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ORIGINAL ARTICLE

Serial Changes of Transmitral and Transtricuspid Pressure Gradients After Simultaneous Mitral and Tricuspid Ring Annuloplasty

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Background Although flexible-ring annuloplasty is more inclined to increase the transmitral gradient over time, its effect on the tricuspid annulus is unknown. This study was conducted to evaluate serial changes in mean pressure gradient (mPG) across tricuspid and mitral valves after simultaneous dual implantation of flexible bands.

Methods Seventy-one (71) patients (median age, 61.6 years; IQR: 50.8–69.0 years) underwent simultaneous mitral/tricuspid annuloplasties using St. Jude Tailor rings. Serial mPGs across mitral and tricuspid valves were evaluated at three postoperative time points: predischarge, 3 years, and 5 years. To gauge the effects and clinical outcomes of prophylactic intervention, patients were categorised as tricuspid regurgitation (TR) $\geq$ moderate or TR $<$ moderate. The median follow-up period was 125 months (IQR: 109–137 months).

Results Unlike transmitral mPG, which increased over time (predischarge, 2.94; 3 years, 3.61; 5 years, 3.87; $p < 0.0005$), transtricuspid mPG did not change (predischarge, 1.65; 3 years, 1.69; 5 years, 1.69; $p = 0.906$). Preoperative TR grade had no impact on serial changes in transtricuspid mPG (TR $\geq$ moderate, $p = 0.542$; TR $<$ moderate, $p = 0.608$). Three observed late recurrences of TR $\geq$ moderate degree displayed TR $\geq$ moderate at baseline, and overall mortality was higher in the TR $\geq$ moderate group ($p = 0.01$).

Conclusions Flexible-band annuloplasty did not promote stenosis of tricuspid valves at mid-term follow-up. These findings confirm the safety of prophylactic tricuspid annuloplasty (via flexible band) as an adjunct to mitral annuloplasty.

Keywords Tricuspid valve • Mitral valve • Annuloplasty

Introduction

Functional tricuspid regurgitation (TR) related to left-sided valve disease will often progress, despite corrective left-sided valvular surgery, necessitating reoperation for advanced isolated TR [1–3]. Current guidelines restrict concomitant tricuspid surgery for less-than-severe functional TR to patients with annular dilation, right-sided heart failure, or pulmonary hypertension at the time of left-sided valvular surgery [4,5]. However, based on mounting evidence in support of more aggressive tricuspid annuloplasty (TAP), TR repair with annuloplasty is now undertaken more frequently [3,6].

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Flexible rings have been used for mitral or tricuspid annuloplasty to preserve physiologic annular contours during the cardiac cycle, while reducing annular size. However, findings of several studies have dampened the popularity of this approach, warning of pannus formation and late-onset mitral stenosis after complete flexible ring implantation [7,8]. Nonetheless, we have encountered no such gradient increases in most patients following tricuspid annuloplasty. Our preliminary observations prompted this investigation, given the current trend for prophylactic TAP.

The aim of our study was to serially monitor mean pressure gradient (mPG) changes at tricuspid and mitral valves in patients undergoing simultaneous flexible-band tricuspid and mitral annuloplasties. We also assessed differences in clinical outcomes among patients with various grades of TR at baseline to weigh efficacy against risk in instances of prophylactic TAP.

Methods

Study Population

Between June 2003 and December 2009, 73 patients underwent simultaneous mitral and tricuspid annuloplasties using partial Tailor rings (St. Jude Medical [SJM], St Paul, MN, USA). Two (2) of these patients had histories of prior cardiac surgeries (aortic valve replacement, pulmonary valvular repair) and thus were excluded. To compare clinical outcomes of procedures viewed as prophylactic, patients were stratified by baseline (preoperative) grade of TR: TR $\geq$ moderate or TR $<$ moderate. The causes of valvular heart disease were confined to the following: degenerative, rheumatic, or consequential to chronic atrial fibrillation (AF). Valvular disease due to chronic AF corresponded with progressive functional TR or MR in the absence of cardiac structural defects (other than annular dilation) once persistent AF was diagnosed. Serial mPG changes across tricuspid and mitral valves were analysed in 52 of the 71 eligible patients whose records properly documented mPG readings at three specified postoperative time points: predischarge, 3 years, and 5 years. Our Institutional Review Board approved this retrospective study, waiving the need for informed consent (IRB number: 2016-03-045).

Surgical Procedures

Upon completing left-sided procedures, TAPs were performed under cardiac arrest. Indications for tricuspid valvular repair were as follows: 1) TR $\geq$ moderate, determined by baseline echocardiogram; 2) significant annular dilation, determined by echocardiography or by surgical access to enlarged right atrium; or 3) associated AF (regardless of TR or annular dilatation). During TAP procedures, mattress stitches were sequentially placed at the annulus, starting at mid-portion of septal leaflet and ending at anteroseptal commissure, abutting the membranous portion of atrioventricular septum. SJM Tailor rings (size range, 27–33) were introduced as band forms extending from start to end of suture placement. Half of the stitches at both ends of the band were tied, without a ring template. Because leaflet prolapse is difficult to gauge in patients with appreciable TR, we used half-tied sutures for temporary interposition of rings, assessing residual TR via subsequent saline test. The tautness of remaining stitches was adjusted accordingly. If central regurgitation persisted, sutures were tightened to further reduce the annulus. Otherwise, they were simply approximated. Eccentric jets or localised leaflet prolapse were remedied through additional leaflet repair techniques before securing the remaining stitches. Such techniques included commissural plication (ie, suturing of anterior and septal leaflets), as well as plication of prolapsed leaflet margins.

Follow-Up Monitoring

Data retrieved from a computerised hospital database were supplemented by telephone surveys of patients or their family members. In those patients lost to hospital-based observation, we searched the National Registry of mortality and survival data for the Republic of Korea. At completion, 74% of patients were monitored at our institution, 18% were followed at other facilities, and the remaining 8% were tracked through the National Registry, accounting for 100% of survival data. The median echocardiographic follow-up period was 88 months (IQR: 39–112 months), and the median outpatient clinic follow-up period was 125 months (IQR: 109–137 months). Transthoracic echocardiography was performed before discharge; at 1, 3, and 5 years postoperatively; and anytime thereafter, as needed. Grading of TR was as follows: absent/minimal, mild, moderate, moderate to severe, and severe.

Statistical Analyses

The Shapiro-Wilk test was used to test for group-wise normality of data distribution. Categorical variables were expressed as frequencies and percentages and continuous variables as medians plus interquartile ranges (IQR). Between-group differences (subsets of TR or MR aetiology) were evaluated using chi-square and Fisher's exact tests for categorical variables. Differences in continuous variables among groups were assessed via Mann-Whitney U test for two-group comparisons, and the Kruskal-Wallis test was applied for three-way group comparisons. Estimates of cumulative survival probability were generated using Kaplan-Meier method. To evaluate changes in transmitral and transtricuspid mPG at predischarge, 3-year, and 5-year marks postoperatively, one-way ANOVA with repeated measures was used. Statistical significance was set at $p < 0.05$.

Results

Patient Characteristics

Patient characteristics at preoperative baseline are summarised in Table 1. Of the 71 patients selected for study, moderate or more-than-moderate TR (TR $\geq$ moderate group) was evident in 36 patients (50.8%), including all seven patients who

Table 1 Baseline patient characteristics.

Variable	Total n = 71	TR ≥ moderate n = 36	TR < moderate n = 35	P-value
Patient characteristics				
Age	61.6 (50.8-69.0)	65.3 (55.6-69.8)	60.0 (49.2-67.7)	0.118
Female	32 (45.1)	19 (52.8)	13 (37.1)	0.186
Body surface area, m^2	1.7 (1.6-1.8)	1.7 (1.6-1.8)	1.7 (1.6-1.9)	0.210
AF	51 (71.8)	27 (75.0)	24 (68.6)	0.547
Hypertension	25 (35.2)	10 (27.8)	15 (42.9)	0.184
Estimated GFR	75.0 (63.3-90.0)	72.2 (61.5-89.1)	76.8 (65.4-94.1)	0.270
Diabetes mellitus	9 (12.7)	4 (11.1)	5 (14.3)	0.688
Stroke	3 (4.2)	2 (5.6)	1 (2.9)	0.572
Coronary artery disease	1 (1.4)	1 (2.8)	0 (0)	0.321
Renal failure	1 (1.4)	1 (2.8)	0 (0)	0.321
NYHA III/IV	7 (9.9)	7 (19.4)	0 (0)	0.011
Logistic EuroScore	4.0 (2.2-5.3)	4.7 (3.1-8.1)	3.1 (1.5-4.2)	0.0001
Aetiology of MR				0.001
Degenerative	56 (78.9)	24 (66.7)	32 (91.4)	
Chronic AF	10 (14.1)	10 (27.8)	0 (0)	
Rheumatic	5 (7.0)	2 (5.6)	3 (8.6)	
Echocardiographic findings				
LV ejection fraction	61.0 (54.0-67.0)	59.0 (51.5-66.8)	62.3 (55.0-67.0)	0.317
LV end-systolic diameter	38.0 (33.0-43.0)	37.0 (33.0-44.5)	38.0 (35.0-43.0)	0.756
LA size	58.0 (51.0-63.0)	55.5 (50.0-63.0)	58.0 (52.0-61.0)	0.584
RV systolic pressure	48.0 (41.0-66.0)	58.5 (43.5-75.0)	45.0 (38.0-57.0)	0.002
Tricuspid annulus size	36.2 (33.1-40.3)	38.1 (33.1-38.1)	34.4 (31.4-39.0)	0.176
Tricuspid annulus size/BSA	20.8 (19.1-22.8)	21.4 (20.0-26.7)	20.3 (17.8-21.0)	0.025
Mitral regurgitation grade				
Absent or trace	0 (0)	0	0	
Mild	5 (7.0)	5	0	
Moderate	5 (7.0)	3	2	
Moderate to severe	12 (16.9)	5	7	
Severe	49 (69.0)	23	26	
Tricuspid regurgitation grade				
Absent or trace	8 (11.3)	0	8	
Mild	27 (38.0)	0	27	
Moderate	20 (28.2)	20	0	
Moderate to severe	6 (8.5)	6	0	
Severe	10 (14.1)	10	0	

Values are presented as median (IQR) or n (%).
Abbreviations: AF, atrial fibrillation; GFR, glomerular filtration rate; NYHA, New York Heart Association; MR, mitral regurgitation; LV, left ventricular; LA, left atrial; RV, right ventricular; BSA, body surface area.

qualified as New York Heart Association (NYHA) functional class III. The logistic EuroSCORE median in the TR ≥ moderate (vs TR < moderate) group was significantly higher (4.7 vs 3.1, $p = 0.0001$). Mitral regurgitation was largely degenerative (78.9%) in this cohort. All 10 patients with MR due to chronic AF belonged to the TR ≥ moderate group. Median right ventricular systolic pressure at baseline was also higher in the TR ≥ moderate (vs TR < moderate) group (58.5 mmHg vs 45.0 mmHg; $p = 0.002$). Although the median tricuspid annular diameter (TAD) tended to be larger in the TR ≥ moderate group, the between-group difference was not statistically significant (38.1 mm/m^2 vs 34.4 mm/m^2; $p = 0.170$). On the other hand, the TAD/body surface area (BSA) index was significantly higher in the TR ≥ moderate group (21.4 mm/m^2 vs 20.3 mm/m^2; $p = 0.025$). Two (2) patients with moderate MR also had TR (< moderate), both undergoing simultaneous

surgical interventions. One (1) patient showed eccentric regurgitation in the A3 area due to chordae prolapse. The other required concomitant TAP during planned aortic valve replacement for severe aortic regurgitation.

Operative Characteristics

The following concomitant procedures were performed: atrial septal defect/patent foramen ovale closure, 10 patients; aortic valvular repair, four patients; aortic valvular replacement, three patients; and coronary artery bypass surgery, one patient. A maze (AF ablation) procedure was performed in 46 patients (64.8%). Median aortic cross-clamp and cardiopulmonary bypass times were 99 minutes (IQR: 84–122 min) and 128 minutes (IQR: 106–155 min), respectively. There were no significant proportionate group differences (TR ≥ moderate vs TR < moderate) in terms of concomitant maze procedures, median aortic cross-clamp time, and cardiopulmonary bypass time ($p = 0.872$, $p = 0.497$, and $p = 0.295$, respectively) (Table 2). Additional tricuspid valvuloplasties were required to reduce residual TR during TAP in two patients with TR of ≥ moderate degree.

Clinical Outcomes

Clinical outcomes are summarised in Table 2. In both groups (TR ≥ moderate vs TR < moderate), prevalences of preoperative AF (75% vs 68.6%) and frequencies of maze procedures performed (65.7% vs 63.9%) were similar ($p = 0.547$ and $p = 0.872$, respectively). However, the efficacy of maze procedure was superior in patients with TR of < moderate degree. There were no differences in postoperative ventilator times, stays in intensive care, or durations of hospitalisation between groups. Overall, only one patient required permanent pacemaker insertion and one suffered mediastinal bleeding postoperatively. There were also two late reoperations, one for mitral valve replacement and the other for artificial chorda implantation. In the former, moderate MR developed due to mitral valve leaflet perforation 1 month after initial surgery. The latter patient experienced a chorda rupture 16 months after initial surgery, culminating in severe MR. These two patients displayed TR of ≥ moderate severity at baseline.

One (1.4%) early cardiac-related death occurred. Another 14 patients (19.7%) died late after discharge. The deaths were attributable to cancer (four patients), heart failure (three patients), and unknown causes (seven patients). The last echocardiographic data of the three patients succumbing to heart failure showed absent, mild, and moderate MR, respectively. Kaplan-Meier survival curves generated for overall mortality according to TR grade at baseline are shown in Figure 1. In all patients, freedom from overall mortality was less in the TR ≥ moderate (vs TR < moderate) group ($p = 0.01$). Mitral regurgitation associated with chronic AF

Table 2 Operative details and clinical outcomes.

Variable	Total n = 71	TR ≥ moderate n = 36	TR < moderate n = 35	P-value
Operative details				
ACC time	99.0 (84.0-122.0)	95.0 (76.5-121.3)	102.0 (88.0-122.0)	0.497
Pump time	128.0 (106.0-155.0)	121.0 (101.3-152.5)	135.0 (111.0-157.0)	0.295
Concomitant operations other than maze procedure				
CABG	1	1	0	
ASD/PFO	10	8	2	
AVP	4	2	2	
AVR	3	1	2	
Early clinical outcomes				
Ventilator time (hours)	12.0 (8.0-18.0)	13.0 (10.0-19.0)	10.0 (8.0-18.0)	0.059
ICU stay (days)	2.0 (1.0-2.0)	2.0 (1.0-3.0)	1.0 (1.0-2.0)	0.122
Hospital stay (days)	9.0 (7.0-13.0)	10.0 (7.3-14.0)	8.0 (7.0-10.0)	0.078
PPM	1	1	0/35	
Bleeding control	1	1	0/35	
Early mortality	1	1	0/35	
Heart rhythm				
Preoperative AF	51/71 (71.8)	27/36 (75.0)	24/35 (68.6)	0.547
Maze procedure	46/71 (64.8)	23/36 (65.7)	23/35 (63.9)	0.872
AF at discharge	22/70 (31.4)	15/35 (42.9)	7/35 (20.0)	0.039
AF at last follow-up	22/70 (31.4)	17/35 (48.6)	5/35 (14.3)	0.002

Abbreviations: AF, atrial fibrillation; ACC, aortic cross-clamp; CABG, coronary artery bypass graft; ASD, atrial septal defect; PFO, patent foramen ovale; AVP, aortic valvuloplasty; AVR, aortic valve replacement; ICU, intensive care unit; PPM permanent pacemaker.

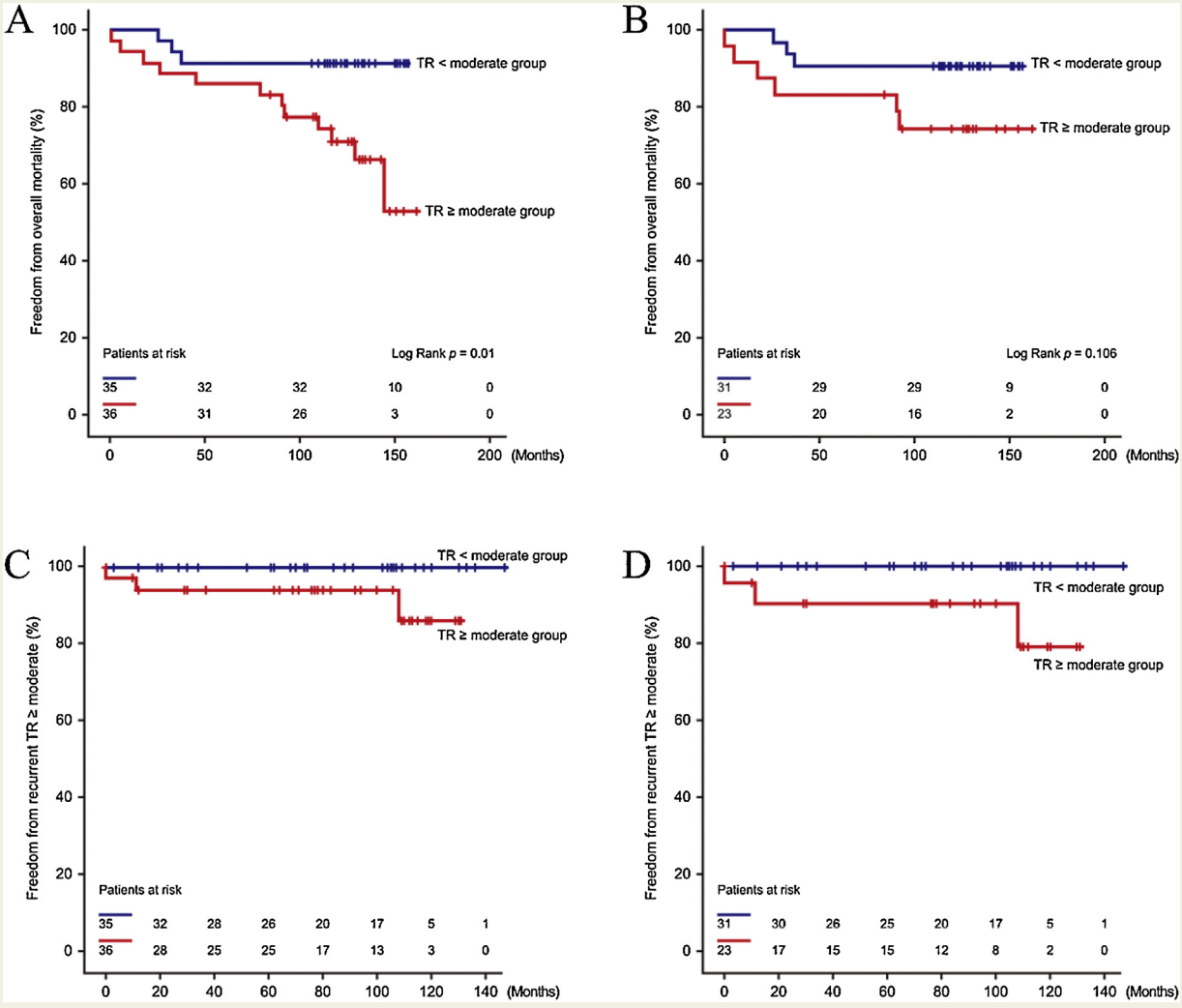

Figure 1 Kaplan-Meier postoperative actuarial survival curves shown by preoperative grade of tricuspid regurgitation (TR): Freedom from overall mortality in (A) all patients and (B) patients with degenerative mitral regurgitation (MR); Freedom from recurrences of TR ≥ moderate degree in (C) all patients and (D) patients with degenerative MR.

conferred significantly higher mortality, compared with degenerative and rheumatic causes ($p = 0.007$), and all of these patients were confined to the TR ≥ moderate group (Table 3). Three (3) patients experienced postoperative recurrences of TR ≥ moderate degree. Again, all three patients exhibited TR ≥ moderate degree at baseline, but a statistically significant group difference was not achieved in this regard ($p = 0.239$).

Mean Pressure Gradient (mPG) Analysis

In the 52 patients analysed, neither mitral nor tricuspid valve demonstrated clinically significant stenosis. However, transmitral mPG increased postoperatively over time (predischarge, 2.94 ± 1.09; 3-year, 3.61 ± 1.17; 5-year, 3.87 ± 1.53; $p < 0.0005$), without corresponding changes in transtricuspid mPG (predischarge, 1.65 ± 0.74; 3-year, 1.69 ± 0.67; 5-year, 1.69 ± 0.68; $p = 0.906$) (Figure 2). This finding was again confirmed in subgroup analysis, stratifying patients by preoperative TR grade (TR ≥ moderate: 1.65 ± 0.71, 1.77 ± 0.70, and 1.83 ± 0.78 at predischarge, 3-year, and 5-year marks, respectively [$p = 0.542$]; TR < moderate: 1.66 ± 0.78, 1.62 ± 0.65, and 1.56 ± 0.55 at predischarge, 3-year, and 5-year marks, respectively; [$p = 0.608$]).

Discussion

Despite concerns that prophylactic TAP may prolong operative time, induce heart block, or adversely impact the right coronary artery (injury short-term; stenosis long-term), those advocating prophylactic TAP as an adjunct to left-sided valvular surgery have grown in number during recent years [9]. This strategy is rooted in current data indicating that TR does not resolve but instead progresses in some patients, especially those with pertinent risk factors (ie, tricuspid

Table 3 **Clinical outcomes according to underlying cause of MR.**

	Degenerative n = 56	Chronic AF n = 10	Rheumatic n = 5	Total n = 71	P-value
Age	60.1 (49.9-67.7)	69.7 (58.3-73.0)	69.1 (60.8-70.3)	61.6 (50.8-69.0)	0.046
Female	23 (41.1)	6 (60.0)	3 (60.0)	32 (45.5)	0.414
LV ejection fraction	62.1 (57.0-67.0)	58.5 (47.8-65.8)	51.9 (46.0-61.0)	61.0 (54.0-67.0)	0.157
Preoperative AF prevalence	37 (66.1)	10 (100)	4 (80.0)	51 (71.8)	1.000
Preoperative TR ≥ moderate	24 (42.9)	10 (100)	2 (40.0)	36 (50.7)	0.001
Absent/minimal TR	6 (10.7)	0 (0)	2 (40.0)	8 (11.3)	
Mild TR	26 (46.4)	0 (0)	1 (20.0)	27 (38.0)	
Moderate TR	16 (28.6)	3 (30.0)	1 (20.0)	20 (28.2)	
Moderate to severe TR	3 (5.4)	3 (30.0)	0 (0.0)	6 (8.5)	
Severe TR	5 (8.9)	4 (40.0)	1 (20.0)	10 (14.1)	
Preoperative MR ≥ moderate	54 (96.4)	7 (70.0)	5 (100)	66 (93.0)	0.033
Mild MR	2 (3.6)	3 (30.0)	0 (0)	5 (7.0)	
Moderate MR	3 (5.4)	1 (10.0)	1 (20.0)	5 (7.0)	
Moderate to severe MR	6 (10.7)	3 (30.0)	3 (60.0)	12 (16.9)	
Severe MR	45 (80.4)	3 (30.0)	1 (20.0)	49 (69.0)	
Predischarge TR ≥ moderate	1 (1.8)	0 (0)	0 (0)	1 (1.4)	1.000
Predischarge MR ≥ moderate	2 (3.6)	1 (10.0)	0 (0)	3 (4.2)	0.515
Predischarge mPG across TV (mean ± SD)	1.66 ± 0.73	1.70 ± 0.75	1.65 ± 0.46	1.65 ± 0.71	0.815
TR ≥ moderate progression	3 (5.4)	0 (0)	0 (0)	3 (4.2)	0.078
Mortality	9 (16.1)	6 (60.0)	0 (0)	15 (21.1)	0.007

Abbreviations: MR, mitral regurgitation; LV, left ventricular; AF atrial fibrillation; TR, tricuspid regurgitation, mPG, mean pressure gradient.

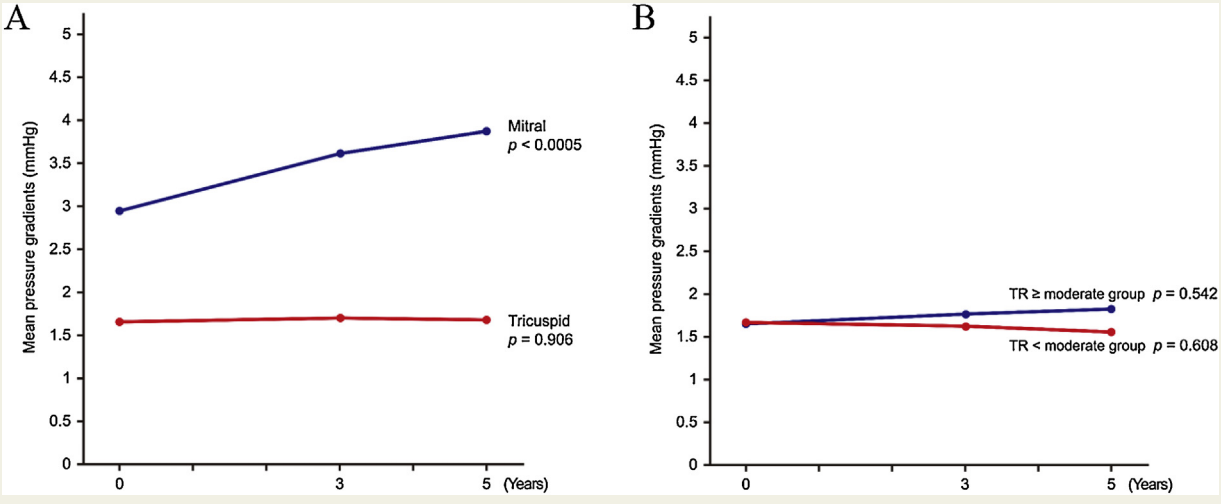

Figure 2 Serial changes in mean pressure gradients across mitral and tricuspid valves.

annulus dilatation, RV dysfunction, significant preoperative TR, AF, pulmonary hypertension, or rheumatic mitral disease), even if left-sided valvular surgery takes place [3,6,10].

In patients with tricuspid annular dilation, annular reduction is best achieved through use of flexible or rigid rings. Both seem equally effective in controlling regurgitation, although rigid rings may be credited with lower rates of recurrent TR [11,12]. Band flexibility also imparts certain benefits, providing normal annular dynamics during the cardiac cycle for less risk of dehiscence [11,13]. Still, the reluctance of surgeons to utilise flexible rings at the tricuspid valve has been fueled by reports of pannus formation after mitral annuloplasty (MAP) [14,15]. Mitral stenosis may redevelop long after ring implantation, resulting from fibrous tissue ingrowth of the annulus and valvular base and foreign body reaction. The flexible Duran ring (Medtronic, Fridley, MN, USA) in particular has been implicated in such events [7,8]. However, only a few brief reports have attested to

development of transtricuspid gradients after ring/band annuloplasty. In general, transtricuspid mPG readings remain low after TAP.

Using the Physio ring (Edwards Lifesciences, Irvine, CA, USA), Chikwe et al. consistently recorded postoperative transtricuspid mPGs of 2.0 mmHg, regardless of ring size [16]. In the longest follow-up study (mean, 6 years), Gatti et al. registered postoperative mPGs of 2.3 ± 1.3 mmHg and 2.6 ± 1.3 mmHg using rigid rings and flexible bands, respectively for TAP [12]. The only source to report serial change in transtricuspid gradients has been Huffman et al., citing mean transtricuspid gradients of 1.75 ± 0.12 mmHg, 2.3 ± 0.18 mmHg, and 2.8 ± 0.74 mmHg at sequential points in time (immediately postoperative, 4 weeks postoperatively, and last follow-up, respectively) after simultaneous mitral and tricuspid annular implantation of same-sized rigid rings [17]. These findings suggest the possibility of increased transtricuspid mPG over time. Unfortunately, statistical support was not offered, and final transtricuspid gradients were obtained in follow-up from only 5 of 53 patients who were monitored for relatively short and widely disparate time periods (2–33 months).

In a previous study of ours, assessing concomitant mitral valve replacement and prophylactic TAP, we found that TR progressed without TAP, even in instances where the TAD/BSA index (TADI) fell below the consensus level for surgical intervention [6]. Consequently, it seemed that current standards for prophylactic TAP were unnecessarily restrictive. In the present study, the threshold set for TAP (20.8 mm/m^2) was less than the recommended limit (21 mm/m^2); and in some patients with TR $<$ moderate at baseline, an even lower TADI (20.3 mm/m^2) was not prohibitive. As we have shown, postoperative transtricuspid gradients did not increase over time, despite easing of the TADI threshold. Thus, it is our view that the fear of long-term stenosis after more aggressive prophylactic TAP is unwarranted. Although we encourage a lower threshold for TAP, we are not in favour of aggressively downsizing the ring, as some investigators recently have suggested. In a report by Maghami et al., undersized rigid rings with flat sizes of 26 or 28 mm resulted in relatively high predischarge mPGs (3.2 ± 2 mmHg) [18]. Because an echocardiographic diagnosis of significant tricuspid stenosis is made at mPGs $>$ 5 mmHg, we advise caution in applying an undersized rigid ring, given the lack of long-term data [18,19].

Herein, we have demonstrated a lack of appreciable stenosis over time after flexible partial-band tricuspid and mitral annuloplasties; and although transmitral gradients did progressively increase, transtricuspid gradients remained stable (Figure 2). Hence, the use of a flexible band for MAP has declined at our institute since 2009, but is still in use for TAP, allowing convenient adjustment of annulus size by varying the tautness of sutures. Once the size of a rigid ring is selected, further adjustment is not possible. Owing to difficulty in pinpointing the source of TR (leaflet prolapse vs dilated annulus), ring implantation should precede leaflet prolapse evaluation. Additional valvuloplasty for leaflet prolapse may impose a transtricuspid gradient under a small rigid ring.

The Kaplan-Meier survival curves in our cohort showed higher mortality in the TR $\geq$ moderate group. Although a statistical difference in survival by TR grade at baseline disappeared in patients grouped as degenerative aetiology, this may simply reflect an insufficient sampling. Another finding of interest is that AF-induced TR (vs other causes) was linked to higher mortality. In patients with AF alone and no cardiac structural defects other than annular dilation, TR has proved more problematic than MR [20]. Typically, left ventricular (LV) systolic function is preserved in such patients [21], who are then referred for surgery as LV dysfunction worsens in old age, making patient management difficult. Sinus conversion by maze procedure is also precarious under these circumstances, perhaps owing to the high incidence of advanced heart failure and severe TR responsible for chronic AF. Overall, we achieved better outcomes after performing maze procedures in patients with TR $<$ moderate. For all reasons above, early prophylactic TAP ultimately may improve patient outcomes and functional capacities in this setting [22].

Limitations

Given the retrospective observational nature of this study, detailed echocardiographic data was unavailable. In addition, variations in underlying aetiologies of MR that produce functional TR were unknown, so existing pre and postoperative patient heterogeneities were unaccountable as a result. We also included all patients undergoing simultaneous mitral and tricuspid annuloplasties using the SJM Tailor flexible partial band, regardless of MR aetiology. Nevertheless, to our knowledge, this is the first study to directly compare progressive haemodynamic effects of the same flexible annular band used for both mitral and tricuspid valves. Furthermore, our stratification of patients by TR grade at baseline served to remove potential confounding variables. Further corroboration from larger prospective studies is needed to validate these results.

Conclusion

Use of a flexible partial band for TAP did not increase transtricuspid mPG, yielding satisfactory results in preventing the progression of TR over time. Based on present findings, we conclude that aggressive TAP in this manner, coupled with left-sided valvular surgery, is a safe and effective approach that dispels common concerns of late-onset tricuspid stenosis.

References

[1] Desai RR, Vargas Abello LM, Klein AL, Marwick TH, Krasuski RA, Ye Y, et al. Tricuspid regurgitation and right ventricular function after mitral valve surgery with or without concomitant tricuspid valve procedure. J Thorac Cardiovasc Surg 2013;146:1126–32. e10.

[2] Goldstone AB, Howard JL, Cohen JE, MacArthur Jr JW, Atluri P, Kirkpatrick JN, et al. Natural history of coexistent tricuspid regurgitation in patients with degenerative mitral valve disease: implications for future guidelines. J Thorac Cardiovasc Surg 2014;148:2802–9.
[3] Dreyfus GD, Corbi PJ, Chan KM, Bahrami T. Secondary tricuspid regurgitation or dilatation: which should be the criteria for surgical repair? Ann Thorac Surg 2005;79:127–32.
[4] Nishimura RA, Otto CM, Bonow RO, Carabello BA, Erwin 3rd JP, Guyton RA, 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. Circulation 2014;129:e521–643.
[5] Vahanian A, Alfieri O, Andreotti F, Antunes MJ, Baron-Esquivias G, Baumgartner H, et al. Guidelines on the management of valvular heart disease (version 2012): the Joint Task Force on the Management of Valvular Heart Disease of the European Society of Cardiology (ESC) and the European Association for Cardio-Thoracic Surgery (EACTS). Eur J Cardiothorac Surg 2012;42:S1–44.
[6] Lee H, Sung K, Kim WS, Lee YT, Park SJ, Carriere KC, et al. Clinical and hemodynamic influences of prophylactic tricuspid annuloplasty in mechanical mitral valve replacement. J Thorac Cardiovasc Surg 2016;151:788–95.
[7] Bisoi AK, Rajesh MR, Talwar S, Chauhan S, Ray R, Venugopal P. Mitral stenosis after Duran ring annuloplasty for non-rheumatic mitral regurgitation–a foreign body response? Heart Lung Circ 2006;15:189–90.
[8] Ibrahim MF, David TE. Mitral stenosis after mitral valve repair for non-rheumatic mitral regurgitation. Ann Thorac Surg 2002;73:34–6.
[9] Diez-Villanueva P, Gutierrez-Ibanes E, Cuerpo-Caballero GP, Sanz-Ruiz R, Abeytua M, Soriano J, et al. Direct injury to right coronary artery in patients undergoing tricuspid annuloplasty. Ann Thorac Surg 2014;97:1300–5.
[10] McCarthy PM, Bhudia SK, Rajeswaran J, Hoercher KJ, Lytle BW, Cosgrove DM, et al. Tricuspid valve repair: durability and risk factors for failure. J Thorac Cardiovasc Surg 2004;127:674–85.
[11] Zhu TY, Wang JG, Meng X. Is a rigid tricuspid annuloplasty ring superior to a flexible band when correcting secondary tricuspid regurgitation? Interact Cardiovasc Thorac Surg 2013;17:1009–14.
[12] Gatti G, Dell'Angela L, Morosin M, Maschietto L, Pinamonti B, Benussi B, et al. Flexible band versus rigid ring annuloplasty for functional tricuspid regurgitation: two different patterns of right heart reverse remodelling. Interact Cardiovasc Thorac Surg 2016;23:79–89.
[13] Gatti G, Marciano F, Antonini-Canterin F, Pinamonti B, Benussi B, Pappalardo A, et al. Tricuspid valve annuloplasty with a flexible prosthetic band. Interact Cardiovasc Thorac Surg 2007;6:731–5.
[14] Rubino AS, Onorati F, Santarpia G, Achille F, Lorusso R, Santini F, et al. Impact of increased transmitral gradients after undersized annuloplasty for chronic ischemic mitral regurgitation. Int J Cardiol 2012;158:71–7.
[15] Magne J, Senechal M, Mathieu P, Dumesnil JG, Dagenais F, Pibarot P. Restrictive annuloplasty for ischemic mitral regurgitation may induce functional mitral stenosis. J Am Coll Cardiol 2008;51:1692–701.
[16] Chikwe J, Itagaki S, Anyanwu A, Adams DH. Impact of concomitant tricuspid annuloplasty on tricuspid regurgitation, right ventricular function, and pulmonary artery hypertension after repair of mitral valve prolapse. J Am Coll Cardiol 2015;65:1931–8.
[17] Huffman LC, Nelson JS, Lehman AN, Krajacic MC, Bolling SF. Identical tricuspid ring sizing in simultaneous functional tricuspid and mitral valve repair: a simple and effective strategy. J Thorac Cardiovasc Surg 2014;147:611–4.
[18] Maghami S, Ghoreishi M, Foster N, Dawood MY, Hobbs GR, Stafford P, et al. Undersized rigid nonplanar annuloplasty: the key to effective and durable repair of functional tricuspid regurgitation. Ann Thorac Surg 2016;102:735–42.
[19] Baumgartner H, Hung J, Bermejo J, Chambers JB, Evangelista A, Griffin BP, et al. Echocardiographic assessment of valve stenosis: EAE/ASE recommendations for clinical practice. Eur J Echocardiogr 2009;10:1–25.
[20] Zhou X, Otsuji Y, Yoshifuku S, Yuasa T, Zhang H, Takasaki K, et al. Impact of atrial fibrillation on tricuspid and mitral annular dilatation and valvular regurgitation. Circ J 2002;66:913–6.
[21] Takahashi Y, Abe Y, Sasaki Y, Bito Y, Morisaki A, Nishimura S, et al. Mitral valve repair for atrial functional mitral regurgitation in patients with chronic atrial fibrillation. Interact Cardiovasc Thorac Surg 2015;21:163–8.
[22] Kim YJ, Kwon DA, Kim HK, Park JS, Hahn S, Kim KH, et al. Determinants of surgical outcome in patients with isolated tricuspid regurgitation. Circulation 2009;120:1672–8.