# Echocardiographic and Clinical Outcome after Mitral Valve Plasty with a Minimal Access or Conventional Sternotomy Approach

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# ABSTRACT

## Aim

To evaluate the effects of minimal access mitral valve surgery (MAMVS) versus conventional surgery with or without concomitant tricuspid valve plasty (TVP) in consecutive patients with mitral regurgitation (MR) on clinical and echocardiographic outcome.

## Methods

One-hundred-and-twenty patients operated for MR (91 conventional and 29 MAMVS) were followed by echocardiography and quality-of-life assessment before and 6 months after surgery.

## Results

Patients in the MAMVS group were younger, more often in NYHA functional class I-II and had lower NT-proBNP levels. Only four patients (all in the conventional group) underwent mitral valve replacement. There were no significant differences in complications between MAMVS and conventional surgery. At 6-months comparable MR reduction and left ventricular remodeling data were seen, left atrial remodeling was most prominent in the MAMVS group, 71[55-90] to 43[35-58] versus 69[53-89] to 49[41-70] ml/$m^2$ in the conventional group ($P < 0.05$). Significant improvement for all quality of life domains were seen, except for pain, with no intergroup differences. Twenty-seven (23%) patients underwent concomitant TVP, all in the conventional group. Tricuspid regurgitation decreased after concomitant TVP ($P < 0.001$), whereas in patients with no TVP no significant changes occurred. At 6 months tricuspid regurgitation grade was comparable in patients with TVP versus patients without need for TVP.

## Conclusion

MR severity reduced significantly, with no difference between conventional surgery and MAMVS in reducing MR, with superior left atrial remodeling in the MAMVS group. In-hospital complications and NYHA class and quality of life assessment were not different between conventional surgery and MAMVS.

# INTRODUCTION

Mitral regurgitation (MR) is the second most frequent operated form of valve disease [1]. The conventional approach is a full sternotomy, but the last decades a minimal access approach, with a set of small chest wall incisions, has become an alternative. Low mortality and morbidity rates, high rates of mitral valve (MV) repair and excellent late results have been reported [2]. Still, papers in which detailed and complete echocardiographic and clinical outcome are provided are sparse. Therefore, the current study was undertaken to evaluate the effects of MV surgery with or without concomitant tricuspid valve (TV) repair in consecutive patients on clinical and echocardiographic outcome in our hospital.

# METHODS

## Patients population

Approval to conduct the study was granted by the Institutional Review Board at the authors' hospital. Informed consent was waived. A total of 120 consecutive patients who had been operated for MR between November 2009 and February 2013 with complete echo and laboratory results were included in the study (13 patients were excluded because of a missing baseline echocardiogram and 10 patients were excluded because of a missing follow-up echocardiogram). Ninety-one patients were operated according to the conventional approach with a full sternotomy and 29 patients with minimal access mitral valve surgery (MAMVS) by right thoracotomy. Absolute exclusion criteria for MAMVS were: 1) coronary artery disease (CAD) necessitating revascularization, 2) significant calcification of the MV apparatus or ascending aorta, 3) significant sclerosis/calcification or tortuosity of the iliac artery, and 4) adhesions or pathology of the pleural space notified by a computed tomography scan.

All patients underwent transthoracic echocardiography (TTE), electrocardiography (ECG) and blood testing (renal function, NT-proBNP) following on their visit at the outpatient clinic two weeks before and six months after MV surgery. A quality-of-life assessment was performed in 68 patients (16 in the MAMVS and 52 in the conventional group) using the SF-36 questionnaires, consisting of not disease-specific scale-rated questions that measure functioning in different aspects of daily life. According to the guidelines, this questionnaire was given or sent to the patient and completed at home before operation and before visit to the outpatient clinic at 6 months [3].

## Image acquisition and analysis

All TTE studies were performed by expert sonographers using a Philips iE 33 ultrasound system (Philips Medical Systems, Best, the Netherlands), equipped with a S5-1 transducer

according to the recommendations published by Monin et al. [4]. Left atrial (LA) volumes (LAV), left ventricular (LV) volumes and ejection fraction (EF) were measured with TomTec triplane analysis (TomTec Imaging systems, Unterschleissheim, Germany). Left atrial volume index (LAVI) was determined by dividing LAV by body surface area. The mechanism of the MR was scored according to a modified echocardiographic classification proposed by Shah and Raney [5]. MR and tricuspid regurgitation (TR) pre-operative and 6 months postoperative were scored categorically according to 7 scales (from 0 to 6): none, trace, mild, mild-to-moderate, moderate, moderate-to-severe and severe. For MR also the MR index was determined. This index is derived from 6 echocardiographic variables and includes jet penetration, proximal isovelocity surface area, continuous-wave Doppler jet intensity and character, pulmonary artery pressure, pulmonary venous flow pattern and LA size [6]. Surgical complications were noted according to the guidelines published by Akins et al. [7].

## Surgical techniques

A right lateral mini-thoracotomy incision is made of approximately 5 cm in the 3rd or 4th intercostal space. After the thoracotomy is made, two auxiliary working ports are established to allow positioning of a CO2 insufflator, camera device, ventricular vent and pericardial stay sutures. A cut down technique is used to expose the femoral vein and artery, which are cannulated. Femoral vein cannulation is done under echographic guidance. The ascending aorta is cross clamped and antegrade St. Thomas cardioplegia is administered via the aortic root. The mitral valve is exposed via left atriotomy along the groove of Waterston. Depending on the mechanism of MR various standard mitral valve repair techniques were used and, usually, a Physio II ring annuloplasty is performed. Valve competence is confirmed with hydrostatic saline test and the left atrium is closed. If significant tricuspid valve regurgitation or annulus dilation is present, an annuloplasty using a Phsyio ring is performed. The pericardium is approximated in all cases.

In the conventional subgroup a full sternotomy is performed with standard bicaval cannulation. The mitral valve is exposed via left atriotomy, or, in case of concomitant tricuspid valve surgery, a trans-septal approach.

## Statistical analyses

Statistical analysis was performed using R (R Development Core Team, Vienna, Austria, version 3.3.4). Normality of continuous variables was evaluated by Shapiro-Wilk tests Continuous data were then presented as median and interquartile range (IQR) (non-Gaussian) or mean ± standard deviation (SD) (Gaussian) and differences were tested with student t-test or Mann-Whitney U test, as appropriate. Categorical data were presented as percentages and tested with chi-square test or Fisher's exact test, as appropriate. Paired tests were used for within subject comparison at different follow-up moments. For the

ordinal echocardiographic outcomes, within subject differences were tested with the paired Wilcoxon signed rank test. A p-value <0.05 was considered statistically significant.

# RESULTS

## Baseline clinical and echocardiographic characteristics

Table 1 shows the baseline clinical characteristics of the total cohort and the 29 patients with MAMVS compared with the 91 who underwent the conventional or "open" approach. Patients in the MAMVS group were younger (60 [50-63] vs. 66 [60-74] years, P <0.001), more often in New York Heart Association (NYHA) functional class I and II (86% vs. 49%, P <0.001) and had a lower NT-proBNP level (21 [13-51] vs 111 [34-259] pmol/L, P <0.001). Because of the exclusion criteria none of the patients in the MAMVS group had significant CAD, whereas in the conventional group 35 patients (38%) had significant CAD. Patients in the MAMVS group were less often preoperatively treated with oral anticoagulation (14% v. 39%, P <0.05), beta-blockers (38% vs. 65%, P <0.05) and diuretics (24% vs. 71%, P <0.001). There were no significant differences between the groups in terms of gender, atrial fibrillation, heart rate, blood pressure, cardiovascular risk factors and chronic renal failure.

**Table 1.** Baseline clinical characteristics of the study population.

| | **Total cohort N = 120** | **MAMVS N = 29** | **Conventional N = 91** | **P-value** |
|---|---|---|---|---|
| Age (years) | 64 [59-71] | 60 [50-63] | 66 [60-74] | **<0.001** |
| Males | 65 (54%) | 18 (62%) | 47 (52%) | 0.443 |
| NYHA class | | | | **0.001** |
| I | 13 (11%) | 7 (24%) | 6 (7%) | |
| II | 56 (47%) | 18 (62%) | 38 (42%) | |
| III - IV | 51 (42%) | 4 (14%) | 47 (52%) | |
| Rhythm | | | | 0.250 |
| Sinus rhythm | 95 (79%) | 26 (90%) | 69 (76%) | |
| Atrial fibrillation | 20 (17%) | 2 (7%) | 18 (20%) | |
| Other | 5 (4%) | 1 (3%) | 4 (4%) | |
| Heart rate (beats per minute) | 70 [63-81] | 67 [60-76] | 71 [64-84] | 0.051 |
| Blood pressure, systolic (mmHg) | 135 [120-145] | 135 [125-155] | 130 [120-145] | 0.169 |
| Blood pressure, diastolic (mmHg) | 80 [70-85] | 85 [75-90] | 80 [70-85] | 0.096 |
| Coronary artery disease | | | | **0.001** |
| Absent | 85 (71%) | 29 (100%) | 56 (62%) | |
| 1 vessel disease | 13 (11%) | 0 | 13 (14%) | |
| 2 vessel disease | 9 (7%) | 0 | 9 (10%) | |
| 3 vessel disease | 13 (11%) | 0 | 13 (14%) | |
| Previous cardiac surgery | 1 (1%) | 0 | 1 (1%) | -- |

**Table 1.** Baseline clinical characteristics of the study population. (*continued*)

| | Total cohort N = 120 | MAMVS N = 29 | Conventional N = 91 | P-value |
|---|---|---|---|---|
| Percutaneous coronary intervention | 7 (6%) | 1 (3%) | 6 (7%) | 0.862 |
| Cerebro-vascular disease | 13 (11%) | 2 (7%) | 11 (12%) | 0.660 |
| Smoker | 18 (15%) | 3 (10%) | 15 (17%) | 0.612 |
| Chronic renal failure | | | | 0.117 |
| GFR < 30 | 4 (3%) | 0 (0%) | 4 (4%) | |
| GFR 30-59 | 20 (17%) | 2 (7%) | 18 (20%) | |
| GFR > 60 | 96 (80%) | 27 (93%) | 69 (76%) | |
| Diabetes Mellitus | 14 (12%) | 1 (3%) | 13 (14%) | 0.211 |
| Hypertension | 58 (48%) | 14 (48%) | 44 (48%) | 0.999 |
| COPD | 11 (9%) | 2 (7%) | 9 (10%) | 0.907 |
| Medication | | | | |
| Antiplatelet | 36 (30%) | 3 (10%) | 33 (36%) | **0.016** |
| Oral anticoagulation | 39 (33%) | 4 (14%) | 35 (39%) | **0.025** |
| Beta-blocker | 70 (58%) | 11 (38%) | 59 (65%) | **0.019** |
| ACE-inhibitor / ARB | 88 (73%) | 18 (62%) | 70 (77%) | 0.277 |
| Diuretics | 72 (60%) | 7 (24%) | 65 (71%) | **<0.001** |
| Calcium-antagonist | 10 (8%) | 2 (7%) | 8 (9%) | 0.999 |
| NT-proBNP (pmol/L) | 63 [22-191] | 21 [13-51] | 111 [34-259] | **<0.001** |

ACE = angiotensin-converting enzyme, ARB = angiotensin receptor blocker, COPD = chronic obstructive pulmonary disease , GFR = glomerular filtration rate, NT-pro-BNP = N-terminal pro b-type natriuretic peptide, NYHA = New York heart association

Baseline echocardiographic measurements, mechanism of MR and grading of MR and TR are shown in Table 2. LV-EF was significantly higher in the MAMVS group (56 [51-61] vs. 52 [43-57] %, P <0.005) and also the mechanisms of MR were different (P <0.005) with more leaflet restriction in the conventional group. TR severity differed also, although not significant.

The only difference at baseline in quality-of-life assessment was the physical health related to age- and role-specific activities (role limitations/physical), being better in the MAMVS group.

## Surgical results

Four patients in the conventional group underwent MV replacement: one because of extensive endocarditis, one because of substantial calcification of the mitral annulus, and two patients because of unsuccessful repair. Twenty-seven (23%) patients underwent concomitant TV repair, all in the conventional group. None of the MAMVS patients crossed-over to the conventional group. There were no significant differences in complications between the MAMVS and the conventional group (Table 3).

**Table 2.** Baseline echocardiographic characteristics of the study population.

| | Total cohort N = 120 | MAMVS N = 29 | Conventional N = 91 | P-value |
|---|---|---|---|---|
| LV end-diastolic volume (ml) | 177 [140-211] | 181 [152-220] | 173 [135-207] | 0.192 |
| LV ejection fraction (%) | 53 [47-58] | 56 [51-61] | 52 [43-57] | **0.003** |
| LAVI (ml/m$^2$) | 69 [53-89] | 71 [54-90] | 69 [53-89] | 0.818 |
| Mechanism* | | | | **0.002** |
| 1 Annulus dilatation | | | | |
| 1A | 1 (1%) | 0 (0%) | 1 (1%) | |
| 1B | 2 (2%) | 1 (3%) | 1 (1%) | |
| 1C | 7 (6%) | 0 (0%) | 7 (8%) | |
| 2 Leaflet prolapse | | | | |
| 2A | 51 (42%) | 17 (59%) | 34 (37%) | |
| 2B | 12 (10%) | 7 (24%) | 5 (6%) | |
| 2C | 7 (6%) | 2 (7%) | 5(6%) | |
| 3 Leaflet restriction | | | | |
| 3A | 3 (2%) | 0 (0%) | 3 (3%) | |
| 3B | 25 (21%) | 1 (3%) | 24 (26%) | |
| 3C | 8 (7%) | 0 (0%) | 8 (9%) | |
| 5 | 4 (3%) | 1 (3%) | 3 (3%) | |
| MR severity# | | | | 0.154 |
| Moderate | 21 (17%) | 4 (14%) | 17 (19%) | |
| Moderate-severe | 27 (23%) | 4 (14%) | 23 (25%) | |
| Severe | 72 (60%) | 21 (72%) | 51 (56%) | |
| TR Vmax (m/s) | 2.6 [2.3-2.9] | 2.5 [2.3-2.8] | 2.6 [2.4-3.0] | 0.270 |
| TR severity# | | | | 0.098 |
| None | 6 (5%) | 3 (10%) | 3 (3%) | |
| Trace | 50 (42%) | 13 (45%) | 37 (41%) | |
| Mild | 34 (28%) | 8 (28%) | 26 (29%) | |
| Mild-moderate | 11 (9%) | 4 (14%) | 7 (8%) | |
| Moderate | 8 (7%) | 1 (3%) | 7 (8%) | |
| Moderate-severe | 5 (4%) | 0 | 5 (5%) | |
| Severe | 6 (5%) | 0 | 6 (7%) | |

LAVI = left atrial volume index; LV = left ventricle; MR = mitral regurgitation; TR = tricuspid regurgitation
* = see methods for explanation in detail
# = judged 2 weeks before operation

## Follow-up at 6 months

In the post-operative evaluation at 6 months 8 patients had died in the conventional group (Table 4), including the 1 patient with MV replacement, resulting in 11 patients excluded from echocardiographic repair analysis (8 patients died and 3 patients underwent MVR at the time of surgery, all in the conventional group).

**Table 3.** In-hospital complications after surgery.

| | Total cohort N = 120 | MAMVS N = 29 | Conventional N = 91 | P-value |
|---|---|---|---|---|
| Hospital stay median (IQR) | 7 (6-9) | 7 (6-8) | 8 (6-10) | 0.095 |
| Intensive care stay median (IQR) | 1 (1-1) | 1 (1-1) | 1 (1-1) | 0.329 |
| Hospital mortality n (%) | 4 | 0 (0.0) | 4 | 0.572 |
| Re-thoracotomy n (%) | 10 (8.3) | 2 (6.9) | 8 (8.8) | 0.999 |
| Acute Kidney Injury stage n(%) | | | | 0.689 |
| 0 | 97 (80.8) | 26 (89.7) | 71 (78.0) | |
| 1 | 10 (8.3) | 1 (3.4) | 9 (9.9) | |
| 2 | 10 (8.3) | 2 (6.9) | 8 (8.8) | |
| 3 | 3 (2.5) | 0 (0.0) | 3 (3.3) | |
| New permanent PM implantation n (%) | 2 (1.7) | 0 (0.0) | 2 (2.2) | 0.999 |
| Intra-aortic balloon pump n (%) | 3 (2.5) | 1 (3.4) | 2 (2.2) | 0.567 |
| Infection with focus n (%) | 9 (7.5) | 3 (10.3) | 6 (6.6) | 0.450 |
| Fever unkown origin n (%) | 2 (1.7) | 0 (0.0) | 2 (2.2) | 0.999 |
| Delirium n(%) | 6 (5.0) | 1 (3.4) | 5 (5.5) | 0.999 |
| Discharge atrial fibrillation n (%) | 4 (3.3) | 1 (3.4) | 3 (3.3) | 0.999 |
| Valve thrombosis n (%) | 0 (0.0) | 0 (0.0) | 0 (0.0) | - |
| Endocarditis n (%) | 1 (0.8) | 0 (0.0) | 1 (1.1) | 0.999 |
| Thrombo-embolic cerebral n (%) | 3 (2.5) | 1 (3.4) | 2 (2.2) | 0.567 |
| Thrombo-embolic noncerebral n (%) | 0 (0.0) | 0 (0.0) | 0 (0.0) | - |
| Bleeding event n (%) | 3 (2.5) | 0 (0.0) | 3 (3.3) | 0.999 |

PM = pacemaker

**Table 4.** Mortality before and after discharge

| Cause of death | Age | MR mechanism | Pre-operative ejection fraction | Latest known MR severity after surgery |
|---|---|---|---|---|
| **Before discharge** | | | | |
| Mediastinitis | 66 | Prolaps | 68% | moderate-to-severe |
| Sepsis | 78 | Restriction | 56% | none |
| LV failure / assist device | 68 | Prolaps | 55% | not known |
| Cerebro-vascular accident | 81 | prolaps | 64% | mild-to-moderate |
| **After discharge** | | | | |
| Suicide | 52 | Restriction | 40% | moderate |
| Sudden cardiac death | 77 | Restriction | 34% | none |
| Late tamponade | 78 | Annulus dilatation | 48% | mild |
| Cerebro-vascular accident | 72 | Restriction | 24% | mild |

MR = mitral regurgitation

As seen in Figure 1 MR decreased significantly after 6 months for both groups with no significant difference between the groups (P = 0.960). Other echocardiographic parameters as LV end-diastolic volume, LV-EF and LAVI also improved significantly after surgery as well as NYHA class (Table 5). Comparison of the echocardiographic parameters at 6 months for the two groups shows a significant difference for LAVI with more remodeling in the MAMVS group, 71 [55-90] to 43 [35-58] (ml/m$^2$) versus 69 [53-89] to 49 [41-70] (ml/m$^2$) in the conventional group (P < 0.05). For the total cohort NYHA class improved from II [II-III] pre-operatively to I [I-II] post-operatively at 6 months, respectively. NT-proBNP 6 months after surgery shows in the MAMVS group no significant improvement, but in the conventional group this value decreased significantly from 110 [33-242] to 59 [35-123] pmol/L (P <0.05).

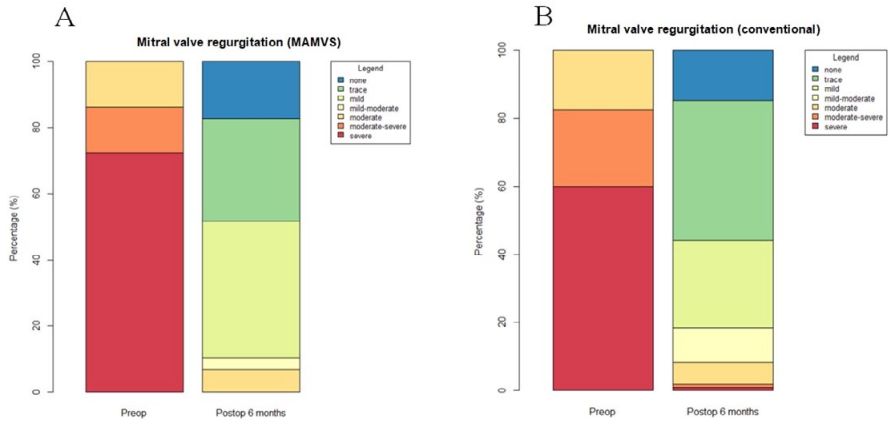


**Figure 1:** Severity of mitral regurgitation at baseline and 6 months after mitral valve surgery for the MAMVS (A) and conventional (B) group.

**Table 5.** Echocardiographic and clinical parameters at baseline and 6 months follow-up

| | **MAMVS N = 29** | | **p-value** | **Conventional N = 80** | | **p-value** |
|---|---|---|---|---|---|---|
| | **Pre** | **6m** | | **Pre** | **6m** | |
| Mitral regurgitation | | | < 0.001 | | | < 0.001 |
| None | 0 | 5 (17%) | | 0 | 11 (14%) | |
| Trace | 0 | 9 (31%) | | 0 | 36 (45%) | |
| Mild | 0 | 12 (41%) | | 0 | 16 (20%) | |
| Mild-moderate | 0 | 1 (3%) | | 0 | 10 (13%) | |
| Moderate | 4 (14 %) | 2 (7%) | | 14 (18%) | 5 (6%) | |
| Moderate-severe | 4 (14%) | 0 | | 21 (26%) | 1 (1%) | |
| Severe | 21 (72%) | 0 | | 45 (56%) | 1 (1%) | |
| LV end-diastolic volume (ml) | 181 [152-220] | 138 [110-170] | < 0.001 | 173 [135-207] | 136 [117.5-170] | < 0.001 |

**Table 5.** Echocardiographic and clinical parameters at baseline and 6 months follow-up (*continued*)

| | MAMVS N = 29 | | p-value | Conventional N = 80 | | p-value |
|---|---|---|---|---|---|---|
| LV ejection fraction (%) | 56 [51-61] | 51 [48-55] | 0.001 | 52 [43-57] | 49 [37-53] | < 0.001 |
| LAVI (ml/m$^2$) | 71 [55-90] | 43 [35-58] | < 0.001 | 69 [53-89] | 49 [41-70] | < 0.001 |
| TR Vmax (m/s) | 2.6 ± 0.5 | 2.4 ± 0.3 | 0.03 | 2.7 ± 0.5 | 2.5 ± 0.5 | 0.001 |
| Tricuspid regurgitation | | | | | | |
| None | 3 (10%) | 1 (3%) | | 3 (4%) | 6 (8%) | |
| Trace | 13 (45%) | 13 (45%) | | 33 (41%) | 40 (50%) | |
| Mild | 8 (28%) | 11 (38%) | | 23 (29%) | 26 (32%) | |
| Mild-moderate | 4 (14%) | 3 (10%) | | 6 (8%) | 5 (6%) | |
| Moderate | 1 (3%) | 1 (3%) | | 7 (9%) | 3 (4%) | |
| Moderate-severe | 0 | 0 | | 4 (5%) | 0 | |
| Severe | 0 | 0 | | 4 (5%) | 0 | |
| Death | | 0 | | | 8 | |
| NYHA class | | | < 0.001 | | | <0.001 |
| I | 7 (24%) | 24 (83%) | | 5 (6%) | 52 (65%) | |
| II | 18 (62%) | 3 (10%) | | 37 (46%) | 25 (31%) | |
| III - IV | 4 (14%) | 2 (7%) | | 38 (48%) | 3 (4%) | |
| NT-proBNP (pmol/L) | 21 [13-51] | 31 [20-51] | 0.127 | 110 [33-242] | 59 [35-123] | 0.018 |

LAVI = left atrial volume index; LV = left ventricle; NYHA = New York Heart Association; TR = tricuspid regurgitation

TR decreased after concomitant TVP (P < 0.001), whereas in patients without TV repair no significant change occurred (P = 0.831). Final results of TR after TV repair were comparable to patients without a need for TV repair at 6 months (P = 0.408) (Figure 2).

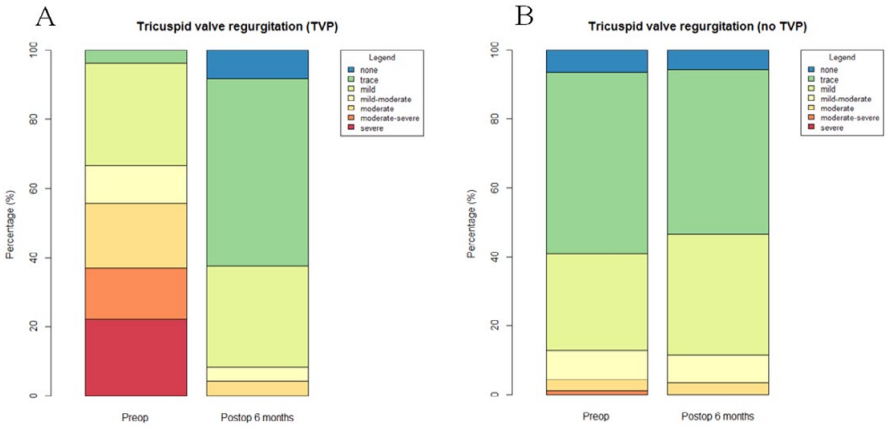


**Figure 2:** Severity of tricuspid regurgitation at baseline and 6 months after mitral valve surgery in patients with (A) and without (B) tricuspid valve plasty.

Analyses of the quality of life questionnaires showed a significant improvement at all domains after 6 months, except for pain (Figure 3). Comparing the improvements of both groups demonstrated no significant differences with P-values between 0.220 and 0.934 for 8 domains.

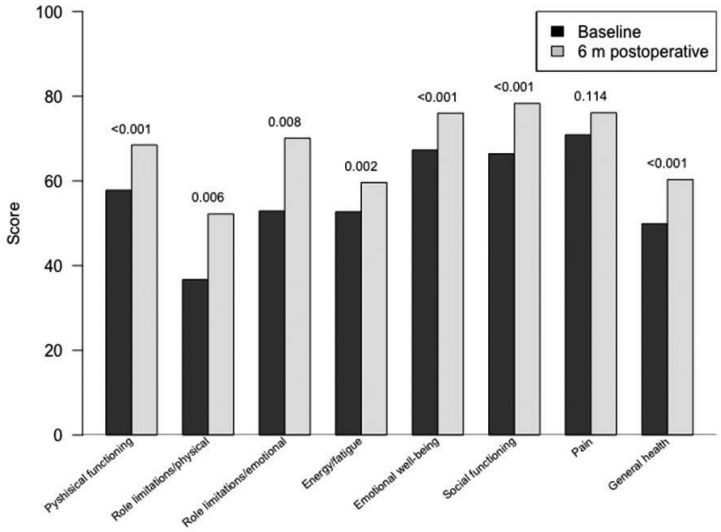


**Figure 3:** Quality of life at baseline and 6 months after mitral valve surgery.

## DISCUSSION

This study investigated the clinical and echocardiographic outcome after MV surgery and concomitant tricuspid valve surgery in our hospital. The main findings are

1) MR severity was significantly reduced, with no difference between conventional surgery and MAMVS in reducing MR
2) LA remodeling was superior in the MAMVS group
3) In-hospital complications were not different between conventional surgery and MAMVS
4) NYHA class and quality of life as measured by SF-36 questionnaires improved after surgery, except for pain with no significant differences between the conventional surgery or MAMVS
5) TV repair was done in a quarter of all patients, usually based on an enlarged tricuspid annular diameter, and only a very small minority of patients (3%) had at short-term (6-months) follow-up moderate TR and none had more than moderate TR

### Reduction in MR severity

Echocardiography is the principal technique to assess the severity and mechanism of the MR, as well the suitability for repair and residual MR after surgery [8,9]. The mechanism of

MR was different in the MAMVS and conventional groups, with more leaflet restriction and moderate to severe TR in the conventional cohort, most likely because these parameters are part of the decision for suitability for MAMVS. MR decreased significantly after 6 months for both groups with no significant difference between the groups. In the MAMVS group only 2 patients (7%) had moderate MR at follow-up and in the conventional group 5 (6%) patients had moderate MR and 2 (2%) had more than moderate MR. So, the overall success of MV repair was greater than 90% (4 patients converted to MV replacement and 9 patients had at least moderate MR at follow-up). Of note, in the 8 patients who died before the 6-month assessment also 2 had at least moderate MR after conventional surgery, so ultimately 11 patients had at least moderate MR at follow-up, still resulting in a successful MV repair rate of >90%.

## LV and LA remodeling

Whereas there were no changes between conventional surgery and MAMVS in LV reverse remodeling, reverse LA remodeling was more pronounced in the MAMVS group. This may be important because LA size may be a predictor of outcome [10-12]. However, the more pronounced reduction in LA volume is most likely explained because of greater pre-operative MR severity at baseline in the conventional surgery group. It should also be noted that patients in the conventional group tended to have a higher incidence of atrial fibrillation, probably limiting LA reverse remodeling. Alternatively, Machdo et al. reported an association of LA reverse remodeling after MV surgery with higher LV-EFs [13]. In our study the preoperative LV-EF was significant higher in the MAMVS group providing an alternative explanation for more LA reverse remodeling in this group.

## In-hospital complications

MAMVS has been shown to have excellent results, compared with the conventional approach, in terms of mortality, morbidities and pain, providing shorter hospital stay, faster recovery and return to normal activities with outstanding long-term results [2,14]. Our results are in line with the current literature with an in-hospital mortality of 0.8% (total cohort) and no significant differences in complications between MAMVS and the conventional approach.

## Clinical follow-up results

The quality of life assessment is, besides the NYHA classification, an essential component in evaluating the efficacy of the benefits obtained after surgery. Only, few studies investigated quality of life after MV surgery for MR, especially in asymptomatic patients [15,16]. In their prospective study Bayer-Topilsky and co-authors report a psycho-emotional status alteration to normal 6 month after MV surgery for organic MR, suggesting that severe MR in patients with NYHA class I and II for symptoms of heart failure has a negative impact

on mental health and that surgical procedures improve their mental outcomes [16]. Our study confirms these data for a more heterogeneous group with 58% of patients in NYHA class I or II and not only organic MR.

## Reduction in TR severity

TR in MV disease may result from 1) pulmonary hypertension and subsequent right ventricular enlargement and dysfunction with an increasing tricuspid valve diameter, leaflet tethering or papillary muscle displacement, 2) atrial fibrillation with subsequent increasing tricuspid valve diameter, and 3) a similar disease process. For MR surgery, concomitant TV repair is recommended in patients with a tricuspid annular dilatation ≥ 40 mm since this is a risk factor for developing late functional TR after left sided valve surgery [8,17]. In our study 27 (23%) of patients underwent TV repair. In 6 patients this was based on severe TR, in the remaining patients it was based on tricuspid annular dilatation, with the notice that the sensitivity of transthoracic echocardiography was less than transesophageal echocardiography. Whereas at baseline 19 (16%) of patients had at least moderate TR, at short-term (6-months) follow-up only 4 (3%) of patients had moderate TR and none had more than moderate TR. In the MAMVS group no patient had undergone TV repair and only 1 patient had progression from pre-operatively mild to moderate TR at follow-up. In the conventional group 3 patients had moderate TR at follow-up; 2 patients without annulus dilatation and without TV repair with pre-operatively respectively mild-to-moderate and moderate TR and 1 patient showed regression of pre-operative severe to moderate TR after TV repair. So, actually in total only 2 patients showed mild progression of untreated TR [18,19].

## Limitations

This was a single center experience and in particular the number of patients that underwent MAMVS was relatively small. Therefore we opted for univariable comparisons. Approximately 15% of patients from the consecutive series could not be included in the study because of missing baseline or follow-up echocardiograms. At baseline, significant differences were seen between the two patient groups in age, NYHA class, CAD presence and LV-EF and this selection bias may obviously limit the comparison between the groups. However, the main goal of the study, the reduction of MR, will only to a small extent not be affected by these differences. Also, three-dimensional echocardiography was not used in this study although it may improve volumetric [20] and functional analysis [21]. Finally, in most studies for MAMVS, long-term successful repair was defined as absence of moderate or more MR >6 months after surgery [2,14,22]. Our 6-months data do therefore not provide true long-term outcome. However, in the 47 patients in whom 2 year echo follow-up data were available (14 in the MAMVS group and 33 in the conventional group) none of the patients showed progression from less than moderate to moderate or more MR. Also, in

three additional patients with restrictive MR who died in the 6 to 24 month period none had moderate or greater MR after surgery.

## CONCLUSIONS

MR severity was significantly reduced, with no difference between conventional surgery and MAMVS in reducing MR, with greater LA remodeling in the MAMVS group. In-hospital complications and NYHA class and quality of life assessment were not different between conventional surgery and MAMVS. The overall successful MV repair rate was >90%.

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