristics remained similar over the whole study period. The median age was 59 years (interquartile range, 50-68 years), and 66.0% (n = 3217) patients were male. There was no difference between the cohorts regarding left ventricular function or end-systolic and end-diastolic left ventricular diameter. The incidence of atrial fibrillation at baseline decreased over the decades (period 1, n = 200 [47%]; period 5, n = 110 [25%]), a decline that could be attributed to a higher proportion of patients having mitral stenosis in the earlier cohorts. Concomitant surgery for atrial fibrillation was the highest in periods 3 (n = 447; 21.0%) and 5 (n = 79; 15.0%). Severe tricuspid regurgitation was most frequent in periods 2 (n = 107; 7.6%) and 3 (n = 156; 8.5%), and the median left ventricular ejection fraction was 61% (interquartile range, 55%-67%), not varying across periods. Average cross-clamp times (median, 72 minutes), bypass times (median, 120 minutes), and procedural times (median, 167 minutes) remained constant throughout the study. Conversion to sternotomy was required in 0.2% of cases. Early in-hospital outcomes steadily

improved over time, with overall 30-day mortality being 1.1%, the highest in period 1 (n = 12; 2.9%) and the lowest in period 5 (n = 1; 0.3%). Postoperative stroke occurred in 1.1% of overall patients, with the lowest incidence in periods 3 (1.1%) and 4 (0.4%); thoracic wound healing disorder occurred in 1.2% of all patients, and perioperative myocardial infarction occurred in 0.2%, with rates constant over the entire study period.

Groin complications at the cannulation site, including lymph fistula, impaired wound healing, and vascular injuries requiring repair, were lowest in period 2 (1.3%), highest in period 4 (5.6%), and decreased in the most recent period (3.4%). The median follow-up was 9 years and was complete for the survival end point. The estimated 1-year survival ranged from 94.7% in period 1 to 98.1% in period 5 (log-rank $P < .001$). The 10-year estimated survival ranged from 68.1% in period 1 to 83.7% in period 4 (log-rank $P < .0001$) (Figure 1). The estimated 1- and 10-year survival in patients with concomitant TV surgery steadily improved, with the lowest survival in period 1 (1-year, 62.3%; 10-year, 8.9%) and the highest survival in period 4 (1-year, 92.5%; 10-year, 62.7%) (Figure 2).

COMMENT

The current report delivers additional evidence to the field of minimally invasive MV surgery and highlights the continuously improving outcomes of this surgical approach over time. Studies published by Götte and colleagues[3] and Feirer and colleagues[4] from high-volume centers report similar 1-year (98.8% in both studies) and 10-year (83.1%-91.6%) survival rates. Despite increasing surgical complexity over time reflecting the greater number of patients who require concomitant procedures, outcomes have continuously improved after minimally invasive MV surgery, either as an isolated procedure or with concomitant TV surgery.

The surgical technique has remained mainly similar over the last decades. After implementing the loop technique for chordal replacement in the early 2000s, our center adopted this technique for nearly all cases when the valve pathology is suitable, following the "respect" rather than "resect" strategy with good long-term results.[5] The chordal replacement is always stabilized using a semirigid annuloplasty ring. However, a few changes have

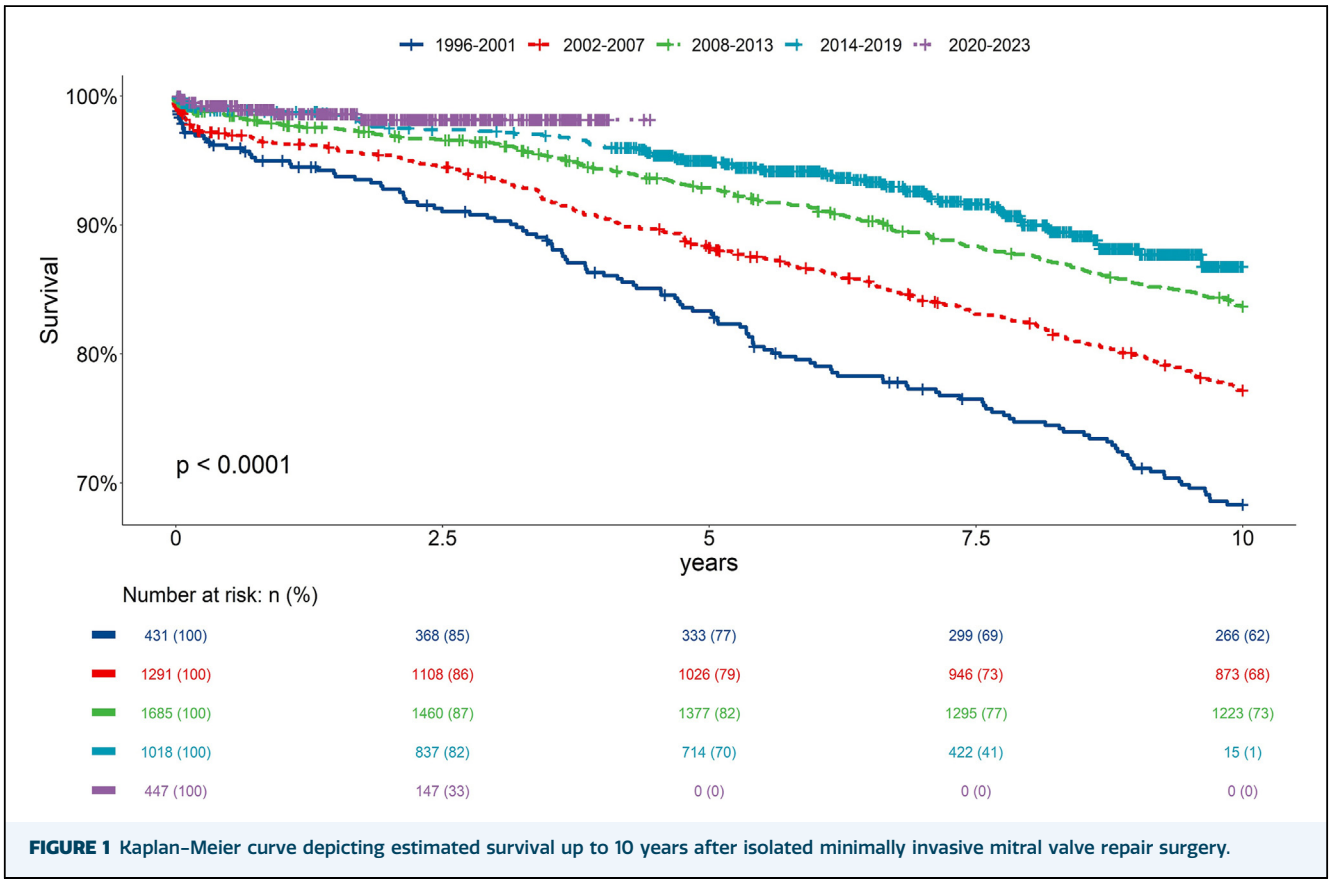

FIGURE 1 Kaplan-Meier curve depicting estimated survival up to 10 years after isolated minimally invasive mitral valve repair surgery.

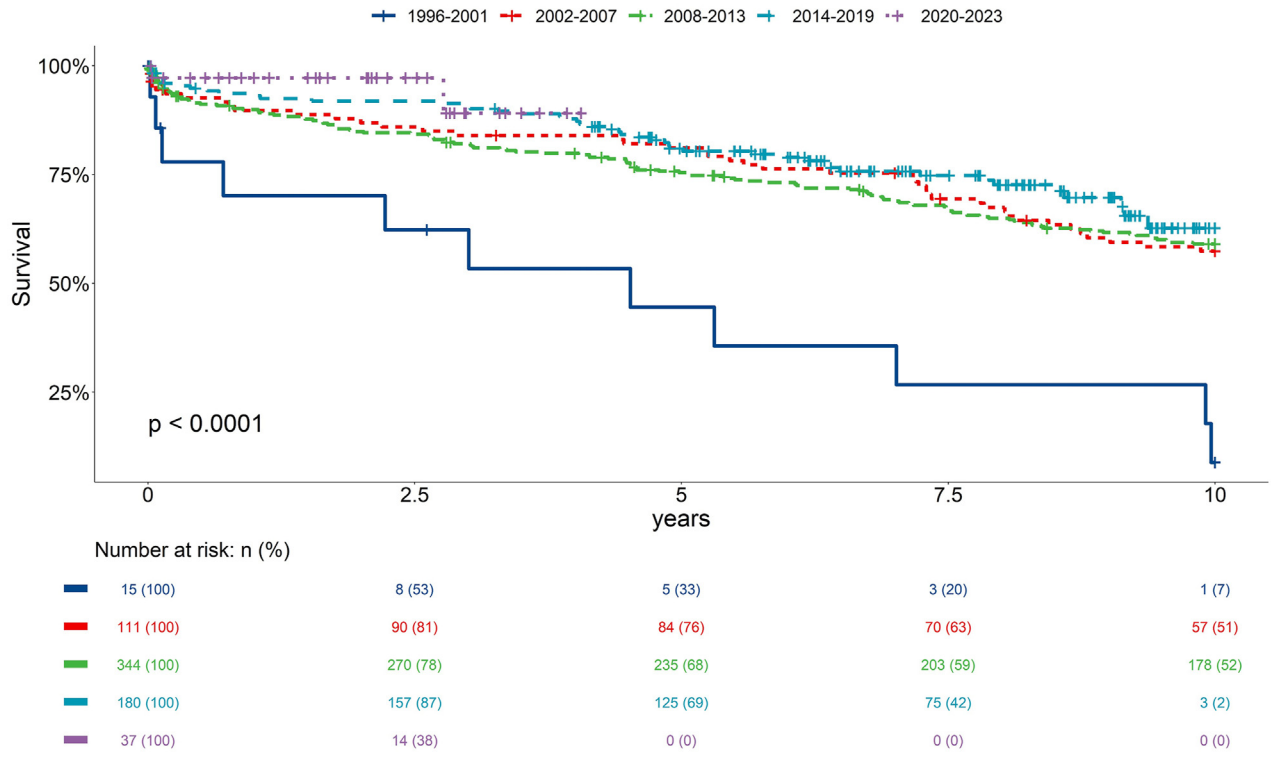

FIGURE 2 Kaplan–Meier curve depicting estimated survival up to 10 years after minimally invasive mitral valve repair and tricuspid valve surgery.

been made over the last decades in response to technical and scientific advancements. After identifying the posterior annulus, especially in the P3, area as the most common location of annuloplasty ring dehiscence, more careful suture placement was implemented regarding depth and spacing during annuloplasty.[6]

Improved endoscopic technology and soft tissue retractors have allowed for more minor surgical incisions. Double-lumen intubation was discontinued entirely from our practice because of the associated risk of unilateral lung edema. As a result, this postoperative complication is hardly ever observed.

The incidence of groin complications at the cannulation site changed over time in our study cohort, with a trend toward an increased complication rate in period 4 and a decrease in the complication rate in period 5. To minimize groin complications associated with surgical cut-downs for cannulation, we initiated the implementation of ultrasound-guided percutaneous cannulation of the femoral vessels and the use of closure devices. For the past 5 years, percutaneous cannulation has become the standard of care at our institution, and this may explain the reduction in groin complications.[7] Our observed groin complication rate of 3.4% is comparable to recently published data.[4]

In addition to the foregoing technical changes, the increasing experience of individual surgeons and the institution with this approach could explain the constantly improving outcomes over the last decades.

The present study, being retrospective, is susceptible to all the inherent weaknesses and limitations of this study design. Additionally, we cannot account for the variability caused by the effect of multiple surgeons with varying experience and surgical volumes who operated on the patients from this cohort over the last 3 decades. Furthermore, follow-up for the most recent cohort is limited to only a few years. Moreover, we lack long-term echocardiographic follow-up. Large, multicenter, randomized control trials would be required to evaluate the actual benefits of minimally invasive MVr.

In conclusion, minimally invasive MVr surgery is a safe and reproducible surgical approach with low complication rates, infrequent conversion to sternotomy or failed MVr, and excellent early and long-term survival.

FUNDING SOURCES

The authors have no funding sources of interest to disclose.

DISCLOSURES

Michael A Borger reports a relationship with Edwards Lifesciences Corporation that includes: consulting or advisory and speaking and lecture fees; with Medtronic Inc that includes: consulting or advisory and speaking and lecture fees; with Abbott Vascular that includes: consulting or advisory and speaking and lecture fees; and with Artivion that includes: consulting or advisory and speaking and lecture fees. All other authors declare that they have no conflicts of interest.

REFERENCES

1. Akowuah EF, Maier RH, Hancock HC, et al; UK Mini Mitral Trial Investigators. Minithoracotomy vs conventional sternotomy for mitral valve repair: a randomized clinical trial. *JAMA*. 2023;329(22):1957-1966. https://doi.org/10.1001/jama.2023.7800

2. Davierwala PM, Seeburger J, Pfannmueller B, et al. Minimally invasive mitral valve surgery: "the Leipzig experience". *Ann Cardiothorac Surg*. 2013;2:744-750 https://doi.org/10.3978/j.issn.2225-319X.2013.10.14. Published correction appears in *Ann Cardiothorac Surg*. 2014;3:436.

3. Götte J, Zittermann A, Deutsch MA, et al. Early and late results after surgical mitral valve repair: a high-volume center experience. *Thorac Cardiovasc Surg*. 2024;72:624-630. https://doi.org/10.1055/a-2266-7677

4. Feirer N, Kornyeva A, Lang M, et al. Non-robotic minimally invasive mitral valve repair: a 20-year single-centre experience. *Eur J Cardiothorac Surg*. 2022;62:ezac223. https://doi.org/10.1093/ejcts/ezac223

5. 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;59:180-186. https://doi.org/10.1093/ejcts/ezaa255

6. Noack T, Kiefer P, Vivell N, et al. Annuloplasty ring dehiscence after mitral valve repair: incidence, localization and reoperation. *Eur J Cardiothorac Surg*. 2020;57:300-307. https://doi.org/10.1093/ejcts/ezz219

7. Saeed D, Gadelkarim I, Otto W, et al. Percutaneous versus open surgical cannulation for minimal invasive cardiac surgery; immediate postprocedural outcome analysis. *JTCVS Tech*. 2022;16:28-34. https://doi.org/10.1016/j.xjtc.2022.08.021