# Tricuspid annuloplasty concomitant with mitral valve surgery: Effects on right ventricular remodeling

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**Objectives:** Tricuspid valve annuloplasty (TVP) has been advocated concomitantly with left-sided cardiac surgery in case of more than moderate tricuspid regurgitation (TR) or tricuspid annular dilation (TAD) (diameter >40 mm or 21 mm/m$^2$) even in the absence of significant TR. Data on postoperative right ventricular (RV) remodeling are lacking in such patients.

**Methods:** Preoperative and postoperative echocardiography data from 45 consecutive TVP procedures, performed in mitral valve surgery in a single tertiary center, were retrospectively analyzed and compared with a propensity-matched control group of 33 procedures without concomitant TVP. RV function and geometry was analyzed by measuring RV size, fractional area change, and end-diastolic sphericity index (RVSI = long-axis length/short-axis width) and compared at baseline versus follow-up.

**Results:** At a mean follow-up of 5 months, a favorable change in RV geometry was observed in TVP patients (RVSI increased from 1.99 ± 0.33 to 2.21 ± 0.42; $P = .001$), whereas the opposite was observed in the control group (RVSI decreased from 2.34 ± 0.52 to 2.17 ± 0.13; $P = .05$). Only in control patients, indexed RV end-diastolic area increased significantly ($P = .003$). In TVP patients, when comparing patients with baseline more than moderate TR (n = 13) to patients with isolated TAD (n = 32), there was a significant decrease in RV end-diastolic area only in the group with more than moderate TR (from 12.9 ± 3.5 cm$^2$/m$^2$ to 10.3 ± 1.9 cm$^2$/m$^2$; $P = .009$).

**Conclusions:** Adding TVP to mitral valve surgery in patients with more than moderate TR or TAD leads to favorable changes in RV geometry and prevents postoperative RV dilation. This is most pronounced in patients with more than moderate TR at baseline. (J Thorac Cardiovasc Surg 2014;147:1256-64)

ACD

De novo or progressive tricuspid regurgitation (TR) after successful left-sided heart surgery is commonly observed and associated with increased morbidity and mortality.[1-3] Therefore, tricuspid valve annuloplasty (TVP) has been advocated to be performed concomitantly in case of more than moderate TR (TR >2+) and, more recently, also in case of tricuspid annular dilation (TAD, defined as a tricuspid annular diameter >40 mm or 21 mm/m$^2$), irrespectively of TR.[4,5] The rationale for performing TVP, even in patients with TAD but without significant TR (TR ≤2+), relies on evidence that TAD is an ongoing disease process that over time often leads to severe functional TR.[6] Although the effect of mitral valve surgery on left ventricular (LV) geometry and function in patients with severe mitral regurgitation (MR) has been extensively studied,[7-13] data on right ventricular (RV) geometry and function changes in response to TVP are surprisingly scarce. Although results have shown that mitral valve repair (MVP) induces reverse LV remodeling in a gradual and time-dependent fashion, it is not known whether TVP has similar beneficial effects on RV shape and function. Furthermore, it is not known whether the effects of TVP are different for patients with severe coexistent TR compared with those in whom mere TAD was the reason to intervene on the tricuspid valve.

Therefore, the objectives of this study were as follows: (1) to determine the differential effects on RV size, geometry, and function of TVP performed because of severe TR versus TAD without significant TR in patients scheduled for mitral valve surgery and (2) to compare the echocardiography data of this population with data from a propensity-matched cohort of patients undergoing similar procedures without TVP.

## METHODS

### Study Population

Figure 1 summarizes the study flow chart. Between July 2007 and December 2011, 316 mitral valve procedures of any kind were performed at

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**Abbreviations and Acronyms**

LV = left ventricular
MR = mitral regurgitation
MVP = mitral valve repair
MVR = mitral valve replacement
RV = right ventricular
RVFAC = right ventricular fractional area change
RVSI = right ventricular sphericity index
TAD = tricuspid annular dilation
TR = tricuspid regurgitation
TVP = tricuspid valve annuloplasty

Ziekenhuis Oost-Limburg (Genk, Belgium). These comprised mitral repair (MVP) or replacement (MVR) procedures in all patients, with a proportion of patients receiving concomitant coronary artery bypass grafting and/or concomitant aortic valve surgery. Concomitant TVP was systematically performed in 137 patients, when more than moderate TR (TR >2, ie, color Doppler jet area/atrial area >20%[14]) and/or TAD (tricuspid annular diameter >40 mm or >21 mm/m$^2$) was present. Only patients with complete preoperative and postoperative (3-6 months) echocardiography data and examinations performed at our center were included in the analysis. The TVP population thus consisted of 45 consecutive patients who underwent TVP together with left-sided heart surgery. There were no patients with structural (organic) tricuspid valve disease in the study population. From the remaining 53 patients undergoing mitral valve surgery without concomitant TVP, we recruited a control population of 33 patients by using propensity matching for age, gender, LV ejection fraction, LV end-diastolic volume, and cardiopulmonary bypass time. The study was approved by the locally appointed ethics committee, which waived the need for individual consent owing to the retrospective and observational nature of the study.

## Surgical Procedure

All surgical procedures were performed through midline sternotomy under normothermic cardiopulmonary bypass with intermittent antegrade warm blood cardioplegia. Patients with an indication for revascularization underwent coronary artery bypass grafting first. Subsequently, the mitral valve was exposed through a vertical transseptal approach along the right border of the foramen ovale, leaving the left atrial roof untouched. In patients with structural mitral valve disease, MVP was performed after thorough intraoperative visual and echocardiographic valve analysis according to standard Carpentier techniques.[15] In patients in whom the mitral valve was deemed irreparable, MVR was performed. Mitral annuloplasty ring size was determined after careful measurement of the height of the anterior leaflet; in patients with functional MR, downsizing by 2 sizes (ie, size 26 when measuring 30) of a complete semirigid annuloplasty ring (Carpentier-Edwards Physio Ring; Edwards Lifesciences, Irvine, Calif) was routinely performed. In patients with severe degenerative aortic valve disease, aortic prosthetic valve replacement was performed if indicated. TVP was subsequently performed, also on normothermic cardiopulmonary bypass with intermittent antegrade warm blood cardioplegia, with a Carpentier-Edwards MC3 ring (Edwards Lifesciences) using the surface of the anterior leaflet as a reference. In patients with severe tricuspid valve leaflet tethering (ie, ≥8-mm tethering distance), an additional pericardial patch augmentation of the anterior leaflet was performed to increase tricuspid leaflet coaptation.[16] The restored leaflet coaptation was confirmed at the time of surgery by filling the RV and/or LV with saline through a bulb syringe and by visually inspecting the leaflets. Additionally, after weaning from cardiopulmonary bypass, intraoperative transesophageal echocardiography was used to assess the result of the valve reconstructions.

## Transthoracic Echocardiography

Comprehensive 2-dimensional echocardiography examinations were performed with a commercially available system (IE33; Philips Medical Systems, Andover, Mass). Standard 2-dimensional and Doppler echocardiographic images were acquired in the left lateral decubitus position using a phased-array transducer in the parasternal and apical views by experienced cardiac sonographers. Three consecutive cardiac cycles were recorded and stored for subsequent offline analysis. LV end-diastolic and end-systolic dimensions were measured from parasternal acquisitions. LV volumes and ejection fraction were calculated using Simpson's biplane method according to the guidelines of the American Society of Echocardiography.[17] Left and right atrial areas were measured by planimetry at end-systole from the apical 4-chamber views. Left atrial volumes were measured by Simpson's biplane method. Color flow was applied in the apical 4-chamber view to assess severity of TR, which was graded semiquantitatively on a scale from 0 to 4 as follows: 0, none or trace; 1+, jet area/atrial area <10% (mild TR); 2+, jet area/atrial area 10% to 20% (moderate TR); 3+, jet area/atrial area 20% to 33% (moderate-to-severe TR); and 4+, jet area/atrial area >33% (severe TR).[14,18] From the apical 4-chamber view, the RV end-systolic and end-diastolic areas were measured by planimetry with the transducer positioned to maximize the RV area and to include the RV apex. RV fractional area change (RVFAC) was used to determine RV systolic function and was calculated by the following formula: FAC = ([diastolic area − systolic area]/diastolic area) × 100%.[19] RV long-axis length and RV short-axis width at the midventricular level were measured as described by Matsunaga and Duran[20] and used to calculate the end-diastolic RV sphericity index as previously described (RVSI = RV long-axis length/RV short-axis width).[21] Systolic pulmonary artery pressure was measured by echocardiography using the modified Bernoulli equation on the transtricuspid continuous-wave Doppler signal, while adding right atrial pressure. In a minority of patients with no transtricuspid Doppler signal on preoperative echocardiography, systolic pulmonary artery pressure was adapted from preoperative right heart catheterization.

## Statistical Analysis

Results are expressed as mean ± standard deviation for continuous variables and as percentages for categorical variables. Continuous variables were compared using the 2-tailed Student *t* test or the Wilcoxon signed rank test when the normality test failed. Categorical values were compared using the Fisher exact test. Interobserver and intraobserver agreement for RVFAC and RVSI measurement was tested by Bland-Altman analysis. Statistical analyses were performed using the Statistical Package for Social Sciences release 20.0 (SPSS, Inc, Chicago, Ill). We had full access to the data and take responsibility for its integrity. All of us have read and agreed to the manuscript as written.

# RESULTS

## Patient Characteristics

Baseline characteristics of the patients are summarized in Table 1. Mitral valve disease was the primary indication for cardiac surgery in both groups: 40 (89%) patients and 27 (82%) patients underwent MVP in the TVP and control groups, respectively, whereas 5 (11%) patients and 6 (18%) patients needed MVR in both groups, respectively. In the TVP group, 29% of TVP procedures were performed because of more than moderate (>2+) preoperative functional tricuspid insufficiency and 71% because of TAD