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Minimally invasive approach compared to re sternotomy for mitral valve surgery in patients with prior cardiac surgery: retrospective multicentre study based on the Netherlands Heart Registration

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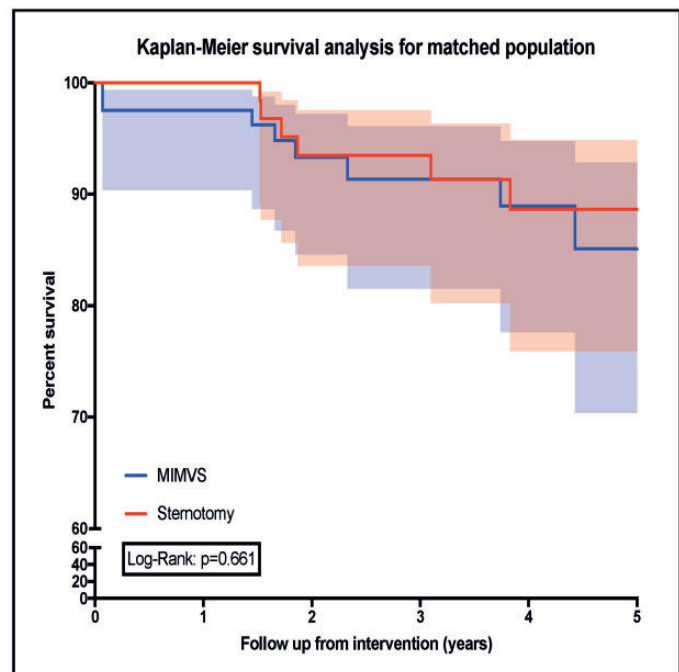
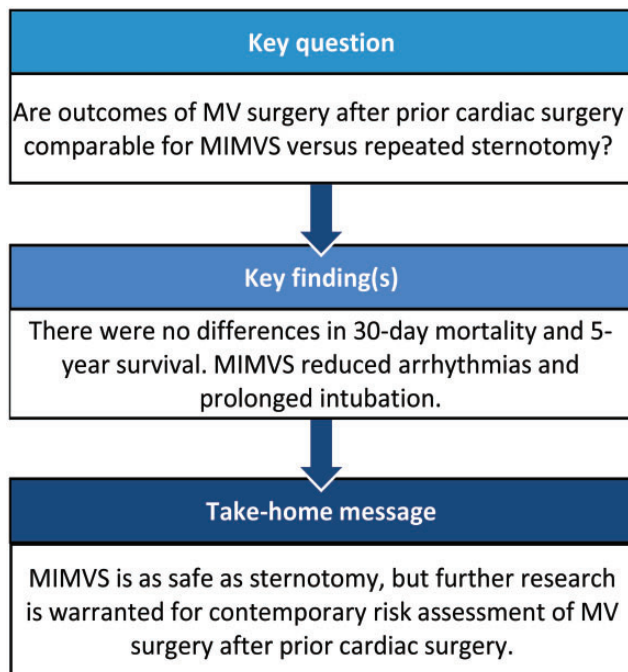
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Abstract

OBJECTIVES: Mitral valve (MV) surgery after prior cardiac surgery is conventionally performed through re sternotomy and associated with increased morbidity and mortality. Alternatively, MV can be approached minimally invasively [minimally invasive mitral valve surgery (MIMVS)], but longer-term follow-up of this approach for MV surgery after prior cardiac surgery is lacking. Therefore, the aim of the current study is to evaluate short- and mid-term outcomes of MIMVS versus MV surgery through re sternotomy in patients with prior sternotomy, using a nationwide registry.

METHODS: Patients undergoing isolated MV surgery after prior cardiac surgery between 2013 and 2018 were included. Primary outcomes were short-term morbidity and mortality and mid-term survival. Cox proportional hazard analysis was used to investigate the association between surgical approach and mortality. Propensity score matching was used to correct for potential confounders.

RESULTS: In total, 290 patients underwent MV surgery after prior cardiac surgery, of whom 205 patients were operated through re sternotomy and 85 patients through MIMVS. No significant differences in 30-day mortality (3.4% vs 2%, $P=0.99$) were observed between both groups. Five-year survival was 86.3% in the re sternotomy group, compared to 89.4% in the MIMVS group (log-rank $P=0.45$). In the multi-variable analysis, surgical approach showed no relation with mid-term mortality [hazard ratio 0.73 (0.34–1.60); $P=0.44$]. A lower incidence of prolonged intubation and new-onset arrhythmia was observed in MIMVS.

CONCLUSIONS: MV surgery after prior cardiac surgery has excellent short- and mid-term results in the Netherlands, and MIMVS and re sternotomy appear to be equally efficacious. MIMVS is associated with a lower incidence of new-onset arrhythmia and prolonged intubation.

Keywords: Mitral valve surgery • Minimally invasive mitral valve surgery • Re sternotomy • Reoperation • Nationwide registry

ABBREVIATIONS

CI	Confidence intervals
HR	Hazard ratios
MIMVS	Minimally invasive mitral valve surgery
MR	Mitral regurgitation
MV	Mitral valve
MVr	MV repair
MVR	MV replacement
NHR	Netherlands Heart Registration
STS	Society of Thoracic Surgeons
TMVR	Transcatheter MV replacement

INTRODUCTION

With the ageing population, mitral valve (MV) surgery after prior cardiac surgery is increasingly performed [1], currently comprising 10% of the total case load of surgical MV interventions [2]. Conventionally, cardiac reoperations are performed through a re sternotomy with significant perioperative morbidity and mortality [3], as reflected by its incorporation in contemporary surgical risk scores. During re sternotomy, dense adhesions can be encountered, which are amenable to severe bleeding, occurring in 7–9% of reoperative procedures [4, 5]. Especially in the proximity of cardiac chambers or in the presence of patent bypass grafts, such bleedings can have devastating consequences.

Alternatively, MV surgery after prior cardiac surgery can be performed using a minimally invasive approach [minimally invasive mitral valve surgery (MIMVS)], through a right-sided anterolateral thoracotomy [6, 7]. Through this access, many of the potential complications associated with re sternotomy can be circumvented, as the left atrium is approached directly from the side, without the need for complete adhesiolysis of the heart. In addition, potentially patent bypass grafts are usually not in the vicinity. Some retrospective studies have demonstrated a beneficial short-term effect of MIMVS in a reoperative setting [7, 8], which was corroborated in a recent meta-analysis by our research group [9], demonstrating superiority of MIMVS in terms of

early mortality. Still, these studies comprised relatively small study cohorts and expert single-centre experiences with limited follow-up. As such, longer-term outcomes of MIMVS after prior cardiac surgery remain unknown.

The aim of current study is to compare short- and mid-term outcomes of MIMVS versus conventional MV surgery through a re sternotomy in patients with prior cardiac surgery, using a multicentre nationwide registry.

PATIENTS AND METHODS

Source of study data

All patients undergoing cardiac surgery in the Netherlands are collected in a prospective mandatory database: the Netherlands Heart Registration (NHR). In short, this prospective database contains a variety of data on all cardiac surgical procedures performed in the Netherlands, including demographic factors, type of intervention, parameters concerning perioperative morbidity and mortality, mid-term survival and all risk factors required for the calculation of contemporary risk scores. All data are anonymized for both patients, surgeons and centres.

Inclusion

Patients were considered for inclusion if they were 18 years and older, had previous cardiac surgery performed through a median sternotomy and underwent isolated MV surgery for new-onset or recurrent MV disease. Isolated MV surgery was defined as either isolated MV repair (MVr) or MV replacement (MVR) or MVr/MVR combined with tricuspid valve repair/replacement and/or rhythm surgery (pulmonary vein isolation/MAZE procedure) and/or atrial septal closure. Patients undergoing other concomitant interventions were excluded. As robotic surgery is a distinct area within the field of MIMVS, patients undergoing a reoperative robotic procedure were excluded as well. MIMVS was defined as right-sided anterolateral mini-thoracotomy with

peripheral or central cannulation, avoiding (re)sternotomy. No distinctions were made between the length of the incision, or the use of a video-assisted or direct-vision approach.

Study design

The current study is a retrospective multicentre cohort study of prospectively collected data from 16 cardiothoracic centres in the Netherlands. Data were collected for patients with previous cardiac surgery through sternotomy, undergoing MV surgery in the period between January 2013 and December 2018.

Outcomes

Short-term outcomes, defined as early mortality (30-day mortality) and postoperative complications and duration of hospital stay, were retrieved. Definitions regarding postoperative complications are presented in [Supplementary Material, S5](#). Mid-term outcomes were defined as mid-term survival at 5 years. Survival data were derived from the municipal administration records and was completed for all patients. Survival follow-up was completed through December 1, 2020.

Missing values

All mandatory variables for the NHR were complete. However, 2 non-mandatory variables had a relatively high proportion of missing data: cardiopulmonary bypass-time (46%) and aortic cross-clamp time (48%). Given the higher levels of missing data for these variables, which clearly exceed >10% and most likely had a non-random distribution, it was inappropriate to apply a multiple imputation method, impairing analysis of these surgical times.

Statistical analysis

Normality of the continuous variables was tested by the Shapiro-Wilk test. Continuous data are presented as mean \pm SD (or as median with interquartile range in the presence of skewedness). Categorical data are expressed as frequencies and percentages (in case of <100 patients, integers were used for the reporting of percentages) and were compared using the χ^2 test. Fisher's exact test was used when the minimum expected cell-size assumption did not apply. Continuous variables were compared using the Mann-Whitney *U*-test. Kaplan-Meier survival curves were used to demonstrate mid-term survival. Between survival curve differences were assessed using the log-rank test. Follow-up was reported as median in months and interquartile range. The influence of the surgical approach (sternotomy versus MIMVS) on mid-term survival was assessed using the Cox proportional hazards model in the total population. Significant covariates ($P < 0.10$) in the univariable analysis and surgical approach (forced in the model, independent of *P*-value) were included in a multivariable Cox regression analysis. Hazard ratios (HRs) are reported with 95% confidence intervals (CIs). Proportionality was evaluated using a goodness-of-fit test, in which a *P*-value of <0.05 demonstrated violation of the proportional hazards assumption. All reported *P*-values were two-sided and were considered statistically significant when $P < 0.05$. Statistical analyses of the data were performed using SPSS software (V26; IBM,

Armonk, NY, USA) and R Statistics (the R Foundation, Vienna, Austria).

Propensity score matching

Propensity score matching analyses were performed to compare sternotomy to MIMVS, while correcting for potential confounders. Propensity scores were estimated using covariates identified in binary logistic regression model. Propensity scores were matched using nearest neighbour matching in a 1:1 ratio, replacement was not allowed and calliper distance was set at 0.1, as advocated by experts in our field. Standardized mean difference was used to compare the difference in means in units of the pooled standard deviation. A value of higher than 0.10 was considered an index of residual imbalance. After matching for baseline differences, data on operative characteristics and outcomes were compared using paired tests, as advocated by experts in our field [10].

Ethical statement

No institutional review board approval was necessary. This study is in line with the institution's ethical policies and standards.

RESULTS

Baseline characteristics

NHR database contained 290 patients undergoing MV surgery after prior cardiac surgery through sternotomy, with a registered surgical approach and known previous cardiac procedure through sternotomy between 2013 and 2018. A total of 205 patients were operated through repeated median sternotomy and 85 patients using an MIMVS approach. Male gender was more frequent in MIMVS ($n = 107$, 52.2% vs $n = 57$, 67% $P = 0.02$). Patients operated through resternotomy were younger (66.0 [54.0–73.5] years vs 70.0 [61.5–74.0] years, $P = 0.02$). Patients undergoing MIMVS more frequently underwent prior primary MV surgery ($n = 47$, 22.9% vs $n = 36$, 42%, $P = 0.001$). Details regarding the primary procedure in the past are summarized in [Supplementary Material, S4](#). At baseline, no difference in median EuroSCORE I was observed (resternotomy 11.85% [6.39–19.48] vs MIMVS 12.43% [5.97–17.61], $P = 0.73$). Baseline characteristics of the total population, repeated sternotomy group and MIMVS group are summarized in [Table 1](#).

Operative characteristics

In the total cohort ($n = 290$ patients), 76 patients underwent MVR, 211 patients underwent MVR and 3 patients underwent other procedures (such as paravalvular leak closure), resulting in an overall repair rate of 26.2% ($n = 76$). When specified for patients without previous MV surgery, the repair rate increased to 33.3% ($n = 69$). No significant difference in repair rate between repeated sternotomy and MIMVS was observed [$n = 59$ (28.8%) vs 17 (20%), $P = 0.12$], even when specified for patients without previous MV surgery [$n = 54$ (32.4%) vs $n = 15$ (31%), $P = 0.64$]. In patients with repeated sternotomy, concomitant tricuspid valve reconstruction was performed in more instances [$n = 67$ (33.2%)

Table 1: Baseline characteristics

	Resternotomy, N = 205	MIMVS, N = 85	P-Value
Age, median [IQR]	66.0 [54.0–73.5]	70.0 [61.5–74.0]	0.02
Male sex, n (%)	107 (52.2)	57 (67)	0.02
Diabetes, n (%)	33 (16.1)	7 (8)	0.08
Chronic lung disease, n (%)	28 (13.7)	9 (11)	0.48
Extracardiac arteriopathy, n (%)	23 (11.2)	7 (8)	0.45
Recent myocardial infarction, n (%)	4 (2.0)	1 (1)	0.99
Active endocarditis, n (%)	9 (4.4)	1 (1)	0.29
Serum creatinine (>200 µm/l)	7 (3.4)	2 (2)	0.99
Prior cardiac procedures ^a			
Prior CABG, n (%)	74 (36.1)	42 (49)	0.04
Prior MV intervention	47 (22.9)	36 (42)	0.001
LVEF, median [IQR]	55 [40–55]	55 [40–55]	0.75
Good, n (%)	109 (53.2)	51 (60)	0.29
Moderate, n (%)	89 (43.4)	32 (38)	0.37
Poor, n (%)	6 (2.9)	2 (2)	0.99
Very poor, n (%)	1 (0.5)	0 (0.0)	0.99
PA pressure, median [IQR]	25.0 [25.0–31.5]	25.0 [25.0–25.0]	0.002
Normal, n (%)	130 (63.4)	72 (85)	<0.001
Moderate increased, n (%)	54 (26.3)	8 (9)	0.001
Severe increased, n (%)	21 (10.2)	5 (6)	0.24
EuroSCORE I, median [IQR]	11.85 [6.39–19.48]	12.43 [5.97–17.61]	0.73

^aPatients could have both.

Bold denotes statistical significance.

CABG: coronary artery bypass grafting; IQR: interquartile range; LVEF: left ventricular ejection fraction; MIMVS: minimally invasive mitral valve surgery; MV: mitral valve; PA: pulmonary artery.

Table 2: Procedural characteristics of the matched and unmatched groups

	Unmatched			Matched		
	Resternotomy, N = 205	MIMVS, N = 85	P-Value	Resternotomy, N = 80	MIMVS, N = 80	P-Value
Type of procedure						
MV repair, n (%)	59 (28.8)	17 (20)	0.12	18 (23)	15 (19)	0.25
MV replacement, n (%)	144 (70.2)	67 (79)	0.14	62 (78)	64 (80)	0.50
Other MV procedures, n (%)	2 (1.0)	1 (1)	0.99	0 (0)	1 (1)	0.99
Tricuspid valve reconstruction, n (%)	67 (33.2)	10 (12)	<0.001	26 (33)	10 (13)	0.005
Atrial septal closure, n (%)	4 (2.0)	3 (4)	0.42	2 (3)	3 (4)	0.99
Rhythm surgery, n (%)	18 (8.8)	4 (5)	0.23	5 (6)	3 (4)	0.69
Type of prosthesis						
Mechanical, n (%)	80 (55.6)	42 (48)	0.29	30 (48)	32 (50)	0.99
Biological, n (%)	64 (44.4)	35 (52)	0.29	32 (52)	32 (50)	
Patients without previous MV surgery	N = 158	N = 49		N = 57	N = 45	
MV repair, n (%)	54 (32.4)	15 (30.6)	0.64	14 (25)	13 (29)	0.99

Bold denotes statistical significance.

MIMVS: minimally invasive mitral valve surgery; MV: mitral valve.

vs $n = 10$ (12%), $P < 0.001$). Other concomitant procedures were presented in Table 2. When performing MVR, in 53.1% of cases ($n = 112$), a mechanical valve, and in 46.9% ($n = 99$), a biological valve were implanted. There were no differences in choice of prosthesis for both procedures. Operative characteristics are summarized in Table 2.

Short-term outcomes

In the overall cohort, 30-day mortality was 3.1%. There were no significant differences in 30-day mortality between repeated sternotomy ($n = 7$, 3.4%) and MIMVS ($n = 2$, 2%, $P = 0.99$). The median length of hospital stay was 7 days [5.0–13.0] vs 7 days [5.0–11.5] $P = 0.98$) for

repeated sternotomy and MIMVS, respectively. A lower incidence of new-onset arrhythmia ($n = 79$, 38.5% vs $n = 18$, 21%, $P = 0.004$) and prolonged intubation (> 24 hours) was observed in the MIMVS group ($n = 14$, 6.8% vs $n = 0$, $P = 0.01$). No significant differences in other postoperative complications were seen. These postoperative outcomes are depicted in [Supplementary Material, S1](#).

Mid-term outcomes

Survival. The median follow-up of the total cohort was 3.26 [1.68–4.64] years, with a 5-year survival rate of 87.2%. Five-year survival rate was 86.3% in the repeated sternotomy group compared to 89.4% in the MIMVS group (log-rank $P = 0.45$).

Table 3: Cox regression analysis for investigating the effect of surgical approach on mid-term mortality in the overall population

	Univariable		Multivariable	
	HR (95% CI)	P-Value	HR (95% CI)	P-Value
Minimally invasive approach	0.83 (0.40–1.70)	0.60	0.73 (0.34–1.60)	0.44
Age	1.03 (1.00–1.05)	0.09	1.02 (0.99–1.05)	0.30
Male sex	1.29 (0.67–2.48)	0.46		
Chronic lung disease	1.43 (0.60–3.43)	0.42		
Extracardiac arteriopathy	3.35 (1.57–7.14)	0.01	2.56 (1.16–5.67)	0.02
Recent myocardial infarction	4.12 (0.98–17.34)	0.05	2.55 (0.44–14.80)	0.30
Serum creatinine (>200 µm/l)	4.80 (1.69–13.65)	0.01	3.41 (1.14–10.27)	0.03
Active endocarditis	3.46 (1.05–11.43)	0.04	2.11 (0.49–9.02)	0.32
Diabetes	1.50 (0.66–3.45)	0.34		
LVEF <50%	2.23 (1.16–4.31)	0.02	1.85 (0.95–3.61)	0.07
Pulmonary artery pressure >30 mmHg	1.53 (0.787–2.97)	0.21		
Prior bypass grafting	0.89 (0.46–1.73)	0.73		
Prior mitral valve intervention	1.51 (0.77–2.94)	0.23		
Mitral valve repair	0.44 (0.17–1.12)	0.08	0.53 (0.20–1.38)	0.19
Concomitant tricuspid procedure	1.33 (0.66–2.64)	0.43		
Concomitant rhythm surgery	0.40 (0.05–2.92)	0.37		

Bold denotes statistical significance.

CI: confidence interval; HR: hazard ratio; LVEF: left ventricular ejection fraction.

Cox regression analysis

Univariable analysis showed no influence of surgical approach (i.e. re-sternotomy or MIMVS) on mid-term mortality. Univariable Cox regression analyses identified age, extra cardiac arteriopathy, recent myocardial infarction, increased serum creatinine (>200 µm/l), active endocarditis and decreased left ventricular function as predictors for late mortality. MVr was identified as protective factor for late mortality. Multivariable analysis showed no influence of surgical approach on mid-term mortality [HR 0.73 (0.34–1.60), $P=0.44$]. Only extracardiac arteriopathy (HR 2.56, 95% CI 1.16–5.67, $P=0.02$) and increased serum creatinine (HR 3.41, 95% CI 1.14–10.27, $P=0.03$) were found to be the independent predictive risk factors for mid-term mortality in MV surgery after prior cardiac surgery. Cox regression analyses are depicted in Table 3. Of note, goodness-of-fit for all included variables indicated proportionality ($P>0.05$).

Propensity score matching

To correct for the differences in baseline characteristics, propensity score matching was performed. Age, gender, pulmonary artery pressure, logistic EuroSCORE, and chronic obstructive pulmonary disease were used as covariates for the propensity score matching model. Eighty pairs were matched in a 1:1 ratio. After matching, a residual imbalance remained for diabetes only, which was not considered clinically relevant as diabetes did not show to be a risk factor in univariable and multivariable analyses. All other baseline characteristics showed no residual imbalance (standardized mean difference <0.10). Details on propensity score matching can be found in [Supplementary Material, S3](#).

Comparison matched cohort

Baseline characteristics after propensity matching are summarized in [Supplementary Material, S2](#). Prior MV intervention was more frequently performed in the MIMVS compared to repeated

sternotomy [$n=35$ (44%) vs $n=23$ (29%), $P=0.04$]. The repair rate in patients without previous MV surgery was 25% in the repeated sternotomy group and 29% in the MIMVS group respectively ($P=0.99$). As seen in the unmatched population, more concomitant tricuspid valve procedures were performed in the sternotomy group ($n=26$, 33% vs $n=10$, 13%, $P=0.005$). In the matched population, no significant difference in 30-day mortality was observed (1% vs 3%, $P=0.99$). A lower incidence in prolonged intubation (>24 hours) and new-onset arrhythmia was observed in the MIMVS group (Table 4). Most importantly, regarding mid-term follow-up, no significant differences were found in 5-year survival in the propensity-matched cohorts (MIMVS 92.5% vs repeated sternotomy 90.0, log-rank $P=0.661$) (Fig. 1).

DISCUSSION

The current study evaluated the role of a minimally invasive approach for MV surgery after prior cardiac surgery through sternotomy, compared to repeated sternotomy in a multicentre nationwide registry and is the first to establish mid-term follow-up for this procedure. In addition, as patient data were collected from all centres performing MV surgery in the Netherlands, the current results can be interpreted as contemporary 'real-world data'. Based on these findings, some important conclusions can be drawn.

First, MV surgery, either through re-sternotomy or MIMVS, is an exceptionally safe reoperative cardiac surgical procedure, as reflected by both unmatched and matched cohorts, with an overall 30-day mortality rate of 3.1%. In retrospective single-centre analyses of high-volume expert institutions, mortality rates ranged between 1.2% and 3.0% [11, 12]. However, mortality is reported to range up to 11.1% in the Society of Thoracic Surgeons (STS) database [13], which is based on a multicentre registry, potentially more accurately reflecting real-world results. In accordance with a prior comparison between MIMVS and sternotomy in primary MV surgery of the Dutch national registry, no difference in 30-day mortality regarding surgical approach

Table 4: Postoperative outcomes of matched cohort

	Resternotomy, N = 80	MIMVS, N = 80	P-Value
30-Day mortality, n (%)	1 (1)	2 (3)	0.99
Hospital stay in days, median [IQR]	7 [4–14]	7 [5–12]	0.97
Perioperative myocardial infarction, n (%)	1 (1)	2 (3)	0.99
Pneumonia, n (%)	7 (9)	3 (4)	0.29
Urinary tract infection, n (%)	0 (0)	0 (0)	–
Reintubation due to respiratory insufficiency, n (%)	3 (4)	0 (0)	0.99
Prolonged intubation (>24 h), n (%)	9 (11)	0 (0)	0.003
Readmission to ICU, n (%)	2 (3)	3 (4)	0.99
Stroke, n (%)	1 (1)	1 (1)	0.99
Stroke without neurological deficit, n (%)	0 (0)	1 (1)	0.99
Stroke with neurological deficit, n (%)	1 (1)	0 (0)	0.99
Kidney failure, n (%)	5 (6)	3 (4)	0.63
Gastrointestinal complications, n (%)	2 (3)	0 (0)	0.50
Vascular complications, n (%)	2 (3)	0 (0)	0.50
New-onset arrhythmia, n (%)	33 (41)	17 (21)	0.01
Mediastinitis, n (%)	1 (1)	0 (0)	0.99
Reexploration (within 30 days), n (%)	4 (5)	8 (10)	0.39

Definitions of postoperative complications are summarized in the [Supplementary Material](#). Bold denotes statistical significance.

ICU: intensive care unit; IQR: interquartile range; MIMVS: minimally invasive mitral valve surgery.

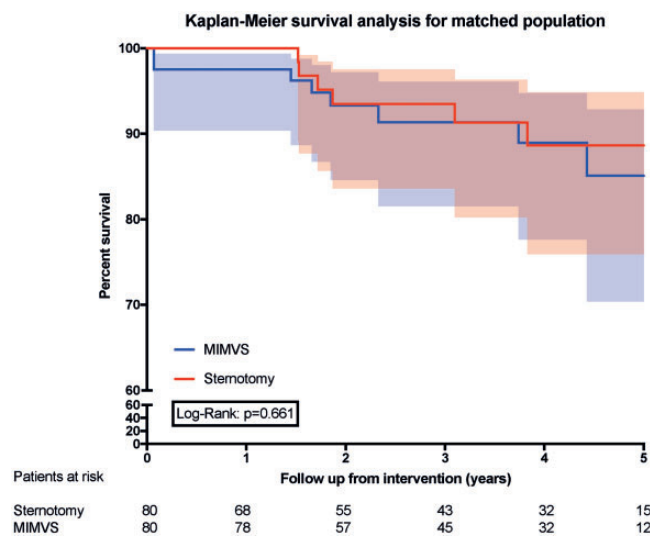


Figure 1: Kaplan-Meier survival analysis of the matched population. MIMVS: minimally invasive mitral valve surgery

was observed [14]. Of note, in a previous meta-analysis by our research group, a significant early mortality benefit of the MIMVS approach in a reoperative setting was found [9]. However, the included studies comprised relatively small single-centre experiences and were subjected to potential bias. Furthermore, in the included studies in that meta-analysis, there was a markedly increased use of MVr in the MIMVS group (41% vs 17%). As MVr is associated with superior short- and long-term outcomes, especially in degenerative MV disease, this might explain the mortality differences in this prior analysis.

Interestingly, in the current study, the median preoperative logistic EuroSCORE for the overall cohort (used for the prediction of 30-day mortality) was 12.18%, contrasting the actual reported 30-day mortality rate. However, as EuroSCORE I was introduced in 1999 and the subsequent logarithmic evaluation in 2003, these risk evaluations were based on more historical data, inherently

overestimating surgical risk in contemporary patients. For mortality prediction of patients undergoing MV surgery, EuroSCORE II proved superior discriminatory ability compared to both STS score and EuroSCORE I, in a recent analysis [15]. Still, in patients with degenerative mitral regurgitation (MR) operated in a high-volume centre with a high level of expertise in MVr, EuroSCORE II also significantly overestimated actual 30-day mortality [16]. Moreover, in MIMVS, EuroSCORE II overpredicted mortality, potentially limiting its value in this specific patient group [17], undergoing MVr through a minimally invasive approach, especially in a reoperative setting.

In terms of morbidity and complication rate, a low incidence of major postoperative complications for both repeated sternotomy as MIMVS was observed. As known from other large registries and a recent analysis of primary MV surgery [14], MV surgery through a minimally invasive approach is associated with a lower incidence of new-onset postoperative arrhythmia compared to sternotomy. This finding is confirmed in the current analysis of patients undergoing reoperative procedures and is potentially explained by less need of adhesiolysis, less cardiac manipulation and a subsequent reduction in inflammation [18]. In addition, in the current analysis, the incidence of prolonged intubation (>24 h) was significantly increased in the matched sternotomy group compared to MIMVS, which might be related to preservation of pulmonary function due to sternal sparing in MIMVS patients. However, these findings have to be appreciated with care, because these parameters are susceptible to various confounding factors.

In the majority of patients referred for MV surgery after prior cardiac surgery, MVR was performed, with an equal distribution of mechanical and biological valve prostheses. The repair rate, when specified for patients without prior MV intervention, is considerably lower (33.3%) compared to the repair rate in primary MV surgery. In a previous analysis of patients undergoing primary MV surgery, repair rate for all-comers approached through sternotomy was 80.0%, while repair rate was 75.9% for MIMVS patients [14]. In contrast to the prior findings in primary

MV surgery, we did not observe a difference in surgical approach in terms of repair rate in patients undergoing MV surgery after prior cardiac surgery through sternotomy. Unfortunately, the current study design, based on predefined parameters of the NHR, did not allow for evaluation of aetiology of MV disease. Subsequently, the proportion of patients with mitral stenosis, ischaemic MR or degenerative MR remains unknown, complicating the correct interpretation of the reported repair rate. In a 2018 analysis of the STS database for patients undergoing MV surgery after prior cardiac surgery, Mehaffey *et al.* [13] found a significantly higher incidence of mitral stenosis as surgical indication in redo cases compared to primary surgery (36% vs 10%, $P < 0.001$). Although they were also not able to differentiate between MR aetiology, they reported an overall repair rate of 12% in a cohort of 1096 all comers, which is markedly lower compared to the current study findings.

As MV surgery after prior cardiac surgery is increasingly performed [1], mostly due to the ageing population, it is more important than ever to evaluate short- and longer-term results of these different surgical approaches. As an alternative strategy, transcatheter mitral procedures have emerged rapidly, following the successful evolution of transcatheter aortic valve implantation. As MV pathology is more diverse than aortic valve disease, a plethora of devices exist which have the potential to address all different forms of MR. As such, different techniques can be used to perform transcatheter MVr, by chordal replacement or annuloplasty, or MVR in specific cases. Especially transcatheter MV replacement (TMVR) is believed to play an important role in the near future, enabling minimally invasive correction of ischaemic MR or valve-in-valve implantation in failed bioprostheses [19]. Still, both transcatheter MVr and TMVR are currently only applicable in specific subsets of MV patients and require specific conditions related to MV anatomy and left ventricular geometry [20]. Of note, especially long-term outcomes and durability of TMVR and repair are yet to be determined. Therefore, although promising, the exact role and value of transcatheter techniques in the mitral position remains to be defined. When considering such an approach, one must weigh these outcomes to the excellent short- and mid-term results of reoperative surgery, either by MIMVS or sternotomy, as presented in the current study. In that light, patients with new-onset or recurrent MV disease after a previous cardiac surgical procedure through sternotomy, warrant a personalized approach [21], based on extensive preoperative imaging, and should be evaluated in a dedicated MV heart team, incorporating surgeons, interventionalists and imaging cardiologists [22].

Limitations. The current study has several limitations mostly due to the character of the database used. The NHR database was initially designed for quality evaluation (value-based healthcare) rather than for research purposes. Therefore, the retrospective review has an inherent bias, due to selection of patient, patient lost to follow-up and missing data. Of note, these missing data only comprise non-mandatory variables, such as surgical times. For the mandatory variables, data completion was exceptionally high (100%). Some important characteristics were not included, such as information on MV disease characteristics as aetiology, complexity, gradation and reason for failed repair during first procedures in patients with prior MVr. In addition, no detailed analyses could be performed regarding surgical access (direct vision vs endoscopic), mode of arterial cannulation (femoral, axillary or direct aortic cannulation) and cardiac preservation (i.e.

cooling, cardioplegia). Unfortunately, the database has no information regarding mode of anaesthesia and the use of pain regimen (i.e. intercostal block, erector spinae block), either. Of note, as the database is anonymous, data cannot be traced back to individual centres and surgeons, impairing evaluation of a potential volume-outcome effect. Furthermore, the database includes all surgical procedures performed by 16 cardiothoracic centres in the Netherlands. However, not all centres perform MV surgery after prior cardiac surgery through a minimally invasive approach, therefore the data regarding a minimally invasive approach was only reported by centres with substantial expertise. In line with this, the MIMVS cohort was relatively small, increasing the risk of type 2 error. Then, perhaps most importantly, an analysis of MIMVS versus sternotomy patients is prone to selection bias, as it is possible that patient with a more favourable profile were selected for MIMVS. In an effort to correct for these issues, all consecutive patients undergoing MV surgery after prior cardiac surgery were included and matched using propensity score matching, based on the recommendations by experts in our field [10]. Although this is the least biased method to perform such analyses—matching for *known* confounders—only randomization can correct for *unknown* confounders, and results should be interpreted with caution. Finally, as data were collected starting from 2013, simultaneously with the introduction of EuroSCORE II, risk evaluation was evaluated by EuroSCORE I (log), overestimating surgical risk.

CONCLUSION

The current multicentre nationwide study showed excellent outcomes for MV surgery after prior cardiac surgery in the Netherlands, and MIMVS and resternotomy appeared to be equally efficacious. MIMVS is associated with a lower incidence of new-onset arrhythmia and prolonged intubation. These excellent short- and mid-term results of MV surgery after prior cardiac surgery, regardless of the approach, should be taken into consideration when evaluating transcatheter interventions. Further investigation is necessary to develop contemporary risk score models for MV surgery after prior cardiac surgery.

SUPPLEMENTARY MATERIAL

Supplementary material is available at *EJCTS* online.

Conflict of interest: Peyman Sardari Nia has a consultancy agreement with Neochord Inc, Edwards Lifesciences and Fujifilm medical and is the inventor of a MV simulator that is commercialized through a start-up (Ma-trac) of Maastricht University Medical Center+. The other authors report no conflicts of interest.

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Data Availability Statement

Data will be shared on reasonable request to the corresponding author with the permission of the Netherlands Heart Registration.

Author contributions

Jules R. Olsthoorn: Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Validation; Visualization; Writing—original draft; Writing—review & editing. **Samuel Heuts:** Data curation; Formal analysis; Investigation; Methodology; Validation; Visualization; Writing—original draft; Writing—review & editing. **Saskia Houterman:** Formal analysis; Writing—original draft; Writing—review & editing. **Jos G. Maessen:** Supervision; Validation. **Peyma Sardari Nia:** Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Supervision; Validation; Visualization; Writing—original draft; Writing—review & editing.

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