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Mid-term results of a randomized trial of tricuspid annuloplasty for less-than-severe functional tricuspid regurgitation at the time of mitral valve surgery†

Matteo Pettinari[a,*], Laurent De Kerchove[b], Siham Lazam[c], Agnes Pasquet[c], Bernard Gerber[c], Jean-Louis Vanoverschelde[c] and Gebrine El-Khoury[b]

[a] Cardiac Surgery Department, Ziekenhuis Oost Limburg, Genk, Belgium
[b] Cardiac Surgery Department, Universitair Clinique St. Luc, Brussel, Belgium
[c] Cardiology Department, Universitair Clinique St. Luc, Brussel, Belgium

* Corresponding author. Cardiac Surgery Department, Ziekenhuis Oost Limburg, Schiepse Bos 6, 3600 Genk, Belgium. Tel: +32-89-327077; fax: +32-89-327936; e-mail: matteo.pettinari@zol.be (M. Pettinari).

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Key question

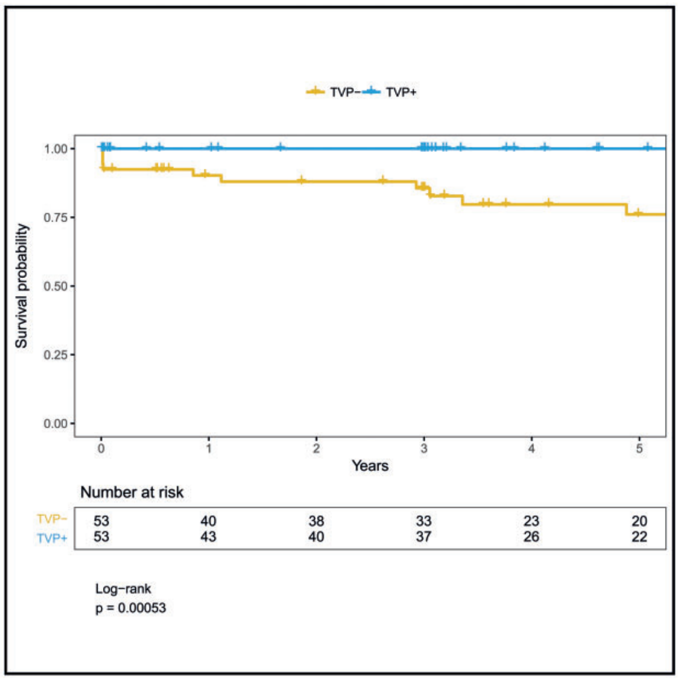
How does one evaluate the worth of less-than-severe functional tricuspid regurgitation (FTR) repair during mitral valve procedures?

Key finding(s)

Tricuspid annuloplasty at the time of mitral valve surgery reduced the recurrence of FTR.

Take-home message

Prophylactic tricuspid annuloplasty reduces the recurrence of FTR but has no effect on functional capacity and right ventricular remodelling.



Abstract

OBJECTIVES: The optimal management of functional tricuspid regurgitation (FTR) in the setting of mitral valve operations remains controversial. The current practice is both centre specific and surgeon specific with guidelines based on non-randomized data. A prospective randomized trial was performed to evaluate the worth of less-than-severe FTR repair during mitral valve procedures.

METHODS: A single-centre randomized study was designed to allocate patients with less-than-severe FTR undergoing mitral valve surgery to be prophylactically treated with or without tricuspid valve annuloplasty (TVP- or TVP+). These patients were analysed using longitudinal cardiopulmonary exercise capacity, echocardiographic follow-up and cardiac magnetic resonance. The primary outcome was freedom

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from more than or equal to moderate tricuspid regurgitation with vena contracta ≥4 mm. Secondary outcomes were maximal oxygen uptake and right ventricular (RV) dimension and function.

RESULTS: A total of 53 patients were allocated to receive concomitant TVP+, and 53 patients were treated conservatively (TVP-). At 5 years, tricuspid regurgitation was observed to be greater than mild in 10 patients in the TVP- group and no patients in the TVP+ group ($P < 0.01$). Maximal oxygen uptake, RV basal diameter, end-diastolic diameter and end-systolic diameter and fractional area changes were similar in both groups. Cardiac magnetic resonance confirmed no differences in RV end-diastolic volume, RV end-systolic volume and RV ejection fraction.

CONCLUSIONS: This single-centre prospective randomized trial demonstrated that prophylactic tricuspid annuloplasty irrespective of annular dilatation at the time of mitral surgery reduced the recurrence of moderate or severe FTR at 5-year follow-up and reduced the pulmonary pressure. Nevertheless, the functional capacity, the RV function and the RV dimension remained similar.

Keywords: Tricuspid valve • Regurgitation • Mitral valve

INTRODUCTION

Functional tricuspid regurgitation (FTR) during left-sided surgery has been treated only when severe and surgical tricuspid repair had been avoided for years because of the concept that tricuspid regurgitation (TR) should disappear once the primary left-sided problem was eliminated [1]. However, moderate-to-severe late FTR has been reported in up to one-third of patients after isolated mitral surgery for rheumatic [2], functional, ischaemic [3] and degenerative mitral valve (MV) diseases [4]. Severe FTR late after cardiac surgery is associated with substantial morbidity and mortality [5] and is also done to avoid high-risk reoperations. Dreyfus *et al*. proposed that annular dilatation should be considered as much as, if not more than, FTR grading. TR is a less reliable parameter because it depends on many factors, including preload, afterload and right ventricular (RV) function. Treating annular dilatation beyond a given size has been shown to improve functional status with a trend towards better survival when compared with a group of patients who did not receive tricuspid annuloplasty (TA), irrespective of TR severity [4]. Many publications reinforced this concept [6–8], and the European and American Association guidelines include the annular size of the tricuspid valve with a threshold diameter of 40 mm as a type IIa recommendation [9, 10]. The aforementioned threshold of 40 mm is derived from a published retrospective study which compared 2 patient cohorts treated during different historical periods [7], finding a higher rate of TR in patients with the dilated annulus (≥40 mm).

Only 1 small prospective randomized study has been published reporting 1-year clinical and echocardiographic results [11] in patients with less-than-severe TR and annular dilatation.

We designed a prospective single-centre randomized study to test the hypothesis that concomitant TA in patients treated for left-heart valve disease prevents and improves TR progression after MV surgery and to evaluate whether this is associated with improved RV remodelling or a functional benefit irrespective of the annular dimension.

METHODS

Among 139 consecutive patients undergoing MV surgery (both repair or replacement) between May 2009 and December 2010, 106 patients with less-than-severe functional TR [<7 mm vena contracta (VC)] [12] were enrolled. Exclusion criteria consisted of several parameters: (i) the presence of pacemaker leads through the tricuspid valve; (ii) acute endocarditis; (iii) minimally invasive approach and/or (iv) type IIIb MV insufficiency. Tricuspid annular dilatation (>40 mm or >21 mm/m^2) was not considered as an inclusion criterion.

A total of 53 patients were allocated to receive concomitant tricuspid valve annuloplasty (TVP+), and 53 patients were treated conservatively (TVP-) at the time of MV surgery. Participants in each group were analysed according to the 'intention-to-treat' principle. The local ethics committee approved this study, and each patient signed an informed consent form.

Clinical and functional assessments

At baseline and during each year of follow-up, the functional New York Heart Association (NYHA) class was assessed. A cardiopulmonary exercise test was performed in 61 and 60 patients at 1 and 3 years, respectively. Symptom-limited treadmill exercise testing with respiratory gas exchange analysis used a modified Bruce protocol (2-min workloads, 2 W/min increments in work). Electrocardiograms were continuously monitored, and blood pressure was assessed during the last 30 s of each 2-min workload. Patients were encouraged to exercise to exhaustion. Oxygen consumption (VO_2) was measured using a Medical Graphics metabolic cart, and peak VO_2 was taken as the highest average 30-s VO_2 during exercise and expressed as absolute peak VO_2.

Echocardiography

A transthoracic echocardiography was performed within 7 days before the operation and yearly in our valve clinic; the last available echocardiographic analysis was used for follow-up. Technicians performed the transthoracic echocardiography, and an experienced and dedicated cardiologist with specific subspecialization in cardiac imaging validated the images. Echocardiographic data were obtained using commercially available ultrasound systems. All patients underwent comprehensive examination, including M-mode and 2-dimensional (2D) echocardiography in addition to conventional and colour Doppler examinations. All tests were conducted by experienced technicians. Carpentier classification was used to describe the MV disease. The proximal isovelocity surface area method with the evaluation of effective regurgitant orifice and regurgitant volume was used to quantify MV regurgitation [13]. FTR grading was based on the VC width measured from the apical 4-chamber view and defined using 3 categories: (i) mild <3 mm; (ii) moderate between 3 and 6 mm or (iii) severe ≥7 mm [12].

Dimensions of the right and left chambers (atrial and ventricular) and systolic pulmonary artery pressures (using tricuspid regurgitant velocity) and functions were measured as recommended [14].

Cardiac magnetic resonance

At 6 months post-surgery, 30 patients (18 in the TVP- group vs 12 in the TVP+ group) underwent cardiac magnetic resonance (CMR) study. A standardized CMR protocol was performed using a 1.5-T Intera CV scanner (Philips Medical Systems, Best, Netherlands) as described previously [15]. Briefly, 10–12 consecutive short-axis cine steady-state free precession images covering the entire left ventricle and right ventricle were acquired for the assessment of myocardial function. Ten to 15 min after injection of gadolinium-based contrast, identical prescriptions of short-axis and long-axis slices were acquired for myocardial viability assessment. CMR images were analysed using the Segment 1.9 software (http://segment.heiberg.se). Left ventricular (LV) and RV volumes and ejection fraction were obtained by manual tracing of contours on the short-axis images in the end diastole and end systole. A dedicated cardiologist (B.G.) evaluated and performed the measurement.

Surgical procedure

All operations were performed through a median sternotomy using standard aortic and bicaval venous cannulation. The patients were fully heparinized and placed on normothermic cardiopulmonary bypass (CPB). The MV was exposed through a left atriotomy. Whenever possible, MV repair was performed following the classical Carpentier approach. In all repair cases, a semirigid annuloplasty ring was used to complete the procedure. In case of MV replacement, the posterior leaflet was preserved, and 2-0 polyester valve sutures were used. If chordal preservation was not feasible, artificial polytetrafluoroethylene chordae were implanted from the papillary muscles to the posterior sewing ring.

The TA was performed using a semirigid ring [Carpentier-Edwards rings were used most of the time and just 3 Medtronic countour 3-dimensional (3D) rings were used]. The size was chosen based on the functional area of the anterior leaflet of the tricuspid valve. This area should match with the tricuspid ring sizer.

Outcomes

The primary outcome was the freedom from more than or equal to moderate TR (VC $\geq$4 mm), freedom from severe TR (VC $\geq$7 mm) and progression of FTR defined as an increase in >3 mm VC between preoperative and follow-up echocardiography. Secondary outcome was maximal oxygen uptake (VO_2 max), the right ventricular dimension and function, freedom from tricuspid valve reoperation, cardiac-related death and NYHA class >II.

Statistical analysis

All analyses are conducted using the RStudio software (Version 1.0.153–© 2009–2017 RStudio, Inc.). Continuous variables are expressed as mean ± standard deviation, categorical variables are expressed as counts and percentages and follow-up times are expressed as median and range. Patients' characteristics were compared between 2 groups using the Student's *t*-test or Mann–Whitney *U*-test for continuous variables or the χ^2 or Fisher's exact test for dichotomous variables where appropriate. A *P*-value = 0.05 was considered statistically significant.

The Kaplan–Meier analysis was used to analyse the freedom from TR, freedom from mitral regurgitation, freedom from MV reoperation and from NYHA >II [16]. The log-rank test was used to compare the 2 groups.

The Cox proportional hazards regression model was used to evaluate the possible association between the freedom from moderate or more TR with the clinical and echocardiographic parameters. Sample size of 49 patients per group was calculated using the reference incidence of recurrence of FTR at 5 years of 25%, a type I error of 5%, a type II error of 20% and a risk ratio of 0.2 [17].

Table 1: Preoperative characteristics

	TVP- (*N* = 53)	TVP+ (*N* = 53)	*P*-value
Age (years), mean ± SD	62.1 ± 14.5	64.2 ± 13.7	0.44
Male gender, *n* (%)	33 (62.3)	36 (67.9)	0.68
Hypertension, *n* (%)	22 (41.5)	23 (43.4)	1.00
Diabetes, *n* (%)	3 (5.7)	5 (9.4)	0.72
Smoker, *n* (%)	10 (18.9)	8 (15.1)	0.80
COPD, *n* (%)	5 (9.4)	2 (3.8)	0.44
Renal failure, *n* (%)	3 (5.7)	1 (1.9)	0.62
PVD, *n* (%)	3 (5.7)	1 (1.9)	0.62
CVA, *n* (%)	1 (1.9)	5 (9.4)	0.21
Beta-blockers, *n* (%)	22 (41.5)	26 (49.1)	0.56
ACE inihibitor, *n* (%)	17 (32.1)	17 (32.1)	1.00
Diuretics, *n* (%)	13 (24.5)	14 (26.4)	1.00
Redo, *n* (%)	3 (5.7)	2 (3.8)	1.00
NYHA class, mean ± SD	2.1 ± 0.8	2.2 ± 0.9	0.65
Weight (kg), mean ± SD	71.6 ± 15.4	75.1 ± 16.0	0.26
Length (cm), mean ± SD	169.3 ± 9.8	170.0 ± 11.5	0.74
AF persistent, *n* (%)	6 (11.3%)	7 (13.2%)	1.00
AF permanent, *n* (%)	5 (9.4%)	10 (18.9%)	0.26
MV pathology, *n* (%)			
Degenerative	33 (62.3)	31 (58.5)	0.84
Barlow	7 (13.2)	9 (17.0)	0.79
Rheumatic	13 (24.5)	13 (24.5)	1.00

ACE: angiotensin converting enzyme; AF: atrial fibrillation; BMI: body mass index; COPD: chronic obstructive pulmonary disease; CVA: cerebrovascular accident; MV: mitral valve; NYHA: New York Heart Association; PVD: peripheral vascular disease; SD: standard deviation; TVP: tricuspid valve annuloplasty.

RESULTS

Preoperative characteristics

Preoperative patient demographics are listed in Table 1. There were no statistically significant differences between the 2 groups with regard to age, sex, history of atrial fibrillation, previous myocardial infarction, NYHA functional class and VO_2 max. The underlying valvular lesion of the MV was similar in both groups with the predominant lesion being a degenerative mitral regurgitation (mitral stenosis was similar in 11 patients in the TVP- group and 10 patients in the TVP+ group, $P = 0.9$). Echocardiographic characteristics are presented in Table 2. LV

Table 2: Echocardiographic data (preoperative vs follow-up) of the atria and left ventricle

	TVP-, mean ± SD	TVP+, mean ± SD	*P*-value
LA volume-i (ml/m^2)			
Preoperative	61.81 ± 29.46	66.65 ± 25.92	0.39
Follow-up	42.84 ± 22.16[a]	51.05 ± 23.63[a]	0.08
RA volume-i (ml/m^2)			
Preoperative	35.42 ± 14.43	40.77 ± 37.31	0.37
Follow-up	34.32 ± 16.26	33.63 ± 13.11	0.83
LVEDDi (mm/m^2)			
Preoperative	28.84 ± 4.39	28.82 ± 4.86	0.99
Follow-up	26.24 ± 3.96[a]	26.29 ± 3.33[a]	0.94
LVESDi (mm/m^2)			
Preoperative	18.99 ± 3.66	18.75 ± 4.26	0.76
Follow-up	19.56 ± 4.05	19.94 ± 3.76[a]	0.63
LVEDVi (ml/m^2)			
Preoperative	121.65 ± 32.40	123.47 ± 34.04	0.78
Follow-up	80.23 ± 72.21[a]	74.96 ± 23.81[a]	0.63
LVESVi (ml/m^2)			
Preoperative	50.43 ± 21.74	51.58 ± 18.52	0.77
Follow-up	36.76 ± 15.17[a]	39.34 ± 12.15[a]	0.36
EF			
Preoperative	0.59 ± 0.10	0.58 ± 0.09	0.57
Follow-up	0.49 ± 0.11[a]	0.47 ± 0.09[a]	0.22

[a]$P < 0.05$ compared the preoperative value.

EF: ejection fraction; LA: left atrium; LVEDDi: left ventricle end diastolic diameter index; LVEDVi: left ventricle end diastolic volume index; LVESDi: left ventricle end systolic diameter index; LVESVi: left ventricle end systolic volume index; RA: right atrium; SD: standard deviation; TVP: tricuspid valve annuloplasty.

dimensions, volumes and function were comparable between the 2 cohorts. TR grade was similar between both cohorts as were the RV dimensions and functions.

Operative outcomes

MV repair was performed in 92 patients (47 in the TVP- group vs 45 in the TVP+ group; $P = 0.77$), with resection of the posterior leaflet in 54 patients (22 in the TVP- group vs 32 in the TVP+ group; $P = 0.22$). Artificial chordae were used in 33 patients, and a mix of other techniques were used, including commissurotomy (6 patients), flip-over technique (2 patients), papillary muscle reimplantation (1 patient) and annular decalcification (5 patients). The median mitral ring size was 32.8 ± 2.9. MV replacement was performed in 6 patients in the TVP- group and 8 patients in the TVP+ group. TA was performed using a semirigid ring. The median ring size was 31.8 ± 1.3. In 5 patients of this group, the surgeon did not perform TA: 3 cases were not done because it was at the end of a very long procedure already (double-valve replacement with decalcification of the MV annulus and patch repair of the annulus), and in the other 2 cases, the surgeon was reluctant because the annulus size was normal, and he did not want to increase the complexity of the procedure.

Coronary artery bypass grafting (TVP+ = 15.1% vs TVP- = 26.4%; $P = 0.23$), aortic valve repair (TVP+ = 7.5% vs TVP- = 5.7%; $P = 1$) or replacement (TVP+ = 3.8% vs TVP- = 1.9%; $P = 1$) and atrial fibrillation ablation (TVP+ = 18.9% vs TVP- = 13.2%; $P = 0.6$) were similarly performed in both groups. CPB and clamp times [123 ± 35 and 100 ± 36 min, respectively ($P = 0.01$)] were increased in the TVP+ group.

Clinical and echocardiographic results

The median follow-up was 3.8 years (3–5.6 years). Thirty-day freedom from mortality was 98.11 ± 1.9% and 96.2 ± 2.6% in the TVP- and TVP+ groups, respectively ($P = 0.57$). Five-year freedom from cardiac-related mortality was also similar [89.7 ± 4.3% in the TVP- group vs 94.1 ± 3.2% in the TVP+ group ($P = 0.9$)]. VO_2 max at 1 and 3 years [TVP- 20.1 ± 7.6 vs TVP+ 19.2 ± 8 ml/min/kg ($P = 0.22$) and TVP- 20.7 ± 5.2 vs TVP+ 20.3 ± 5 ml/min/kg ($P = 0.24$), respectively] did not differ between the groups. In the TVP+ group, 96.4% patients was free from NYHA >II versus 92.9% in the TVP- group ($P = 0.37$).

At follow-up, 5 and 7 patients had moderate TR and severe TR, respectively. The freedom from moderate or more TR at 5 years was higher in the TVP+ group (100% vs 76.1 ± 6.9%; $P < 0.01$) (Fig. 1); freedom from severe TR was also lower in the TVP+ group (0% vs 87.4%) (Fig. 2). Only 1 patient had undergone repeat surgery on the tricuspid valve for a moderate recurrence of regurgitation in the TVP- group during a reoperation for a severe recurrence of MV insufficiency. The progression of FTR (defined as an increase in >3 mm VC between preoperative and follow-up echocardiography) was more frequent in the TVP- group (17.6% vs 0%, $P < 0.01$). Individual evolution of TR is presented in Fig. 3.

The recurrence of mitral regurgitation (defined as vena contracta >7 mm or effective regurgitant orifice (ERO) ≥ 0.4 cm^2 or regurgitant volume ≥ 60 ml) or MV reoperation at 5 years was also similar (TVP- = 9.4 ± 1.6% vs TVP+ = 5.6 ± 1%; $P = 0.29$) and the mean gradient across the MV as well (TVP- = 3.6 ± 2.4 mmHg vs TVP+ = 3.5 ± 1.3 mmHg; $P = 0.95$).

Echocardiographic follow-up data are presented in Tables 1 and 2. The LV and RV dimensions and functions did not differ between the groups, which was similar to that observed in the left and right atria. The pulmonary artery pressure measurement was available in 92 patients (46 in the TVP+ group and 46 in the TVP- group) and in the TVP+ group was significantly reduced ($P < 0.01$) (Table 3).

Predictors of tricuspid regurgitation

The Cox analysis identified TA ($P = 0.04$) and preoperative mitral regurgitation VC ($P = 0.04$), whereas preoperative tricuspid annulus diameter (systolic and diastolic) did not influence postoperative TR.

Magnetic resonance imaging data

Data obtained from the CMR imaging are presented in Table 4. The RV volumes and function were similar in both groups pre- and post-surgery. The differential in terms of RV end-diastolic (TVP- = 5.8 ± 31.5 vs TVP+ = 19 ± 39.4; $P = 0.4$) and end-systolic volumes (TVP- = 5.8 ± 18.8 vs TVP+ = 16.8 ± 27.1; $P = 0.5$), stroke volume (TVP- = 3.2 ± 19.7 vs TVP+ = 6.7 ± 27.5; $P = 0.4$) and ejection fraction (TVP- = 3.2 ± 9.6 vs TVP+ = 2.7 ± 11.8; $P = 0.8$) was also similar.

DISCUSSION

The main finding of the current study indicated that concomitant TA prevents TR recurrence in patients who are referred for

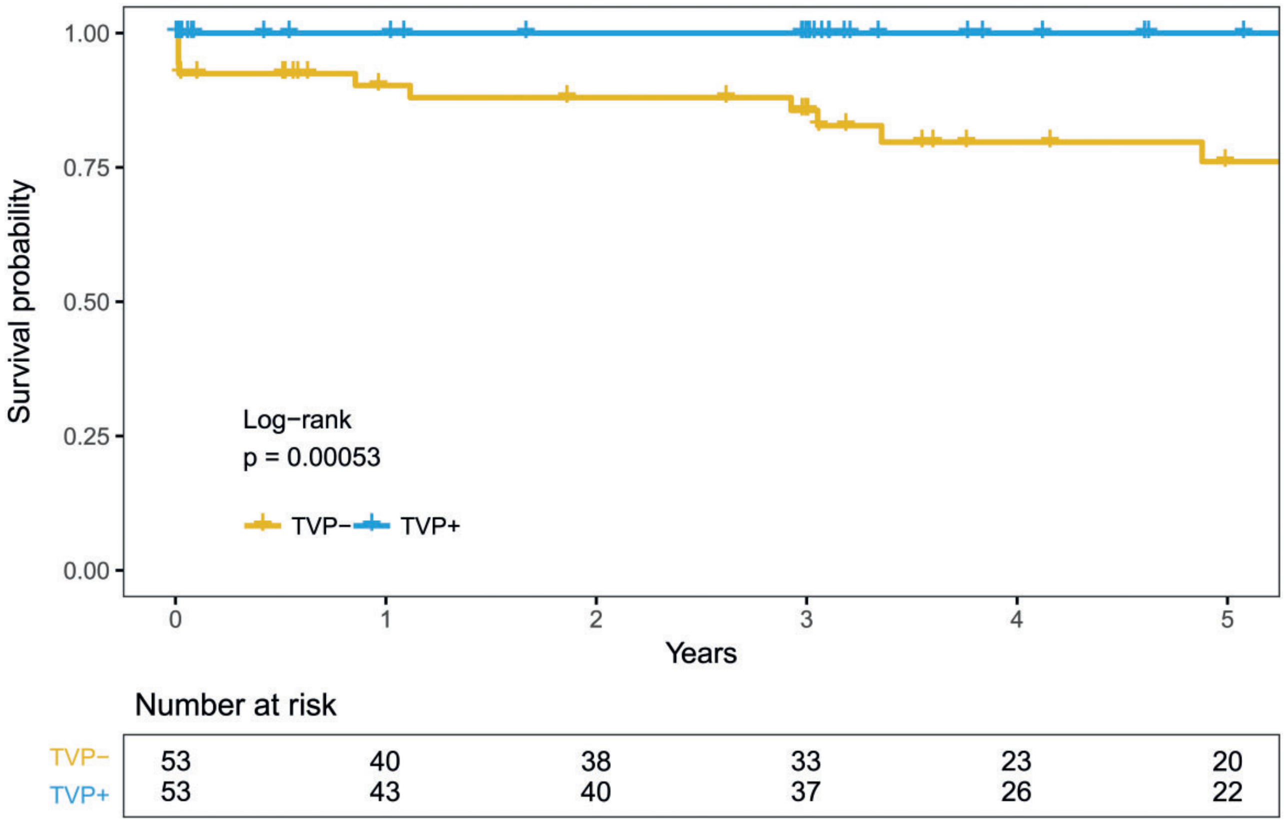

Figure 1: The Kaplan–Meier curve for moderate or severe tricuspid regurgitation. TVP: tricuspid valve annuloplasty.

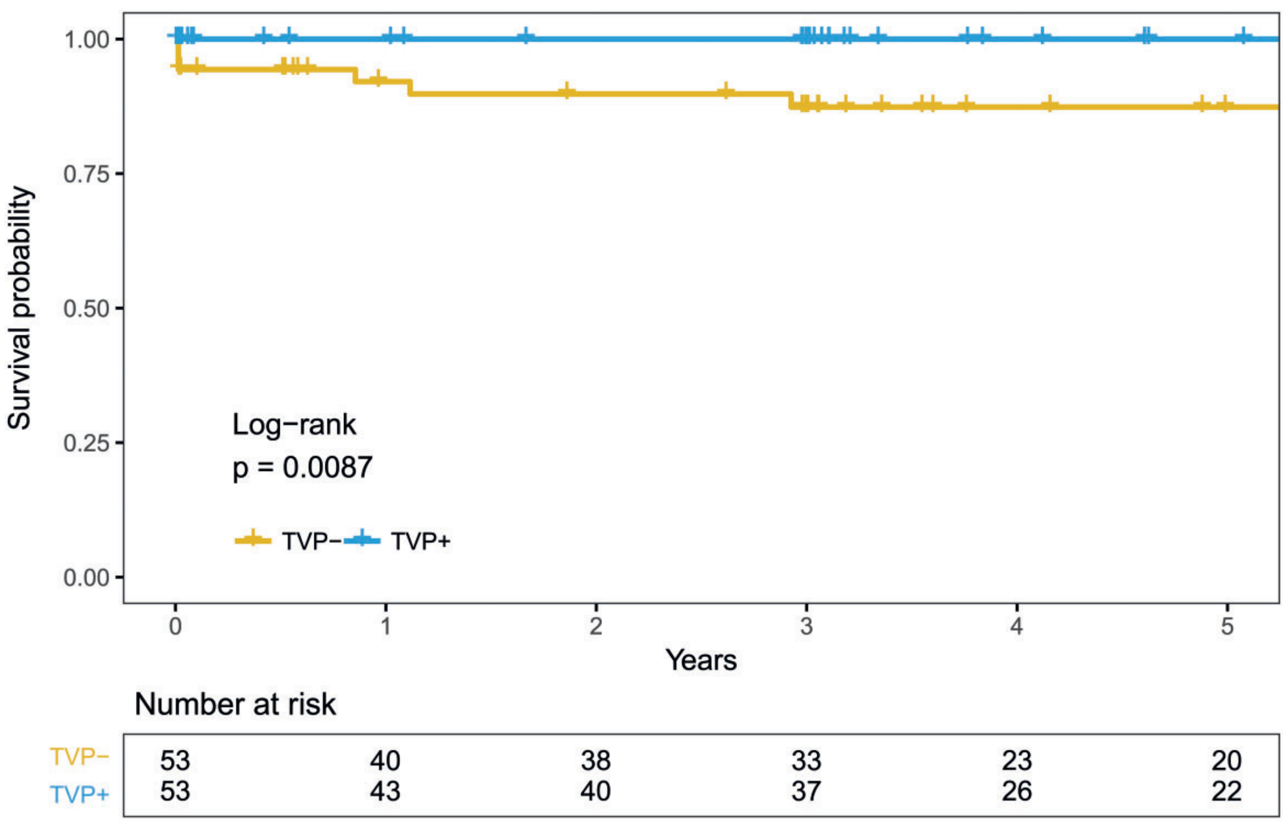

Figure 2: The Kaplan–Meier curve for severe tricuspid regurgitation. TVP: tricuspid valve annuloplasty.

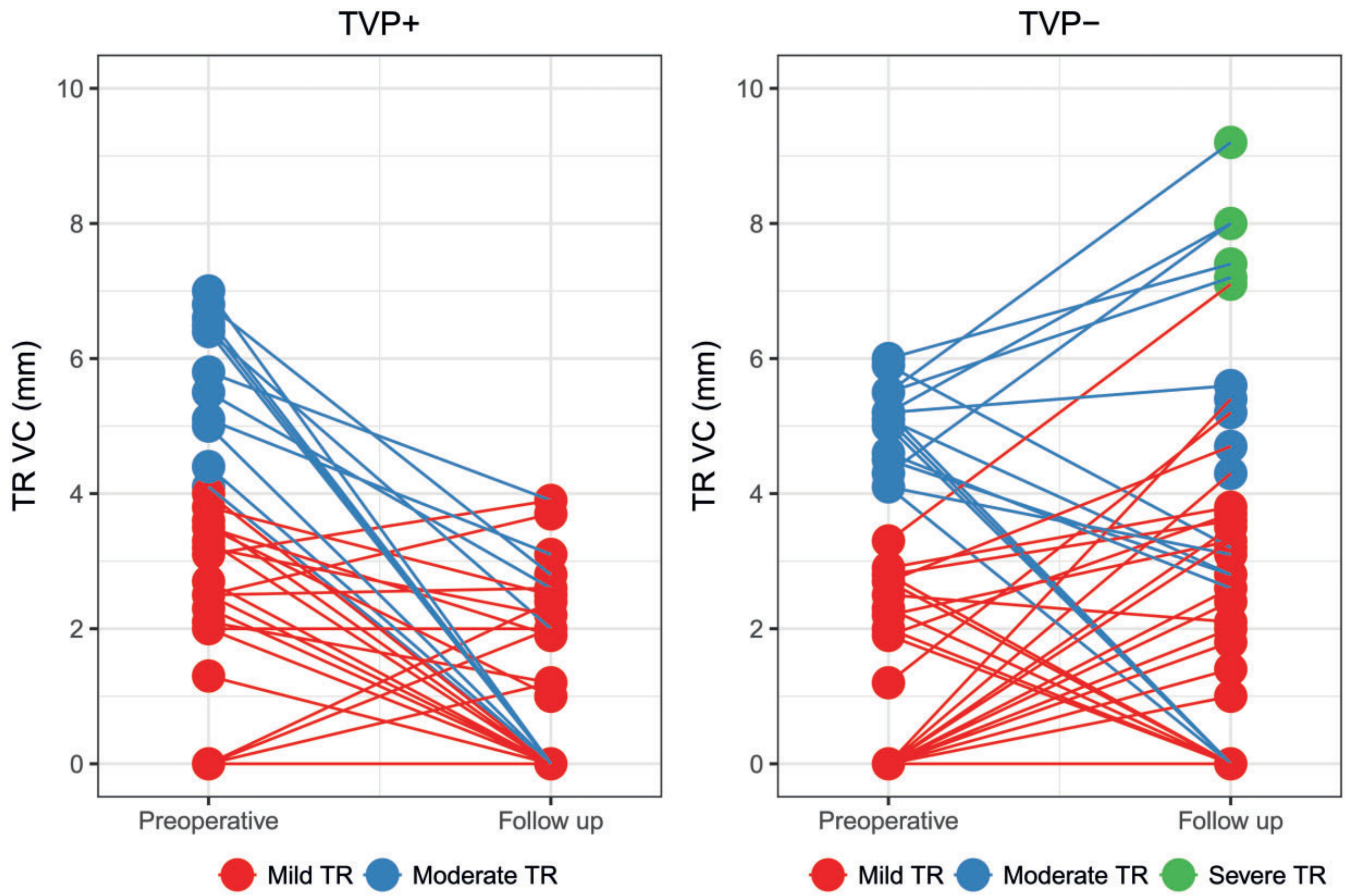

Figure 3: Differences in TR VC preoperatively and at follow-up according to groups. TR: tricuspid regurgitation; TVP: tricuspid valve annuloplasty; VC: vena contracta.

MV surgery with less-than-severe TR. Tricuspid annular dimensions were not identified as predictors of TR recurrence but preoperative mitral regurgitation and TA were. The use of a prophylactic TA at the time of MV surgery is presently a highly debated topic. After the seminal paper by Dreyfus *et al*. [4], who defined annular dilatation as ≥70 mm of distance from the commissure between the septal and anterior leaflets to the base of the posterior leaflet, several other authors confirmed annular dilatation as a predictor of TR recurrence, and the use of a prophylactic TA reduced the risk of TR and improved RV remodelling. Van deVeire *et al*. [7], after measuring the tricuspid annulus in a 4-chamber view using a transthoracic echocardiogram, defined tricuspid dilatation as ≥40 mm; using this cut-off, RV reverse remodelling and TR grade improvement (1.6 ± 1 vs 0.9 ± 0.6, on a scale of 1 to 4) were observed at the 2-year follow-up in patients with tricuspid annular dilatation who underwent concurrent TA during surgery for degenerative or functional MV disease. Those findings were confirmed by Adams and coworkers [6]. After treating a group of 645 patients for degenerative disease, TA was performed in any case of moderate TR and annular dilatation (≥40 mm). It was also performed in cases of equivocal findings on the basis of direct assessment and comparison of the anterior/posterior leaflet surface area with the annulus size and the presence of additional risk factors (such as atrial fibrillation, pulmonary hypertension or RV dysfunction as found in 301 patients). With this more liberal policy, 65% of the patients received TA. They observed that the RV function recovery occurred more rapidly in the TA group and that TA was the main independent positive predictor of late RV recovery in the subgroup of patients with predischarge RV dysfunction by 5 years postoperatively even if the reduction in TR recurrence was not really significant (freedom from moderate TR of 97% vs 91%; $P = 0.07$). They reported an improvement in pulmonary hypertension as we did. It could be speculated that there is a correlation with RV function, which was shown to be improved in the article by Adams and coworkers. These findings were also influenced by the recent European guidelines [9], which suggested that a preoperative echocardiographic TV annulus ≥40 mm is an indication for TA (class IIa, level C), supporting the use of this marker as early predictor of the right chamber remodelling before the appearance of TR. Our study confirmed this finding only partially; we reported an increase in TR recurrence without annuloplasty, but annular dilatation did not predict this complication, and the RV dimension and function did not improve.

In contrast, David *et al*. [18] recently stated that TR recurrence is uncommon after MV repair for degenerative diseases, counting for 13.6% of the patients treated for degenerative disease at 15 years, but 11 of them had had TA. It was also associated with advanced age at surgery, unrepaired preoperative moderate/severe TR and the development of postoperative MR. Similarly, Yilmaz *et al*. [19] from the Mayo Clinic examined the outcomes of 693 patients who had undergone isolated MV repair for MR due to MV prolapse. They observed a significant reduction in the overall grade of TR within the first 3 years but a slight increase after 5 years. Female sex, preoperative atrial fibrillation and diabetes mellitus were independent risk factors for increased TR with time. A more recent evaluation of this issue at that institution confirmed that MV repair in addition to MV replacement reduced postoperative TR grade, and the development of new TR was uncommon [20]. It was associated with female gender, left atrial dimension and RV systolic pressure. More recently, Sordelli *et al.* [21], using 3D imaging, failed to show a correlation between the diameters of the TV annulus (anteroposterior and septolateral) and TR development after MV repair for degenerative diseases. The authors concluded that 'newly developed significant TR is a rare event after successful repair of degenerative MR.' Again, our findings only partially support this part of their discussion, confirming that a single measurement of 40 mm as the cut-off point of dilated TV annulus is probably inappropriate, and it may be too large for patients with small TV leaflets (such as patients with MR due to fibroelastic deficiency) and too small for patients with MR due to advanced myxomatous degeneration. Furthermore, 2D measurements are not adequate to quantify tricuspid annular dilatation, and only 3D images should be used. The ability to predict TR recurrence should be researched with respect to several factors: (i) preload (annular dilatation, atrial enlargement and atrial fibrillation); (ii) afterload (recurrence of MR and pulmonary hypertension); and (iii) the RV function (which, unfortunately, is not appropriately defined). All these parameters were found in the previous papers as major predictors of TR.

Table 3: Echocardiographic data (preoperative vs follow-up) of the right ventricle and tricuspid valve

	TVP-, mean ± SD	TVP+, mean ± SD	*P*-value
RVEDAi (cm^2/m^2)			
Preoperative	12.76 ± 2.75	12.80 ± 2.82	0.95
Follow-up	12.96 ± 2.66	12.82 ± 2.76	0.81
RVESAi (cm^2/m^2)			
Preoperative	8.27 ± 2.44	8.31 ± 2.04	0.94
Follow-up	7.98 ± 1.83	8.88 ± 3.90	0.19
FAC (%)			
Preoperative	35.30 ± 11.74	34.92 ± 9.69	0.87
Follow-up	38.03 ± 7.56	35.58 ± 7.51	0.14
RV basal diameter-i (mm/m^2)			
Preoperative	23.93 ± 4.77	24.38 ± 4.34	0.65
Follow-up	25.87 ± 3.52	23.59 ± 4.52	0.01
RV mid-diameter-i (mm/m^2)			
Preoperative	19.33 ± 4.62	19.69 ± 3.72	0.69
Follow-up	19.54 ± 3.63	19.86 ± 3.97	0.71
RV long axis (mm)			
Preoperative	71.68 ± 9.98	70.12 ± 8.34	0.44
Follow-up	70.72 ± 8.98	71.78 ± 11.13	0.63
TR VC width (mm)			
Preoperative	2.20 ± 2.22	2.55 ± 2.37	0.43
Follow-up	2.44 ± 2.62	0.74 ± 1.23	<0.01
TAPSE (mm)			
Preoperative	1.96 ± 0.56	1.99 ± 0.68	0.76
Follow-up	2.11 ± 4.18	1.12 ± 0.49	0.12
PAP systolic (mmHg)			
Preoperative	37.10 ± 12.47	37.50 ± 18.37	0.90
Follow-up	29.49 ± 12.33[a]	22.96 ± 14.38[a]	0.02
TA end diastolic (mm)			
Preoperative	39.55 ± 5.41	40.14 ± 5.76	0.60
TA end systolic (mm)			
Preoperative	34.50 ± 5.38	35.51 ± 5.94	0.48

[a]$P < 0.05$ compared the preoperative value.

FAC: fractional area change; PAP: pulmonary artery pressure; RV: right ventricular; RVEDAi: right ventricle end diastolic area index; RVESAi: right ventricle end systolic area index; SD: standard deviation; TA: tricuspid annulus; TAPSE: tricuspid annulus plane excursion; TR: tricuspid regurgitation; TVP: tricuspid valve annuloplasty; VC: vena contracta.

Limitations

The limitation of our study was the relative small sample size, which was probably too small to draw some conclusions about the correlation of recurrent TR and VO_2 max. In addition, the data concerning RV volumes and function are limited (from only 30 patients). The median follow-up was approximately 4 years; therefore, longer follow-up periods are desired to confirm the preliminary results, also because the mean age of the patients was 62 years.

CONCLUSION

In conclusion, our study confirmed that TR recurrence after MV surgery for degenerative and rheumatic diseases can be improved by prophylactic TA and by evidence of improvements in a patient's PAH at follow-up but did not demonstrate a difference in reverse remodelling or clinical benefits. This article reinforces the concept that FTR cannot be limited to TR only or annular dilatation, that many other factors play a major role and that we are still not handling them properly. We hope that the ongoing randomized controlled clinical trial will address this

Table 4: Magnetic resonance imaging measurements

	Preoperative, mean ± SD			Postoperative, mean ± SD		
	TVP-	TVP+	*P*-value	TVP-	TVP+	*P*-value
RVEDV (ml)	161.82 ± 52.84	173.12 ± 58.62	0.65	157.60 ± 37.72	153.15 ± 34.03	0.78
RVEDVi (ml/m^2)	91.80 ± 24.73	90.47 ± 29.72	0.95	85.58 ± 17.01	73.62 ± 10.23	0.17
RVESV (ml)	83.97 ± 35.91	85.96 ± 36.61	0.90	75.66 ± 27.41	72.74 ± 22.54	0.79
RVESVi (ml/m^2)	48.01 ± 17.89	49.64 ± 28.69	0.93	41.39 ± 13.28	34.01 ± 8.34	0.28
RVSV (ml)	77.85 ± 20.88	87.16 ± 33.61	0.49	81.93 ± 19.57	80.41 ± 12.89	0.82
RVSVI (ml/m^2)	43.80 ± 9.17	40.83 ± 11.07	0.70	44.19 ± 9.87	39.60 ± 1.89	0.13
RVEF (%)	49.61 ± 7.22	50.90 ± 9.61	0.74	52.99 ± 9.67	53.27 ± 4.87	0.93

RVEDV: right ventricle end diastolic volume; RVEDVi: right ventricle end diastolic volume index; RVEF: right ventricle ejection fraction; RVESV: right ventricle end systolic volume; RVESVi: right ventricle end systolic volume index; RVSV: right ventricle stroke volume; RVSVi: right ventricle stroke volume index; SD: standard deviation; TVP: tricuspid valve annuloplasty.

controversy. Such a trial is currently enrolling study participants. The Cardiothoracic Surgical Trials Network will randomly assign 400 patients with degenerative MV disease with 1 of 2 issues: (i) moderate TR or (ii) tricuspid annular dilatation ($\geq$40 mm) and TR graded as trace or mild to undergo either MV surgery alone or MV surgery plus a rigid, non-planar, undersized TA.

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