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Additional tricuspid annuloplasty in mitral valve surgery results in better clinical outcome.

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ABSTRACT:

Objective: The clinical benefit of tricuspid annuloplasty (TA) in patients undergoing mitral valve surgery (MVS) is still debated. We evaluated the immediate surgical success, post-operative outcome and the medium-term effect of TA in MVS.

Methods: Patients were included between 09-2003 and 12-2009 and followed until 09-2013 to achieve a median follow-up time of 5 years (IQ3.7-6.9). The endpoint of mortality due to cardiac causes and combined endpoint of cardiac mortality or hospitalization for heart failure were evaluated. Propensity score adjusted cox regression was used to evaluate the clinical benefit of TA at the time of MVS.

Results: Of 150 patients (84 female;67±12 years), 82 presented with tricuspid regurgitation (TR)<2/4 and underwent isolated MVS. Sixty-eight patients presenting with TR≥2/4, 31 underwent isolated MVS whereas 37 underwent additional TA.

In patients with preoperative TR≥2/4, TR was significantly reduced until 5 years post-operatively [mean reduction 0.81±1.31;p=0.04] when additional TA was done. The combined endpoint occurred in 29% vs. 6% at 1 year and in 57% vs. 39% at 5 years follow-up for patients with isolated MVS and patients undergoing concomitant TA, respectively.

Patients with preoperative TR≥2/4 had worse unadjusted survival than those with TR<2/4 (log-rank p=0.009) In the patients with TR≥2/4, propensity score-adjusted risk for the combined end-point was higher in those with isolated MVS versus MVS with additional TA [Cox HR 2.855(1.082-7.532);p=0.035].

Conclusion: Additional TA is an effective surgical measure to reduce functional TR severity. This approach results in a decreased risk of cardiac mortality and hospitalization in patients with preoperative TR≥2/4.

Key Words: Mitral regurgitation, Tricuspid valve disease, Valve disease surgery.

KEY QUESTIONS:

What is already known about this subject?

Tricuspid valve regurgitation often accompanies mitral valve regurgitation. Development or deterioration of tricuspid valve function is known to be associated with decreased functional capacity and increased mortality. Although no outcome study has proven the clinical benefit of tricuspid valve annuloplasty at the time of mitral valve surgery, a liberal approach towards tricuspid annuloplasty is advised in the guidelines.

What does this study add?

Because clinical and echocardiographic factors influence both the decision to perform tricuspid annuloplasty as well as outcome, we adjusted for these factors via propensity scores in our regression models. After adjustment, patients with preoperative tricuspid regurgitation undergoing isolated mitral valve surgery had worse outcome for the combined endpoint of cardiac mortality or hospitalization for heart failure. This endpoint was mainly driven by an increased incidence of heart failure.

How might this impact on clinical practice?

This study provides evidence for the clinical benefit of performing concomitant tricuspid annuloplasty. It supports a more liberal approach towards tricuspid annuloplasty at the time of left-sided cardiac surgery both in functional and degenerative mitral regurgitation. However, due to the observational nature of the data and the relatively small sample size, further research should be done to confirm the existence and the causality of the association between outcomes and surgical practices.

INTRODUCTION:

Functional tricuspid regurgitation (TR) often accompanies mitral regurgitation (MR). Although TR may be only mild at the time of surgery, TR severity progresses after isolated mitral valve surgery in about 30% of patients and can occur years after the initial left-sided surgery.[1, 2, 3] The complex pathophysiology of functional TR makes the natural history unpredictable.[4, 5] Increasing TR severity is known to be associated with worse prognosis.[1, 6] Furthermore, reoperation for isolated TR is associated with a high perioperative, short- and long-term mortality whereas performing tricuspid annuloplasty at the time of mitral valve surgery adds little time to the procedure.[7, 8] Therefore, a more liberal approach in performing tricuspid valve repair at the time of MV surgery is now advocated by both the ESC and the AHA/ACC guidelines on valvular heart disease.[9, 10] Although such an approach results in favourable remodelling of the right ventricle and lower recurrence of TR, data on clinical outcome are scarce. [3, 11, 12] Improved mid-term survival of concomitant tricuspid annuloplasty has been reported in patients with functional MR due to, mainly ischemic, cardiomyopathy.[13] However, the gross majority of mitral valve surgery is performed for chronic degenerative valvular disease.[14] Especially in this patient population, concomitant tricuspid annuloplasty is controversial.[15] Comparison of the outcome in patients undergoing mitral valve surgery with or without tricuspid annuloplasty is notoriously difficult because the former often present in a worse clinical state with more severe TR, higher NYHA functional class and decreased right ventricular function.[3] Cross-sectional studies therefore failed to show improved outcome for patients undergoing simultaneous tricuspid annuloplasty and mitral valve surgery in the past. [16, 17] The aim of our study was to assess the surgical success of mitral valve surgery with or without tricuspid annuloplasty, to examine post-operative outcome and to evaluate the

clinical benefit of tricuspid annuloplasty in the setting of mitral valve surgery corrected for pre-operative parameters using a propensity score analysis.

METHODS:

Patient selection and data collection:

From the institutional database of Cardiac Surgery at the University Hospitals Leuven, patients undergoing mitral valve surgery were retrospectively included from September 2003 until December 2009 and followed until September 2013. All patients had their follow-up at the University Hospitals Leuven, a tertiary care center. Patients with primary tricuspid valve pathology, redo surgery or severe non-cardiac disease at the moment of inclusion were excluded.

Patients underwent either isolated mitral valve surgery or mitral valve surgery in combination with tricuspid annuloplasty. Patients were divided into 3 groups: (1) patients with TR<2/4 undergoing isolated mitral valve surgery (Group TR-/MVS); (2) patients with TR≥2/4 undergoing isolated mitral valve surgery (Group TR+/MVS) and (3) patients with TR≥2/4 undergoing mitral valve surgery in combination with tricuspid annuloplasty (Group TR+/MVS+TA).

The mitral valve was repaired whenever feasible, otherwise, mitral valve replacement was performed. The decision to perform concomitant tricuspid annuloplasty was taken after multi-disciplinary discussion by the institutions heart team. Demographic and clinical data as well as echocardiographic data were included. Post-operative data including echocardiography immediately post-operative, at 6-month, 3 years and 5 years follow-up were reviewed. Outcome for every patient was evaluated. The local ethics committee approved patient inclusion and analysis.

Transthoracic echocardiography:

Left ventricular end-diastolic diameter was obtained from a parasternal long axis view. Left ventricular ejection fraction was obtained by the biplane method of disks (modified Simpson's rule). Right ventricular diameter was obtained at end-diastole and at the mid-ventricular level from a right ventricle focused apical 4-chamber view. Tricuspid annular diameter was obtained at end-diastole from the apical 4-chamber view. Tricuspid annulus systolic excursion (TAPSE) was obtained from an apical 4-chamber view by placing the M-mode cursor through the anterior tricuspid annulus. Valvular regurgitation was assessed semi-quantitatively by colour Doppler echocardiography and graded from 0-4/4. The right ventricle to right atrial pressure gradient was calculated from the tricuspid regurgitant velocity by means of the simplified Bernoulli equation.

Endpoints:

Cardiac mortality and the combined endpoint of cardiac mortality or hospitalization for heart failure were evaluated for each group. Cardiac mortality was defined as death due to end-stage heart failure, cardiogenic shock and sudden cardiac death. Heart failure was diagnosed when the patient presented with both clinical signs (NYHA functional class III and higher or signs of sodium and water retention) and evidence of fluid overload on echocardiography or an elevated NT-proBNP was observed at presentation.

Statistical analysis:

Continuous data and categorical data are represented by means and standard deviation or frequencies and percentages, respectively.

First, pre-operative demographic data and echocardiographic data were analysed. Data from patients with significant TR≤2/4 undergoing either isolated mitral valve surgery or

concomitant tricuspid annuloplasty were compared by unpaired t-test or Fisher's exact test where applicable.

Next, surgical success was evaluated by comparison of pre-operative echocardiographic data with echocardiography directly post-operative, at 6 months, 3 years and 5 years post-operatively by the paired t-test. Differences between patients with TR≥2/4 undergoing mitral valve surgery with or without tricuspid annuloplasty were assessed by the unpaired t-test.

Third, the occurrence of cardiac mortality and the combined endpoint of cardiac mortality or hospitalization for heart failure were evaluated for each group by Kaplan-Meier survival analysis.

Last, a non-parsimonious propensity score was constructed by multivariate binary logistic regression and the probability was calculated for each patient with TR ≥ 2/4 to be allocated by the heart team to concomitant tricuspid annuloplasty (Group TR+/MVS vs. Group TR+/MVS+TA). Based on current guidelines and practice in our hospital, age, preoperative NYHA functional class, TR severity, tricuspid annular diameter and preoperative tricuspid annular plane systolic excursion (TAPSE) were included in the model [C-statistic 0.861 (95%CI=0.767-0.956); Hosmer Lemeshow p=0.279].

Multivariate Cox regression was performed with the propensity score and the surgical approach as variables, and propensity score-adjusted survival curves were plotted subsequently.

All tests were two-tailed. A P-value <0.05 was considered significant. Analyses were performed using SPSS® (version 22 SPSS, Chicago, USA).

RESULTS:

Patient inclusion:

From September 2003 until December 2009, 882 patients underwent mitral valve surgery at the University Hospitals Leuven. Of these, 625 were referred from and later followed outside the hospital. From the remaining 257 patients, 17 were lost to follow-up. Another 90 patients were excluded for various reasons as is summarized in Figure 1. The study cohort comprised the remaining 150 patients. Median follow-up time was 5 years (IQ range 3.7-6.9).

Patient characteristics:

Demographic, echocardiographic, and post-operative data are listed in Table 1. Eighty-two patients had pre-operative TR<2/4 (group TR-/MVS). From the 68 patients with TR ≥ 2/4, 37 underwent concomitant tricuspid valve repair (group TR+/MVS+TA), and 31 patients underwent isolated mitral valve surgery (group TR+/MVS). Patients in group TR+/MVS+TA had significantly more TR and significantly lower TAPSE than patients in group TR+/MVS. The etiology of mitral valve regurgitation can be found in Table 1.

In 82 (55%) patients, mitral valve repair was feasible. The other 68 (45%) patients underwent mitral valve replacement, in 37 (54%) cases with a mechanical prosthetic valve. The distribution of the surgical strategy was not significantly different across groups (Fisher's Exact p=0.518).

Of 37 patients undergoing additional tricuspid annuloplasty, 21 (56%) underwent De Vega annuloplasty and 16 (44%) underwent ring annuloplasty.

Surgical success after mitral and tricuspid valve surgery:

Significant reduction of MR was observed in all patients early post-operatively and at 6 months follow-up. Results are summarized in Table 2. In patients presenting without

significant TR (Group TR-/MVS), TR post-operatively was slightly but significantly increased ($p<0.001$ immediately post-operatively, $p=0.018$ at 6 months, $p<0.0001$ at 3 years follow-up and $p<0.0001$ at 5 years follow-up), albeit still in what is considered to be the physiological range. In Group TR+/MVS, no significant decrease of TR could be seen in follow-up. Patients undergoing simultaneous tricuspid and mitral valve surgery (Group TR+/MVS+TA) presented with a large and significant decrease of TR post-operatively. Mean reduction in TR severity was 1.5 ± 1.1 immediately post-operatively ($p<0.001$), 1.13 ± 1.2 at 6 months ($p<0.001$), 0.89 ± 1.2 at 3 years ($p<0.001$), and 0.81 ± 1.3 at 5 years follow-up ($p=0.040$).

A trend towards lower TR severity in patients with preoperative TR undergoing tricuspid annuloplasty (TR+/MVS+TA) compared to patients undergoing isolated mitral valve surgery (TR+/MVS) throughout follow-up. (Table 2)

TR severity was similar pre-operatively for patients undergoing De Vega annuloplasty compared to patients undergoing ring annuloplasty (2.7±0.7 vs. 2.6±1.0; $p=0.574$). De Vega annuloplasty resulted in significant reduction of TR post-operatively (1.2±0.7; $p<0.0001$), at 6 months (1.8±0.9; $p=0.005$) and at 3years follow-up (2.0±0.67; $p=0.006$). Ring annuloplasty equally resulted in significant reduction of TR severity post-operatively (1.1±0.8; p= $p<0.0001$), at 6 months (1.1±0.8; $p<0.0001$) and at 3 years follow-up (1.3±0.7; $p=0.018$). Ring annuloplasty resulted in a more pronounced reduction of TR severity at 6 months (1.8±0.9 vs. 1.1±0.8; $p=0.015$) and at 3 years follow-up (2.0±0.7 vs. 1.3±0.7; $p=0.023$).

NYHA functional class was significantly better compared to pre-operatively in all patients, alive at 6 months follow-up.

Short- and medium-term clinical outcome after mitral and tricuspid valve surgery:

Early post-operative all-cause mortality at 30 days and 3 months was 3.3% and 6% respectively.(Table 1) Event-rate for the combined endpoint of cardiac mortality or hospitalization for heart failure, for cardiac mortality and for hospitalization for heart failure can be found in Table 3.

Event free survival was significantly better in patients presenting without significant preoperative TR (<2/4), compared to patients with preoperative TR > 2 (30-day cardiac mortality=2.4% vs 4.4%; 1-year=3.7% vs 10.6%; 5-year=7% vs 22.3%; Log Rank p=0.009). In unadjusted analysis, there was no difference in cardiac mortality between patients with TR≥2/4 undergoing isolated mitral valve surgery (Group TR+/MVS) and patients undergoing additional tricuspid annuloplasty (Group TR+/MVS+TA) (30-day cardiac mortality=9.7% vs 0%; 1-year=16.1% vs 5.6%; 5-year=24.6% vs 20.3%; Log Rank p=0.414) whereas a trend towards better outcome for the combined endpoint of cardiac mortality or hospitalization for heart failure in the TR+/MVS+TA group could be seen (30 day event-rate = 9.7% vs 0%; 1-year = 29% vs 5.6%; 5-year=57.2% vs 39.4%; Log Rank p=0.077).(Figure 2 and Table 3)

When incorporating the propensity score into a multivariable Cox regression model, no significant benefit in cardiac mortality of additional tricuspid annuloplasty in patients with preoperative TR≥2/4 could be observed [HR 2.9 (0.8-10.7); p=0.108], whereas propensity score-adjusted event-free survival for the combined endpoint of cardiac death or hospitalization for heart failure was significantly better for patients with preoperative TR >2 undergoing additional tricuspid annuloplasty [HR 2.9 (1.1-7.5); p=0.034]. (Figure 3)

DISCUSSION:

This study shows that additional tricuspid annuloplasty at the time of mitral valve surgery significantly reduces TR severity postoperatively. Patients with TR ≥ 2/4 who undergo simultaneous mitral valve surgery and tricuspid annuloplasty have an improved event-free survival for the combined endpoint of cardiac mortality or hospitalization for heart failure.

The value of tricuspid annuloplasty with mitral valve surgery is still debated. Both the European and American guidelines on valvular heart disease have implemented indications for concomitant tricuspid annuloplasty at the time of mitral valve surgery in their recommendations.[9, 10] Even more so, some authors advocate tricuspid annuloplasty in the absence of preoperative TR to prevent progression of TR in the long term.[18, 19] On the other hand, others question the value of concomitant tricuspid annuloplasty especially in degenerative mitral regurgitation. [15].

Increased pulmonary arterial pressure, right ventricular and tricuspid valve annular dimensions contribute independently to functional TR.[20, 21, 22] Although surgery of the mitral valve can reduce the increased pulmonary arterial pressure caused by chronic MR, structural alterations at the level of the right ventricle often persist after isolated mitral valve surgery.[23, 24] Because of this, it is clear that TR doesn't resolve after isolated mitral valve surgery and even progresses after successful left-side valve surgery.[1] Progression or persistence of TR in the setting of mitral valve surgery occurs frequently and is associated with worse prognosis.[1, 2, 3] If we aim to reduce TR or prevent the development of TR, tricuspid annuloplasty should be considered at the time of mitral valve surgery. The durability of tricuspid annuloplasty in the setting of mitral valve disease has been shown in other published series.[25] Our data show successful reduction of MR severity and NYHA

functional class in all surgical-treated patients. However, when preoperative TR was present, there was no significant reduction of TR when the tricuspid valve was left untreated. On the other hand, persistent reduction of TR up to 5 years post-operatively was noted in the patient group undergoing tricuspid annuloplasty. Both De Vega annuloplasty and Ring annuloplasty resulted in significant reduction of TR severity. However, as shown before, this reduction was more pronounced when ring annuloplasty was performed.[26]

Although tricuspid annuloplasty successfully reduces TR, the net clinical benefit of performing simultaneous tricuspid valve surgery is unclear.[25] In patients with functional MR, mainly due to ischemic cardiomyopathy, 5-year mortality was lower in patients undergoing tricuspid annuloplasty at the time of mitral valve repair.[13] These data were adjusted for left ventricular parameters, as possible confounders of outcome. Opposed to this, several studies failed to show that tricuspid annuloplasty is beneficial in patients with other causes of MR.[16, 17] Especially in degenerative mitral valve disease, the value of tricuspid annuloplasty is controversial. Yilmaz et al. have reported a low need for tricuspid valve reoperation after isolated mitral valve surgery for mitral valve prolapse.[15] A possible explanation might be that recommendations for degenerative mitral valve disease are more clearly defined, and surgery is often offered earlier in the disease process compared to functional mitral regurgitation. However, even in this patient cohort, TR was ≥ 3/4 in 23% of patients at 3-5 years follow-up, regardless of preoperative TR severity. The clinical importance of this is uncertain, and the value of tricuspid annuloplasty to reduce TR in these patients remains to be proven.

In addition, a registry including post-operative results in 17 centers showed a higher mortality and an increased operative time in patients undergoing additional tricuspid annuloplasty.[27]

In our patient cohort, we observed a higher, although not significant, incidence of permanent pacemaker implantation in the TR+/MVS+TA group compared to the TR+/MVS group (27.8% vs 10%; p=0.153). On the other hand, additional tricuspid annuloplasty was not associated with higher post-operative mortality in our study sample and no increased mortality was reported in studies from centers where a liberal approach towards tricuspid annular repair is practiced.[3, 7, 8]

A comparison of both surgical approaches is hampered by the heterogeneity of patients. The decision to operate on the tricuspid valve concomitantly with the mitral valve is taken by multi-disciplinary consultation by the institution's heart team. This often results in proposing the combined approach in "sicker" patients with already decreased right ventricular function, more dilated tricuspid valve annulus, more severe TR and in higher NYHA functional class. These are all known determinants of worse post-operative outcome. [3, 7, 8] To adjust for possible confounders, we calculated the probability for allocation to one of the surgical strategies for each patient. After adjustment, an improved event-free survival for the combined end-point of cardiac mortality or hospitalization for heart failure could be shown in patients with preoperative TR undergoing mitral valve surgery with tricuspid annuloplasty (Group TR+/MVS+TA).(Figure 3) The better event-free survival for patients undergoing simultaneous tricuspid annuloplasty is mainly due to a lower number of hospitalizations for heart failure.(Table 3) The volume-load associated with TR increases stroke work of the right ventricle and impairs ventricular interdependence.[28, 29] Theoretically, tricuspid annuloplasty should better preserve right ventricular function post-operatively and in the long-term. However, the relation between right heart failure and TR severity is still incompletely understood. Some suggest that TR is caused by right ventricular failure rather than vice-versa.[30] Indeed, we observed higher TR severity and lower right ventricular

function in patients undergoing additional tricuspid annuloplasty. This would mean that repairing tricuspid competence does not restore ventricular function. However, others have shown favourable remodelling of the right ventricle after tricuspid annuloplasty, especially in patients with severe TR preoperatively.[11, 12] In our patient cohort, with a mixed etiology of mitral regurgitation, we now add to this evidence with an improved event-free survival.

Lastly, 32% of patients undergoing concomitant tricuspid annuloplasty had a tricuspid annulus diameter >40 mm or >21 mm/m^2 as assessed by echocardiography. The better survival observed in the tricuspid annuloplasty group could be an indication for an even more liberal approach towards tricuspid annuloplasty. It seems to us, that current cut-off values for tricuspid annular dimensions are quite conservative and it seems obligatory to integrate several parameters in the decision process in this difficult patient population. Conversely, 29% of patients with TR≥2/4 preoperatively undergoing isolated mitral valve surgery would currently have a IIa indication for tricuspid annuloplasty according to current guidelines. The exact indication for performing simultaneous tricuspid annuloplasty remains difficult to determine, exactly because of this multi-causality. However, the heart team should be alerted for TR progression during follow-up and if any doubt about the necessity, performing tricuspid annuloplasty seems to be the wiser decision.

CONCLUSION:

These data provide evidence on the clinical benefit to perform tricuspid annuloplasty in conjunction with mitral valve surgery in patients with TR≥2/4. Tricuspid annuloplasty is an effective and durable surgical technique that results in a decreased risk for mortality and hospitalization for heart failure.

LIMITATIONS:

Our results are based on a retrospective analysis of a relatively small cohort of patients followed in a single institution. However, this resulted in accurate data of the studied patients and propensity score adjustment tried to eliminate surgical selection bias, though residual confounding may persist.

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REFERENCES:

1 Kwak J-J, Kim Y-J, Kim M-K, et al. Development of tricuspid regurgitation late after left-sided valve surgery: a single-center experience with long-term echocardiographic examinations. *American heart journal* 2008;**155**:732-7.

2 Matsunaga A, Duran CMG. Progression of tricuspid regurgitation after repaired functional ischemic mitral regurgitation. *Circulation* 2005;**112**:I453-7.

3 Dreyfus GD, Corbi PJ, Chan KMJ, et al. Secondary tricuspid regurgitation or dilatation: which should be the criteria for surgical repair? *The Annals of thoracic surgery* 2005;**79**:127-32.

4 Song H, Kim MJ, Chung CH, et al. Factors associated with development of late significant tricuspid regurgitation after successful left-sided valve surgery. *Heart (British Cardiac Society)* 2009;**95**:931-6.

5 Fukuda S, Gillinov AM, McCarthy PM, et al. Determinants of recurrent or residual functional tricuspid regurgitation after tricuspid annuloplasty. *Circulation* 2006;**114**:I582-7.

6 Nath J, Foster E, Heidenreich PA. Impact of tricuspid regurgitation on long-term survival. *Journal of the American College of Cardiology* 2004;**43**:405-9.

7 Rankin JS, Hammill BG, Ferguson TB, et al. Determinants of operative mortality in valvular heart surgery. *The Journal of Thoracic and Cardiovascular Surgery* 2006;**131**:547-57.

8 De Meester P, Van De Bruaene A, Voigt J-U, et al. Outcome and determinants of prognosis in patients undergoing isolated tricuspid valve surgery: Retrospective single center analysis. *International journal of cardiology* 2014;**175**:333-9.

9 Nishimura RA, Otto CM, Bonow RO, et al. 2014 AHA/ACC guideline for the management of patients with valvular heart disease: A report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines. *The Journal of Thoracic and Cardiovascular Surgery* 2014;**148**:e1-e132.

10 Joint Task Force on the Management of Valvular Heart Disease of the European Society of C, European Association for Cardio-Thoracic S, Vahanian A, et al. Guidelines on the management of valvular heart disease (version 2012). *European heart journal* 2012;**33**:2451-96.

11 Bertrand PB, Koppers G, Verbrugge FH, et al. Tricuspid annuloplasty concomitant with mitral valve surgery: effects on right ventricular remodeling. *The Journal of Thoracic and Cardiovascular Surgery* 2014;**147**:1256-64.

12 Desai RR, Vargas Abello LM, Klein AL, et al. Tricuspid regurgitation and right ventricular function after mitral valve surgery with or without concomitant tricuspid valve procedure. *The Journal of Thoracic and Cardiovascular Surgery* 2013;**146**:1126-32.e10.

13 Calafiore AM, Gallina S, Iacò AL, et al. Mitral valve surgery for functional mitral regurgitation: should moderate-or-more tricuspid regurgitation be treated? a propensity score analysis. *The Annals of thoracic surgery* 2009;**87**:698-703.

14 Iung B, Baron G, Tornos P, et al. Valvular heart disease in the community: a European experience. *Current problems in cardiology* 2007;**32**:609-61.

15 Yilmaz O, Suri RM, Dearani JA, et al. Functional tricuspid regurgitation at the time of mitral valve repair for degenerative leaflet prolapse: the case for a selective approach. *The Journal of Thoracic and Cardiovascular Surgery* 2011;**142**:608-13.

16 Kim JB, Yoo DG, Kim GS, et al. Mild-to-moderate functional tricuspid regurgitation in patients undergoing valve replacement for rheumatic mitral disease: the influence of tricuspid valve repair on clinical and echocardiographic outcomes. *Heart (British Cardiac Society)* 2012;**98**:24-30.

17 Koppers G, Verhaert D, Verbrugge FH, et al. Clinical outcomes after tricuspid valve annuloplasty in addition to mitral valve surgery. *Congestive heart failure (Greenwich, Conn)* 2013;**19**:70-6.

18 Teman NR, Huffman LC, Krajacic M, et al. "Prophylactic" tricuspid repair for functional tricuspid regurgitation. *The Annals of thoracic surgery* 2014;**97**:1520-4.

19 Benedetto U, Melina G, Angeloni E, et al. Prophylactic tricuspid annuloplasty in patients with dilated tricuspid annulus undergoing mitral valve surgery. *The Journal of Thoracic and Cardiovascular Surgery* 2012;**143**:632-8.

20 Spinner EM, Lerakis S, Higginson J, et al. Correlates of tricuspid regurgitation as determined by 3D echocardiography: pulmonary arterial pressure, ventricle geometry, annular dilatation, and papillary muscle displacement. *Circulation: Cardiovascular Imaging* 2012;**5**:43-50.

21 De Meester P, Van De Bruaene A, Delcroix M, et al. Pulmonary arterial pressure and right ventricular dilatation independently determine tricuspid valve insufficiency severity in pre-capillary pulmonary hypertension. *The Journal of heart valve disease* 2012;**21**:743-8.

22 De Meester P, Van De Bruaene A, Herijgers P, et al. Tricuspid valve regurgitation: prevalence and relationship with different types of heart disease. *Acta cardiologica* 2012;**67**:549-56.

23 Duran CM, Pomar JL, Colman T, et al. Is tricuspid valve repair necessary? *The Journal of Thoracic and Cardiovascular Surgery* 1980;**80**:849-60.

24 Van de Veire NR, Braun J, Delgado V, et al. Tricuspid annuloplasty prevents right ventricular dilatation and progression of tricuspid regurgitation in patients with tricuspid annular dilatation undergoing mitral valve repair. *The Journal of Thoracic and Cardiovascular Surgery* 2011;**141**:1431-9.

25 Murashita T, Okada Y, Kanemitsu H, et al. Long-Term Outcomes of Tricuspid Annuloplasty for Functional Tricuspid Regurgitation Associated with Degenerative Mitral Regurgitation: Suture Annuloplasty Versus Ring Annuloplasty Using a Flexible Band. *Annals of thoracic and cardiovascular surgery : official journal of the Association of Thoracic and Cardiovascular Surgeons of Asia* 2014.

26 McCarthy PM, Bhudia SK, Rajeswaran J, et al. Tricuspid valve repair: durability and risk factors for failure. *The Journal of Thoracic and Cardiovascular Surgery* 2004;**127**:674-85.

27 Lapar DJ, Mulloy DP, Stone ML, et al. Concomitant tricuspid valve operations affect outcomes after mitral operations: a multiinstitutional, statewide analysis. *The Annals of thoracic surgery* 2012;**94**:52-7- discussion 8.

28 Redington AN, Rigby ML, Shinebourne EA, et al. Changes in the pressure-volume relation of the right ventricle when its loading conditions are modified. *British heart journal* 1990;**63**:45-9.

29 Vlahakes GJ. Right ventricular failure after cardiac surgery. *Cardiology clinics* 2012;**30**:283-9.

30 Vargas Abello LM, Klein AL, Marwick TH, et al. Understanding right ventricular dysfunction and functional tricuspid regurgitation accompanying mitral valve disease. *The Journal of Thoracic and Cardiovascular Surgery* 2013;**145**:1234-41.e5.

TABLES:

Table 1: Demographic, pre-operative echocardiographic parameters and post-operative variables in patients without significant TR (Group TR-/MVS; n=82) and patients with significant TR undergoing either isolated mitral valve surgery (Group TR+/MVS; n=31) or combined tricuspid and mitral valve surgery (Group TR+/MVS+TA; n=37).

	Group 1	**Group 2**	**Group 3**	
	TR-/MVS	**TR+/MVS**	**TR+/MVS+TA**	P Group 2 vs 3
Demographics				
Female gender	42 (51%)	17 (55%)	27 (73%)	§0.135
Age (years)	64 (12)	72 (8)	70 (11)	0.383
BMI (kg/m^2)	26.8 (5.4)	26.1 (3.8)	24.7 (4.2)	0.146
Creatinine (mg/dL)	1.22 (1.15)	1.22 (0.42)	1.18 (0.32)	0.634
NYHA functional class	2.2 (0.9)	2.5 (0.8)	2.6 (0.7)	0.741
Atrial fibrillation	30 (36.6%)	18 (58.1%)	25 (67.6%)	§0.004*
Pacemaker	3 (3.7%)	1 (3.2%)	1 (2.7%)	§1
Echocardiography				
Mitral Regurgitation (x/4)	3.1 (0.6)	3.2 (0.7)	3.1 (0.6)	0.622
Tricuspid Regurgitation (x/4)	1.06 (0.47)	2.3 (0.4)	2.6 (0.8)	0.018*
RV-RA gradient (mmHg)	29 (9)	43 (13)	37 (14)	0.179
LVEDD (mm)	52 (10)	51 (12)	51 (9.6)	0.996
LVEF (%)	60 (13)	62 (12)	59 (12)	0.385
RV diameter (mm)	29 (5)	31 (7)	33 (6)	0.412
TV annular diameter (mm)	30 (5)	32 (7)	34 (6)	0.412
TV annular diameter≥40 mm or>21 mm/m^2	3 (4.8%)	9 (29%)	12 (32%)	0.798
TAPSE (mm)	22 (5)	23 (4)	18 (4)	<0.0001*
Indication for surgery				
Degenerative	**57 (70%)**	**22 (71%)**	**26 (70%)**	§0.639
Flail leaflet	5 (6%)	2 (7%)	4 (11%)	
Prolaps	30 (37%)	7 (23%)	4 (11%)	
Degenerative/calcified	22 (27%)	13 (42%)	18 (48%)	
Functional	**14 (17%)**	**5 (16%)**	**4 (11%)**	
Ischemic	7 (8.5%)	5 (16%)	4 (11%)	
Cardiomyopathy other	7 (8.5%)	0 (0%)	0 (0%)	
Rheumatic	**11 (13%)**	**4 (13%)**	**7 (19%)**	
+ CABG	24 (29%)	11 (35%)	9 (25%)	§0.424
Post-operative				
30-day all-cause mortality	2 (2.4%)	3 (9.7%)	0 (0%)	§0.090
3-month all-cause mortality	3 (3.7%)	4 (12.9%)	2 (5.4%)	§0.400
Duration ITE stay (days)	5 (8)	6 (12)	6 (9)	0.829

Duration hospitalization(days)	18 (18)	19 (17)	26 (39)	0.399
New onset atrial fibrillation	18 (34.6%)	4 (30.8%)	4 (33.3%)	§1
New permanent pacemaker	12 (15.2%)	3 (10%)	10 (27.8%)	§0.153

Data of Group TR+/MVS were compared to Group TR+/MVS+TA using the unpaired t-test or §Fishers' exact test where applicable. Continuous data and categorical data are represented by means and standard deviation or frequencies and percentages, respectively.

TR-=tricuspid regurgitation<2/4; TR+=tricuspid regurgitation≥2/4; MVS=mitral valve surgery; TA=tricuspid annuloplasty; BMI= body mass index; RV=right ventricle; LVEDD=left ventricular end-diastolic diameter; LVEF=left ventricular ejection fraction; TAPSE=tricuspid annular plane systolic excursion; CABG=Coronary Artery Bypass Grafting.

*p<0.05=significant.

Table 2: Comparison of mitral regurgitation severity, tricuspid regurgitation severity and New York Heart Association (NYHA) functional class within each surgical group.

		Group 1		**Group 2**			**Group 3**			**Group 2 vs 3**
		TR-/MVS		**TR+/MVS**			**TR+/MVS+TA**			
	N	Mean (SD)	Paired t-test	N	Mean (SD)	Paired t-test	N	Mean (SD)	Paired t-test	Unpaired t-test
MR										
Preop	82	3.11 (0.63)		31	3.21 (0.67)		37	3.14 (0.57)		0.622
Postop	80	0.44 (0.71)	<0.0001*	29	0.48 (0.74)	<0.0001*	36	0.68 (0.81)	<0.0001*	0.308
6months	78	0.71 (0.87)	<0.0001*	24	0.71 (0.91)	<0.0001*	34	0.88 (0.78)	<0.0001*	0.437
3 years	72	0.86 (0.66)	<0.0001*	22	1.16 (0.70)	<0.0001*	28	1.23 (0.69)	<0.0001*	0.712
5 years	58	0.87 (0.65)	<0.0001*	16	1.47 (0.72)	<0.0001*	21	1.43 (0.68)	<0.0001*	0.863
TR										
Preop	82	1.06 (0.47)		31	2.27 (0.44)		37	2.65 (0.80)		0.023*
Postop	80	1.44 (0.84)	<0.0001*	29	1.78 (0.86)	0.019*	36	1.15 (0.74)	<0.0001*	0.003*
6months	78	1.30 (0.85)	0.009*	24	1.90 (0.92)	0.110	34	1.46 (0.91)	<0.0001*	0.076
3 years	72	1.51 (0.67)	<0.0001*	22	1.98 (0.88)	0.178	28	1.68 (0.74)	<0.0001*	0.197
5 years	58	1.63 (0.75)	<0.0001*	16	2.19 (0.77)	0.523	21	1.74 (0.68)	0.010*	0.069
NYHA										
Preop	82	2.2 (0.9)		31	2.5 (0.8)		37	2.6 (0.7)		0.741
6months	78	1.5 (0.7)	<0.0001*	26	1.7 (0.9)	<0.0001*	35	1.6 (0.7)	<0.0001*	0.753

Preoperative values were compared with values immediately post-operative and at 6 months, 3 years and 5 years. Mitral regurgitation was reduced in all study groups.

TR+ indicates TR≥2/4 preoperatively. MVS indicates isolated mitral valve surgery. MVS+TA indicates additional tricuspid annuloplasty. TR-=tricuspid regurgitation<2/4; TR+=tricuspid regurgitation≥2/4; MVS=mitral valve surgery; TA=tricuspid annuloplasty.

*p<0.05=significant.

Table 3: Medium-term event-rate for each group studied.

	TR-/MVS	TR+/MVS	TR+/MVS+TA
Combined endpoint			
30 days	3 (4%)	3 (10%)	0 (0%)
1 year	10 (12%)	9 (29%)	2 (6%)
5 years	17 (22%)	16 (57%)	13 (39%)
Cardiac-related death			
30 days	2 (2%)	3 (10%)	0 (0%)
1 year	3 (4%)	5 (16%)	2 (6%)
5 years	5 (7%)	7 (25%)	7 (20%)
Hospitalization for heart failure			
30 days	1 (1%)	0 (0%)	0 (0%)
1 year	7 (9%)	4 (13%)	0 (0%)
5 years	12 (15%)	9 (33%)	6 (19%)

The combined endpoint was composed of cardiac death and hospitalization for heart failure.

TR-=tricuspid regurgitation<2/4; TR+=tricuspid regurgitation≥2/4; MVS=mitral valve surgery; TA=tricuspid annuloplasty.

FIGURES:

Figure 1: Flow chart to identify patients eligible for analysis

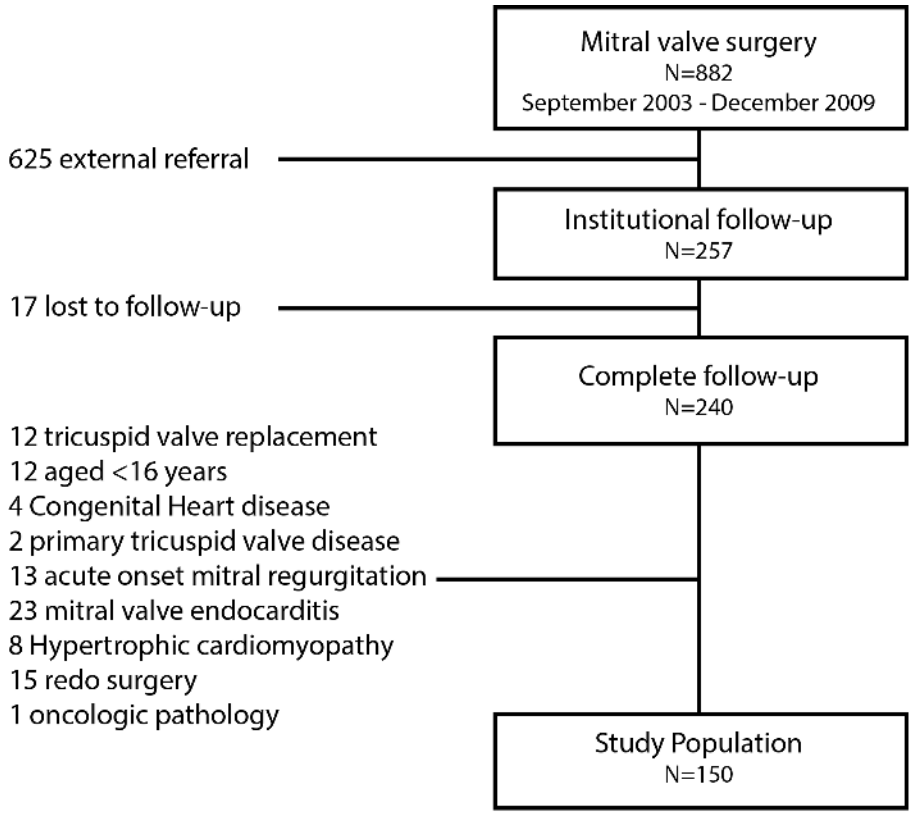

Figure 2: Unadjusted event-free survival for (A) Cardiac mortality and (B) Cardiac mortality or hospitalization for heart failure.

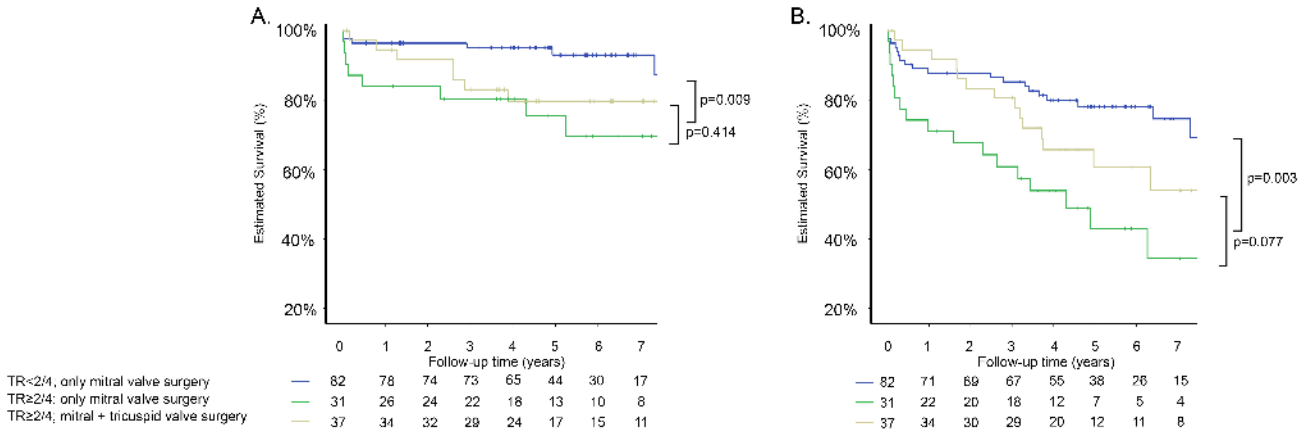

Figure 3: Propensity matched adjusted event-free survival for (A) cardiac mortality and (B) Cardiac mortality or hospitalization for heart failure in patients with significant preoperative functional tricuspid regurgitation (TR ≥2/4).