

# Concomitant Tricuspid Valve Repair during Minimally Invasive Mitral Valve Repair

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## Abstract

**Background** Concomitant use of tricuspid valve (TV) surgery and minimally invasive mitral valve (MV) repair is debatable due to a prolonged time of surgery with presumably elevated operative risk. Herein, we examined cardiopulmonary bypass times and 30-day mortality in patients who underwent MV repair with and without concomitant TV surgery.

**Methods** We retrospectively evaluated 3,962 patients with MV regurgitation who underwent minimally invasive MV repair without ( $n = 3,463$ ; MVr group) and with ( $n = 499$ ; MVr + TVr group) concomitant TV surgery between 1999 and 2014. Preoperative parameters between the groups were significantly different; therefore, propensity score matching was performed.

**Results** Mean cardiopulmonary bypass time for all patients was  $125.5 \pm 55.8$  minutes in MVr and  $162.0 \pm 58.0$  minutes in MVr + TVr ( $p < 0.001$ ). Overall 30-day mortality was significantly different between these groups (4.8 vs. 2.1%;  $p < 0.001$ ); however, after adjustment, there was no significant difference (3.3 vs. 1.2%;  $p = 0.07$ ). Backward logistic regression revealed that cardiopulmonary bypass time was not a significant predictor for early mortality within the MVr + TVr cohort.

**Conclusion** Concomitant TV repair using prosthetic rings through a minimally invasive approach is safe and does not lead to elevated early mortality in our patient cohort. Therefore, prolonged cardiopulmonary bypass time should not be the sole reason to rule out MV repair with concomitant TV repair and to prefer the use of suture techniques, which saves only a few minutes compared with prosthetic ring implantation.

## Keyword

- ▶ mitral valve surgery
- ▶ tricuspid valve
- ▶ minimally invasive surgery

## Introduction

The European guidelines for the management of valvular heart disease recommend the use of mitral valve (MV) surgery with concomitant tricuspid valve (TV) surgery in cases of dilated TV annulus and/or TV regurgitation  $\geq$  grade II.<sup>1</sup> Nevertheless, there are different surgical concepts. There are concerns regarding operative risk due to prolonged cardiopulmonary bypass time during concomitant TV sur-

gery, especially that using a minimally invasive approach. Moreover, there are concerns regarding the repair technique itself as to whether it would be better to avoid implantation of a prosthetic ring with respect to performing a suture annuloplasty to save time in case of concomitant TV surgery. The latter is pointed out in a study on the prosthetic ring annuloplasty of TV: "However, this procedure leads to some prolongation of the operation and cardiopulmonary bypass time. Therefore, intervening on moderate functional TR in

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the context of another cardiac procedure may become a decision making dilemma. For such cases, a modified suture annuloplasty technique was developed...<sup>2</sup>

Therefore, there are several important questions, which we aimed to answer in this study, such as how much time does the prosthetic annuloplasty ring of TV take during minimally invasive procedure, what is the average difference in cardiopulmonary bypass time between patients undergoing isolated MV repair and those undergoing additional TV repair, and does prolonged cardiopulmonary bypass times augment operative risk during minimally invasive MV repair with concomitant TV repair?

## Patients and Methods

We retrospectively analyzed 3,962 patients who underwent minimally invasive MV repair (MVr) and maze procedure without ( $n = 3,463$ ; MVr group) and with concomitant TV surgery using a prosthetic annuloplasty ring ( $n = 499$ ; MVr + TVr group). Patients with MV and/or TV replacements, those with TV repair without using prosthetic rings, those with active endocarditis, and those with intraoperative conversion to sternotomy were excluded from the study.

### Data Collection

Relevant preoperative, intraoperative, and postoperative outcome data of all patients were prospectively entered into the institutional database and retrospectively analyzed. Completely anonymized data were retrieved from the hospital data collecting system.

### Indications for Tricuspid Valve Repair

Indications for TV repair were as follows: TV annulus dilated >40 mm or/and the presence of TR  $\geq$  grade II. TR was

classified by our institutional echocardiography laboratory on the basis of the vena contracta in a four-chamber view according to the European guidelines on the management of valvular heart disease.<sup>3</sup>

### Surgical Procedure

We used a minimally invasive standard approach through a right anterolateral minithoracotomy, which has been previously described in detail by our group.<sup>4-7</sup> For minimally invasive MV repair, we routinely cannulated the right femoral artery and vein in the groin for cardiopulmonary bypass. For TV repair, we cannulated the internal jugular vein for additional venous drainage of the upper body. TV repair was performed with the beating heart or by applying the cross-clamp at the discretion of the surgeon.

### Statistical Evaluation

Categorical variables were reported as count (percentage). Pearson's  $\chi^2$  test was used for group comparisons.

Continuous study variables were tested for normal distribution and were reported as median and interquartile range in case of violation or as mean and standard deviation otherwise.

For metric variables, the statistical test used was assessed by variance of heterogeneity, and normality and was chosen between unpaired *t*-test, unpaired Welch's *t*-test, and Wilcoxon's signed-rank test.

Bootstrapped backward stepwise logistic regression was performed for bypass time and preoperative characteristics (►Table 1) for patients undergoing minimally invasive MV repair and concomitant TV repair to evaluate risk factors for this patient population.

Greedy nearest-neighbor 1:1 propensity score matching with a caliper of 0.2 was applied to variables age, body mass

**Table 1** Preoperative parameters of the cohort

Variable	All patients ( $n = 3,962$ )	Isolated MV surgery ( $n = 3,463$ ) (MVr)	MV surgery + TV repair ( $n = 499$ ) (MVr + TVr)	<i>p</i> -Value (before matching)	<i>p</i> -Value (after matching)
Age (years)	61.6 (51.3–70.5)	59.76 (50.1–69.1)	70.87 (64.0–75.6)	<0.001	n.s.
Gender, male	2,473 (62.4%)	2,232 (64.5%)	241 (48.3%)	<0.001	n.s.
LVEF (%)	59.8 ( $\pm$ 12.5)	60.4 ( $\pm$ 12.3)	55.2 ( $\pm$ 13.0)	<0.001	n.s.
Atrial fibrillation	1,250 (31.6%)	925 (26.7%)	325 (65.1%)	<0.001	n.s.
Arterial hypertension	2,559 (64.6%)	2,140 (61.8%)	419 (84.0%)	<0.001	n.s.
Pulmonary hypertension	679 (17.1%)	493 (14.2%)	186 (37.2%)	<0.001	n.s.
COPD	147 (3.7%)	111 (3.2%)	36 (7.2%)	<0.001	n.s.
Diabetes mellitus	407 (10.3%)	316 (9.1%)	91 (18.2%)	<0.001	n.s.
Dialysis	33 (0.8%)	19 (0.6%)	14 (2.8%)	<0.001	n.s.
BMI (kg/m <sup>2</sup> )	25.7 ( $\pm$ 4.0)	25.6 ( $\pm$ 3.9)	26.0 ( $\pm$ 4.3)	0.0204	n.s.
Previous cardiac surgery	156 (3.9%)	135 (3.9%)	21 (4.2%)	n.s.	n.s.

Abbreviations: BMI, body mass index; COPD, chronic obstructive pulmonary disease; LVEF, left ventricular ejection fraction; MV, mitral valve; MVr, mitral valve repair; n.s., not significant; TV, tricuspid valve; TVr, tricuspid valve repair.

**Table 2** Preoperative MV pathology

	All patients (n = 3,962)	Isolated MV surgery (n = 3,463) (MVr)	MV surgery + TV repair (n = 499) (MVr + TVr)	p-Value
MV stenosis	35 (0.9%)	32 (0.9%)	3 (0.6%)	n.s.
Annulus dilatation	3,384 (85.4%)	2,944 (85.0%)	440 (88.2%)	n.s.
Annulus calcification	108 (2.7%)	90 (2.6%)	18 (3.6%)	n.s.
Prolapse PML	2,600 (65.6%)	2,423 (70.0%)	177 (35.5%)	<0.001
Prolapse AML	1,066 (26.9%)	957 (27.6%)	109 (21.8%)	<0.01
Leaflet restriction	228 (5.8%)	180 (5.2%)	48 (9.6%)	<0.001
Pacemaker	197 (5.0%)	136 (4.0%)	62 (12.2%)	<0.001

Abbreviations: AML, anterior mitral leaflet; MV, mitral valve; MVr, mitral valve repair; n.s., not significant; PML, posterior mitral leaflet; TV, tricuspid valve; TVr, tricuspid valve repair.

index, gender, diabetes, prior cardiac surgery, diabetes, chronic obstructive pulmonary disease, creatinine, arterial and pulmonary hypertension, priority status, peripheral vascular disease, atrial fibrillation, and pacemaker, stratifying 467 patients by treatment. Differences in early mortality and perioperative outcomes were tested thereafter.

Statistical analyses were performed using the SPSS statistical package, version 20.0 (SPSS Inc., Chicago, Illinois, United States) and validated in R, version 3.5.1. A *p*-value of <0.05 was considered statistically significant.

## Results

Mean patients age was 62 (51–71) years, and 62% of the patients were male (*n* = 2,473). Average log EuroSCORE was 2.7 (1.5–5.5) %, and the average left ventricle ejection fraction (LVEF) was 60 ± 13%. In total, 10% of the patients suffered from diabetes mellitus (*n* = 407) and 32% from atrial fibrillation (*n* = 1,250). In 5% of the patients, a previous pacemaker was implanted (*n* = 197), and in 4% of patients, previous cardiac surgery has been performed (*n* = 156).

Preoperative parameters were significantly different between groups (► **Table 1**). MVr + TVr patients were on average 10 years older, had lower LVEF, and were mostly females, compared with the MVr-group. In the MVr + TVr group, the number of patients with diabetes mellitus and atrial fibrillation was twofold higher and the number of patients with a pacemaker was threefold higher than those in the MVr group. The number of patients with a history of cardiac surgery was comparable between both groups.

In the MVr + TVr group, more patients presented with a functional pathology of MV (► **Table 2**). Mitral leaflet repair was more common in isolated MVr, whereas cryoablation due to atrial fibrillation was more common in the MVr + TVr group (MVr: 22.9%; MVr + TVr: 54.7%; *p* < 0.001); MV annuloplasty was usually performed with rigid rings (*n* = 3,395; 85.7%) and TV annuloplasty with flexible bands (*n* = 385; 77.2%).

Comparison of cross-clamp time, bypass time, and surgery time revealed significant differences between both groups (prolonged in MVr + TVr patients; *p* < 0.001), with average differences of 18, 37, and 41 minutes, respectively (► **Table 3**). Outliers in bypass time were less frequent in patients with early mortality (EM) (► **Fig. 1**), and there was noted a difference of 44 minutes in bypass time between patients who underwent MV repair with and without TV surgery.

Early mortality was significantly higher in the MVr + TVr group (4.8 vs. 2.1%; *p* < 0.001) before matching. After matching, early mortality was not significantly different between both groups (4.71 vs. 3.21%; *p* = 0.2403). ICU stay, ventilation time, and hospital stay was longer in the MVr + TVr group than in the MVr group (*p* < 0.0001), and this was also seen after matching (► **Tables 4** and **5**).

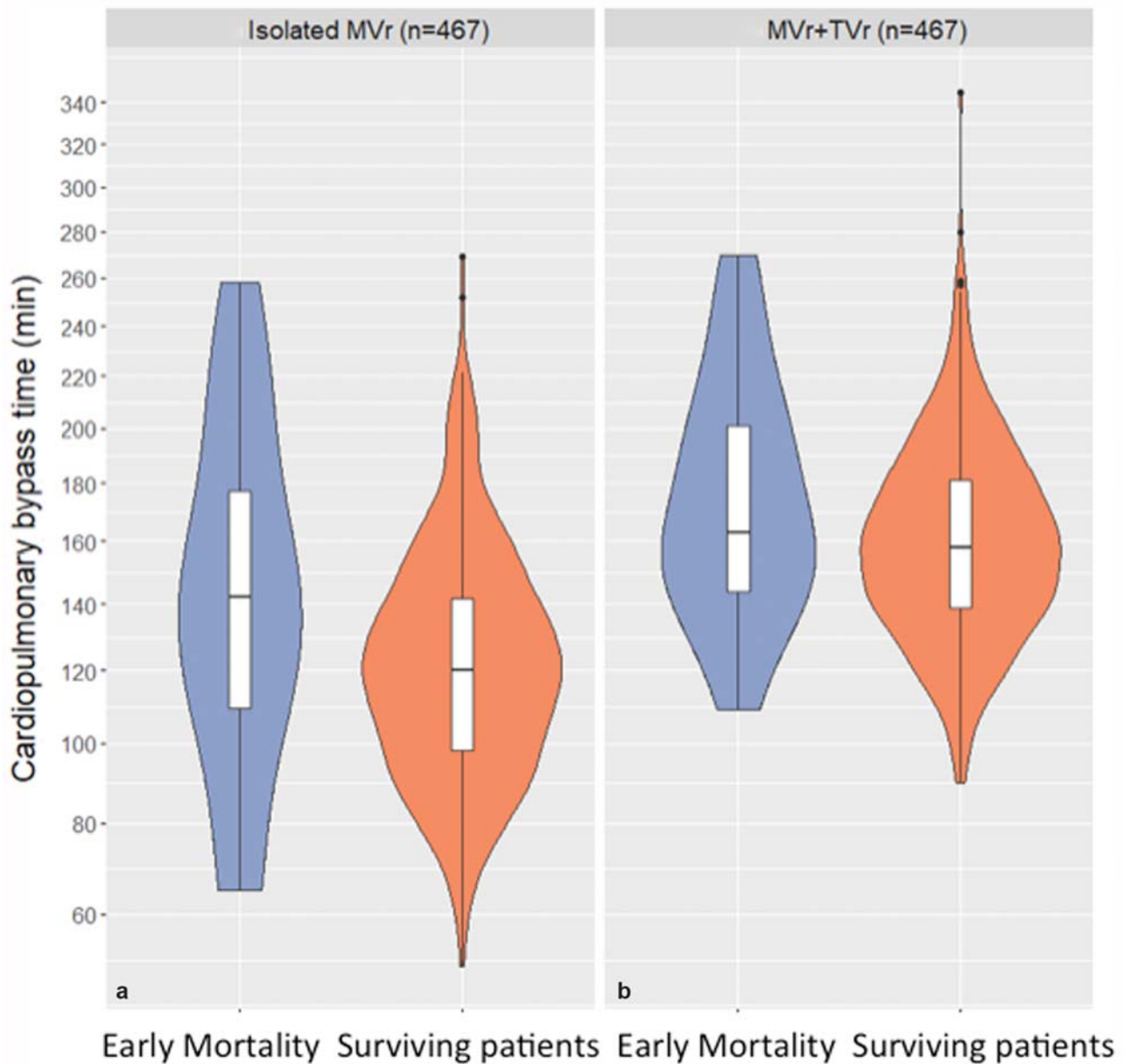
Intensive care unit (ICU) stay and ventilation times were each around 5 hours prolonged in patients with additionally TV repair (after matching), which was significantly different (► **Table 5**).

Binomial logistic regression model after matching revealed LVEF (odds ratio [OR] = 0.95; confidence interval [CI] = 0.91–0.98; *p* = 0.0047) as a predictor for early mortality in the MVr

**Table 3** Intraoperative data

	All patients (n = 3,962)	Isolated MV surgery (n = 3,463) (MVr)	MV surgery + TV repair (n = 499) (MVr + TVr)	p-Value
Cross-clamp time (minutes)	76.1 ± 31.9	74.9 ± 32.0	92.8 ± 30.3	<0.001
Cardiopulmonary bypass time (minutes)	130.3 ± 37.8	127.04 ± 36.1	164.1 ± 34.0	<0.001
Time for surgery (minutes)	178.2 ± 48.0	174.2 ± 46.2	215.5 ± 42.3	<0.001

Abbreviations: MV, mitral valve; MVr, mitral valve repair; TV, tricuspid valve; TVr, tricuspid valve repair.



**Fig. 1** (a) A violin plot showing the distribution and outliers of cardiopulmonary bypass time for the matched cohort: patients who died within 30 days after operation versus surviving patients (isolated MVr). (b) A violin plot showing the distribution and outliers of cardiopulmonary bypass time for the matched cohort: patients who died within 30 days after operation versus surviving patients (MVr + TVr). MVr, mitral valve repair; TVr, tricuspid valve repair.

**Table 4** Postoperative data after matching

	All patients (n = 3,962)	Isolated MV surgery (n = 3,463) (MVr)	MV surgery + TV repair (n = 499) (MVr + TVr)	p-Value
ICU time (hours)	21.9 (8.7–46.4)	19.8 (5.7–27.6)	24.2 (16.3–69.7)	<0.0001
Ventilation time (hours)	13.9 (8.6–27.0)	11.9 (7.4–20.2)	16.8 (9.8–52.2)	<0.0001
Hospital stay (days)	12 (9–17)	11 (9–15)	13 (10–19)	<0.0001
30-d mortality	37 (4.0%)	15 (3.2%)	22 (4.7%)	0.2403

Abbreviations: ICU, intensive care unit; MV, mitral valve; MVr, mitral valve repair; TV, tricuspid valve; TVr, tricuspid valve repair.

**Table 5** Postoperative data before matching

	All patients (n = 3,962)	Isolated MV surgery (n = 3,463) (MVr)	MV surgery + TV repair (n = 499) (MVr + TVr)	p-Value
ICU time (hours)	15.9 (2.6–24.4)	11.3 (0.0–23.3)	24.2 (16.3–69.3)	<0.0001
Ventilation time (hours)	9.6 (6.0–17.8)	8.7 (5.6–15.9)	16.5 (9.7–50.5)	<0.0001
Hospital stay (days)	10 (8–13)	9 (8–12)	13 (10–19)	<0.0001
30-d mortality	96 (2.4%)	72 (2.1%)	24 (4.8%)	0.0002

Abbreviations: ICU, intensive care unit; MV, mitral valve; MVr, mitral valve repair; TV, tricuspid valve; TVr, tricuspid valve repair.

cohort. In the MVr + TVr cohort, atrial fibrillation (OR = 2.79; 2.79; CI = 1.01–9.89;  $p = 0.0709$ ), pulmonary hypertension (OR = 2.69; CI = 1.12–6.73;  $p = 0.0283$ ), and arterial hypertension (OR = 0.35; CI = 0.14–0.96;  $p = 0.0301$ ) were found to be most promising predictors.

## Discussion

Motivation for the current investigation was a discussion on the augmentation of operative risk due to prolonged cardiopulmonary bypass time during MV repair with concomitant TV surgery due to the surgical access and surgical repair technique.

We investigated patients with minimally invasive MV repair with and without concomitant TV repair with an emphasis on surgery time, particularly cardiopulmonary bypass time, because TV repair was performed with either an arrested or a beating heart at the surgeon's discretion. In a previous study, we have shown that the postoperative outcomes were not different between patients who underwent isolated tricuspid surgery with a beating or an arrested heart.<sup>8</sup> Furthermore, several previous studies have proposed that MV repair with concomitant TV repair is not associated with worse postoperative outcomes compared with isolated MV repair, which we were able to show as well.<sup>9–12</sup>

The preoperative parameters of patient cohorts in this investigation were different. We compared patients who underwent MV repair with or without concomitant TV repair. In patients with concomitant TV repair (MVr + TVr group), there were more patients with functional MV regurgitation, whereas in patients with isolated MV surgery (MVr group), there were more patients with structural MV regurgitation. Additionally, patients in the MVr + TVr group were on an average 10 years older, had lower LVEF and higher atrial fibrillation, and had a higher rate of maze procedures than patients in the MVr group. However, on critically analyzing patients with functional versus structural MV surgery ± maze procedure, we noted that the average difference in cardiopulmonary bypass time was usually <40 minutes in patients who underwent MV repair with and without concomitant TV repair in all subgroups. ICU stay and ventilation times were each around 5 hours prolonged in patients with additionally TV repair (after matching), which is significantly different but seems not to be clinically relevant.

We performed propensity score matching to enable direct comparison regarding early mortality. Furthermore, early

mortality was not associated with prolonged cardiopulmonary bypass time.

Augmented operative risk during additional TV, specifically due to prolonged TV repair with a prosthetic ring, was not detected. Additionally, previous studies have shown that prosthetic annuloplasty rings are superior to suture techniques in TV repair.<sup>13,14</sup>

This investigation has some limitations due to the retrospective nature of the study and the heterogenous patient cohort. Additionally, detailed echocardiographic data are missing – for example regarding the extension of MV prolapse with or without annulus dilatation and informations about primary or secondary reasons for TV failure, or right ventricular pathology.

In conclusion, concomitant TV repair using prosthetic rings through a minimally invasive approach is safe and does not lead to elevated early mortality in our patient cohort. Therefore, prolonged cardiopulmonary bypass time should not be the sole reason to rule out MV repair with concomitant TV repair and to prefer the use of suture techniques, which saves only a few minutes compared with prosthetic ring implantation.

## Conflict of Interest

None.

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