Effect of tricuspid annuloplasty concomitant with left heart surgery on right heart geometry and function

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ABSTRACT

Objectives: To elucidate the effect of tricuspid annuloplasty concomitant with left-sided valve surgery on the right heart in patients with mild or more tricuspid regurgitation (TR).

Methods: We enrolled 78 patients with mild or more TR who underwent left-sided valve surgery. Forty-three patients underwent only left-sided valve surgery (group non-T) and 35 underwent concomitant tricuspid annuloplasty (group T). Echocardiographic changes between the preoperative and 1-year follow-up periods were compared. Propensity score matching was used to obtain risk-adjusted outcome comparisons (16 pairs).

Results: In group non-T, there were more operations for aortic stenosis and concomitant coronary artery bypass grafting, and fewer operations for mitral regurgitation. The prevalence of atrial fibrillation was higher in group T. In preoperative echocardiography, there were no significant differences in left ventricular and right ventricular (RV) dimensions and functions. Tricuspid valve annular diameter and TR-related parameters were significantly larger in group T. Left ventricular dimensions and TR-related parameters significantly improved in both groups 1 year after operation. RV diameter was significantly reduced in only group T. In analysis of variance, RV diameter in systole and diastole showed significant interaction, whereas left heart dimensions and function, tricuspid valve tethering height, and RV fractional area change did not show interaction. These results were not attenuated even after propensity-matching analyses.

Conclusions: Among patients with mild or more TR, RV reverse remodeling was not obtained with left-sided valve surgery alone. Additional use of tricuspid annuloplasty might potentially achieve favorable TR regulation as well as RV reverse remodeling. (J Thorac Cardiovasc Surg 2018;156:1050-61)

Interaction between tricuspid annuloplasty and improvement of RV dimensions and function.

Central Message

Tricuspid annuloplasty concomitant with left-sided valve surgery might potentially achieve not only favorable TR regulation but also RV reverse remodeling in patients with mild or more preoperative TR.

Perspective

We assessed the effect of concomitant tricuspid annuloplasty on the right heart in patients with mild or more TR. This study revealed that RV reverse remodeling was achieved 1 year after surgery only when tricuspid annuloplasty was also used in left-sided valve surgery, and that 1 year was not sufficient to show a significant difference in terms of RV functional recovery with additional use of tricuspid annuloplasty.

See Editorial Commentary page 1062.

Tricuspid annuloplasty concomitant with left-sided valve surgery is commonly used to control functional tricuspid regurgitation (TR) and has shown favorable outcomes in

terms of the freedom from recurrent TR.¹⁻⁴ Because TR is affected by right heart dimensions, current guidelines recommend tricuspid annuloplasty for not only preoperative severe TR but also for tricuspid annular dilatation (TAD) of >40 mm.^{5,6} TAD is an ongoing process,¹ and associated with postoperative right ventricular (RV) remodeling. It subsequently leads to right heart failure

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Scanning this QR code will take you to a supplemental video for the article.

Abbreviations and Acronyms

LV	= left ventricular
RA	= right atrial
RV	= right ventricular
TAD	= tricuspid annular dilatation
TR	= tricuspid regurgitation

if preoperative TR remains untreated during primary surgery. Because the presence of a “synergistic relationship” between TR and RV dysfunction has been gradually made clear,^{7,8} the tricuspid valve has, more than ever, become the focus of investigations. Recent reports showed that tricuspid annuloplasty can promote improvement of RV function evaluated with several parameters, including RV diameter, tricuspid annular plane systolic excursion, and pulmonary artery pressure, in 2- to 5-year follow-up periods after surgery.^{1,3,9} The aim of this study was to elucidate the effect of tricuspid annuloplasty concomitant with left-sided valve surgery on right heart geometry and function for up to 1 year after the surgery.

METHODS

Study Population

With permission from our institutional review board (approval number 29-6; date of approval: June 26, 2017), we retrospectively reviewed patient data. The need for individual patient consent was waived. From January 2012 to March 2016, 106 patients with mild or more TR underwent left-sided valve surgery. Among them, patients with primary TR, active infective endocarditis, previous pacemaker lead implantation, and missing data were excluded, leaving 78 patients enrolled. Patients with missing data were postoperatively followed-up at other hospitals from which the patients were originally referred for surgery. Therefore we could not obtain the follow-up echocardiographic data. The cohort was divided into 2 groups: group non-T included 43 patients who underwent only left-sided valve surgery, and group T included 35 patients who underwent left-sided valve surgery and tricuspid annuloplasty (Figure 1). Because some preoperative characteristics were significantly different between groups, propensity score matching was used to enable more balanced comparisons. The end point of this study was the improvement of each echocardiographic parameter between the preoperative and 1 year follow-up periods.

Data Collection and Assessment of Echocardiographic Parameters

Patient characteristics, surgical, and in-hospital outcomes, and follow-up data were extracted from hospital electronic medical records. Preoperative and 1 year follow-up transthoracic echocardiography data were available for all 78 patients. Left heart dimensions and function, right heart dimensions and function, and parameters of TR including pressure gradient, TR jet area, right atrial (RA) area, and their ratio were assessed. To analyze TR severity as a continuous datum, we defined it as the ratio of the TR jet area to the RA area. In this study, trivial TR (1+) corresponds to a ratio of <0.1, mild (2+) between 0.1 and 0.2, moderate (3+) between 0.2 and 0.33, and severe (4+) >0.33.

Right heart dimensions and quantitative TR data were not routinely measured in all patients in our institute. Therefore, echocardiographic data in all 78 patients were remeasured retrospectively by 2 expert

FIGURE 1. Flow chart for patient selection.

echocardiographers. The measurement method was standardized and on the basis of current guidelines. Right heart dimensions, function, and TR severity were obtained from a standard 4-chamber view, which was available in all patients. To ensure internal consistency of echocardiographic data measured by the 2 examiners, preoperative RV diameter in diastole was measured in all 78 patients by each examiner. The values determined by 1 examiner were plotted against those of the other on a scatter diagram (Figure 2). The plotted points were mostly distributed along the $Y = X$ graph.

Surgical Procedure

All surgeries were performed through a median sternotomy with standard cardiopulmonary bypass at mild hypothermia. Myocardial protection was achieved with antegrade and/or retrograde cold crystalloid cardioplegia. When patients had moderate or severe TR, we added tricuspid annuloplasty to left-sided valve surgery according to current guidelines. In addition, tricuspid annuloplasty was also considered in patients with mild TR if they had previously reported risk factors for recurrent TR, including atrial fibrillation and pulmonary hypertension.

For the 35 patients who underwent tricuspid annuloplasty, the repair was done with either the De Vega procedure ($n = 5$) or ring annuloplasty ($n = 30$). We used an MC3 prosthetic ring (Edwards Lifescience Corp, Irvine, CA) of sizes 26, 28, and 30 mm in 13, 15, and 2 patients, respectively. We usually used a 28-mm ring to correct the dilated annulus to the normal size; however, sometimes, other sizes were used according to the body surface area of patients. Nine- or 10-ring sutures were placed carefully to avoid injury to the conduction system (Video 1).

Statistical Methods

Categorical variables are presented as percentages and numbers, and were compared using Fisher exact test. Continuous variables are presented as median and interquartile range, and were compared using Mann–Whitney U test. Changes of each continuous variable with time were analyzed using Wilcoxon signed rank test.

To analyze the effect of tricuspid annuloplasty on the improvement of each echocardiographic parameter between the preoperative and 1 year follow-up periods, 2-factor analysis of variance with repeated measures was conducted. If there was a significant interaction between groups and time, we considered that a parameter was affected by a group difference (whether tricuspid annuloplasty was added or not). Propensity scores were calculated for each patient using multivariate logistic regression on the basis of the following covariates: mitral valve surgery, aortic valve

FIGURE 2. Scatter plot graph with preoperative right ventricular diameters in diastole measured using 2 echocardiographers on each axis. $Y = 0.872X + 7.23$, $R^2 = 0.534$.

surgery, concomitant coronary artery bypass grafting, history of atrial fibrillation, left ventricular (LV) ejection fraction, tricuspid annular diameter, TR jet area, RA area, and the TR jet area/RA area ratio. The same analyses were performed after adjustment.

All analyses were conducted with JMP version 12.0 (SAS Institute Inc, Cary, NC), and $P < .05$ was the criterion for significance. The significant level was set as 0.0042 ($= 0.05/12$) under Bonferroni correction when analysis of variance was performed. In addition to P value, standardized differences were calculated and are noted in Tables 1 and 2.

RESULTS

Patient Characteristics

Table 1 shows the preoperative and surgical characteristics for all 78 patients. Their mean age was 73 (range, 65–77) years, and 44 (56%) of them were women. At baseline, the prevalence of atrial fibrillation was significantly higher in group T. There was no difference in age, sex, other medical history, or New York Heart Association classification.

VIDEO 1. Tricuspid annuloplasty using a 28-mm MC3 ring (Edwards Lifescience Corp, Irvine, Calif). Annuloplasty stitches were placed on the annulus under cardiac arrest. Video available at: [https://www.jtcvs.org/article/S0022-5223\(18\)30882-1/fulltext](https://www.jtcvs.org/article/S0022-5223(18)30882-1/fulltext).

TABLE 1. Patient preoperative and surgical characteristics before adjustment

Characteristic	All patients (n = 78)	Group non-T (n = 43)	Group T (n = 35)	P value	Stand. diff.
Patient					
Age, y (IQR)	73 (65-77)	72 (62-77)	73 (65-76)	.98	0.022
Female sex, n (%)	44 (56)	24 (56)	20 (57)	1	0.02
Body surface area, m ² (IQR)	1.51 (1.39-1.67)	1.55 (1.43-1.70)	1.45 (1.35-1.64)	.1	−0.4
Previous cardiac surgery, n (%)	11 (14)	4 (9)	7 (20)	.21	0.306
Atrial fibrillation, n (%)	32 (42)	10 (24)	22 (63)		
Chronic	29	9	20	.001	0.842
Paroxysmal	3	1	2		
Ischemic heart disease, n (%)	14 (18)	9 (21)	5 (14)	.56	−0.186
NYHA functional class, n (%)					
I	31 (40)	20 (48)	11 (31)		−0.353
II	33 (43)	18 (43)	15 (43)	.11	0
III	13 (17)	4 (9)	9 (26)		0.459
IV	0 (0)	0 (0)	0 (0)		—
Echocardiographic data					
LV diameter in diastole, mm (IQR)	51 (43-57)	50 (43-57)	53 (44-60)	.54	0.127
LV diameter in systole, mm (IQR)	35 (29-42)	32 (28-42)	36 (30-46)	.2	0.233
Left atrial diameter, mm (IQR)	47 (40-55)	47 (39-52)	48 (41-56)	.18	0.363
LV ejection fraction, % (IQR)	60 (51-68)	63 (52-70)	55 (49-67)	.12	−0.285
TR grade, n (%)					
1+ (none-trivial)	0 (0)	0 (0)	0 (0)		—
2+ (mild)	58 (74)	39 (91)	19 (54)	.0005	−0.910
3+ (moderate)	19 (24)	4 (9)	15 (43)		0.841
4+ (severe)	1 (1)	0 (0)	1 (3)		0.249
TR pressure gradient, mm Hg (IQR)	38 (27-46)	37 (26-45)	41 (29-50)	.1	0.39
Tricuspid annular diameter, mm (IQR)	35 (32-39)	34 (31-37)	37 (33-42)	.02	0.518
Tricuspid valve tethering height, mm (IQR)	4.25 (3.50-5.50)	4.2 (3.5-5.5)	4.3 (3.4-5.4)	.73	−0.233
TR jet area, cm ² (IQR)	3.1 (2.1-5.9)	2.3 (1.7-3.1)	52 (32-6.7)	<.0001	0.928
RA area, cm ² (IQR)	16.5 (13.1-22.4)	15.8 (13.1-19.7)	19.0 (13.7-24.3)	.03	0.591
TR jet area/RA area ratio (IQR)	0.20 (0.13-0.33)	0.15 (0.11-0.20)	0.29 (0.22-0.36)	<.0001	1.057
RA diameter, mm (IQR)	38.5 (32.0-44.0)	36 (32-42)	41 (34-47)	.08	0.386
RV diameter in diastole, mm (IQR)	31 (29-35)	30 (29-34)	32 (28-35)	.49	0.165
RV diameter in systole, mm (IQR)	22 (19-25)	23 (20-25)	22 (18-26)	.35	−0.047
RV fractional area change, % (IQR)	38.0 (32.1-45.1)	37.6 (29.6-45.7)	38.2 (33.6-44.0)	.4	0.182
Surgical data					
Left valve surgery					
Aortic stenosis, n (%)	15 (19)	12 (28)	3 (9)	.04	−0.518
Aortic regurgitation, n (%)	23 (29)	12 (28)	11 (31)	.81	0.074
Mitral stenosis, n (%)	7 (9)	2 (5)	5 (14)	.23	0.348
Mitral regurgitation, n (%)	49 (63)	22 (51)	27 (77)		
Degenerative	33	18	15	.02	0.561
Functional (ischemic)	11 (4)	4 (3)	7 (1)		
Prosthetic valve failure	5	0	5		
Concomitant surgery					
Coronary artery bypass grafting, n (%)	9 (12)	8 (19)	1 (3)	.04	−0.526
Maze, n (%)	10 (13)	5 (12)	5 (14)	.75	0.08
Total surgery time, min (IQR)	252 (192-319)	208 (173-303)	290 (236-350)	.002	0.519
Cardiopulmonary bypass time, min (IQR)	156 (110-207)	124 (98-174)	172 (140-223)	.003	0.584
Aortic cross-clamp time, min (IQR)	99 (74-120)	86 (67-114)	108 (88-136)	.02	0.427

Stand. diff., Standardized difference; IQR, interquartile range; NYHA, New York Heart Association; LV, left ventricular; TR, tricuspid regurgitation; RA, right atrial; RV, right ventricular.

Preoperative echocardiographic data showed no significant difference in LV parameters. Although the TR jet area, RA area, TR jet area/RA area ratio, and tricuspid

annular diameter were larger in group T, the RV diameter in systole, diastole, and RV fractional area change showed no significant difference.

TABLE 2. Patient preoperative and surgical characteristics after adjustment

Characteristic	All Patients (n = 32)	Group non-T (n = 16)	Group T (n = 16)	P value	Stand. diff.
Patient					
Age, y (IQR)	70 (61-76)	70 (61-74)	73 (61-77)	.33	0.231
Female sex, n (%)	15 (47)	8 (59)	7 (44)	1	−0.124
Body surface area, m ² (IQR)	1.52 (1.42-1.70)	1.62 (1.43-1.76)	1.45 (1.38-1.67)	.16	−0.473
Previous cardiac surgery, n (%)	3 (9)	1 (6)	2 (13)	1	0.214
Atrial fibrillation, n (%)	15 (47)	7 (44)	8 (50)		
Chronic	14	7	7	1	0.124
Paroxysmal	1	0	1		
Ischemic heart disease, n (%)	3 (9)	1 (6)	2 (13)	1	0.214
NYHA functional class, n (%)					
I	13 (41)	6 (37)	7 (44)		0.128
II	15 (47)	10 (63)	5 (31)	.06	−0.659
III	4 (12)	0 (0)	4 (25)		0.816
IV	0 (0)	0 (0)	0 (0)		
Echocardiographic data					
LV diameter in diastole, mm (IQR)	52 (43-61)	54 (47-65)	49 (42-59)	.22	−0.426
LV diameter in systole, mm (IQR)	35 (29-46)	36 (31-46)	32 (28-44)	.39	−0.302
Left atrial diameter, mm (IQR)	47 (40-55)	50 (43-58)	46 (38-53)	.27	−0.284
LV ejection fraction, % (IQR)	61 (51-68)	61 (51-67)	60 (51-68)	.87	−0.078
TR grade, n (%)					
1+ (none-trivial)	0 (0)	0 (0)	0 (0)		
2+ (mild)	24 (75)	14 (87)	10 (63)	.22	−0.603
3+ (moderate)	8 (25)	2 (13)	6 (37)		0.603
4+ (severe)	0 (0)	0 (0)	0 (0)		
TR pressure gradient, mm Hg (%)	5 (16)	37 (28-45)	40 (26-49)	.76	0.231
Tricuspid annular diameter, mm (IQR)	36 (32-41)	35 (31-41)	37 (32-42)	.56	0.096
Tricuspid valve tethering height, mm (IQR)	4.1 (3.0-5.2)	4.2 (3.2-6.5)	4.1 (2.7-4.6)	.27	−0.6
TR jet area, cm ² (IQR)	3.2 (2.4-4.8)	2.7 (2.1-4.1)	3.9 (3.0-5.1)	.11	0.379
RA area, cm ² (IQR)	17.0 (13.1-23.0)	15.6 (13.2-23.0)	18.5 (12.5-23.8)	.55	0.237
TR jet area/RA area ratio (IQR)	0.22 (0.12-0.29)	0.19 (0.13-0.27)	0.23 (0.12-0.29)	.43	0.266
RA diameter, mm (IQR)	40 (36-46)	39 (36-45)	41 (35-47)	.71	0.06
RV diameter in diastole, mm (IQR)	31 (29-35)	30 (29-35)	32 (28-34)	.61	0.129
RV diameter in systole, mm (IQR)	22 (20-25)	24 (20-26)	22 (18-25)	.14	−0.393
RV fractional area change, % (IQR)	38.1 (30.4-42.8)	33.1 (25.1-44.3)	38.3 (33.8-41.2)	.29	0.367
Surgical data					
Left valve surgery					
Aortic stenosis, n (%)	3 (9)	2 (13)	1 (6)	1	−0.214
Aortic regurgitation, n (%)	9 (28)	3 (19)	6 (38)	.43	0.425
Mitral stenosis, n (%)	2 (6)	2 (13)	0 (0)	.48	−0.535
Mitral regurgitation, n (%)	20 (63)	11 (69)	9 (56)		
Degenerative	13	9	4	.72	−0.26
Functional (ischemic)	5 (1)	2 (1)	3 (0)		
Prosthetic valve failure	2	0	2		
Concomitant surgery					
Coronary artery bypass grafting, n (%)	2 (6)	1 (6)	1 (6)	1	0
Maze, n (%)	5 (16)	4 (25)	1 (6)	.33	−0.535
Total surgery time, min (IQR)	260 (202-317)	227 (185-305)	284 (222-327)	.12	0.653
Cardiopulmonary bypass time, min (IQR)	162 (123-198)	140 (115-185)	167 (139-216)	.19	0.418
Aortic cross-clamp time, min (IQR)	102 (79-118)	93 (74-115)	108 (90-121)	.26	0.311

Stand. diff., Standardized difference; IQR, interquartile range; NYHA, New York Heart Association; LV, left ventricular; TR, tricuspid regurgitation; RA, right atrial; RV, right ventricular.

In group non-T, there were more surgeries for aortic stenosis and concomitant coronary artery bypass grafting, and fewer surgeries for mitral regurgitation. The

surgical time and cardiopulmonary bypass time were longer in group T. No patient required postoperative pacemaker implantation in this cohort.

TABLE 3. One year follow-up echocardiographic data before adjustment

	1 y follow-up data			Wilcoxon signed-rank test		ANOVA
	Group non-T (n = 43)	Group T (n = 35)	P value	Group non-T (n = 43)	Group T (n = 35)	Interaction
LV diameter in diastole, mm (IQR)	44 (39-49)	45 (40-49)	.68	<.0001	<.0001	0.9
LV diameter in systole, mm (IQR)	29 (25-32)	31 (26-34)	.12	<0.0001	0.0001	0.99
LA diameter, mm (IQR)	41 (36-47)	43 (36-50)	.42	<0.0001	<0.0001	0.24
LV ejection fraction, % (IQR)	63 (58-67)	61 (52-65)	.12	0.97	0.92	0.78
TR pressure gradient, mm Hg (IQR)	24 (20-28)	23 (17-26)	.34	<0.0001	<0.0001	<0.0001
TR jet area, cm ² (IQR)	1.5 (1.1-2.4)	1.0 (0.3-1.9)	.01	0.0008	<0.0001	<0.0001
RA area, cm ² (IQR)	14.3 (12.0-16.5)	16.4 (13.6-18.7)	.05	0.004	0.006	0.04
TR jet area/RA area ratio (IQR)	0.10 (0.07-0.18)	0.06 (0.02-0.11)	.002	0.002	<0.0001	<0.0001
TV tethering height, mm (IQR)	4.1 (3.2-5.3)	3.4 (2.7-4.5)	.04	0.09	<0.0001	0.12
RV diameter in diastole, mm (IQR)	32 (29-35)	30 (26-33)	.01	0.009	0.004	0.0004
RV diameter in systole, mm (IQR)	23 (21-27)	20 (16-24)	.01	0.52	0.004	0.004
RV fractional area change, % (IQR)	40.4 (34.7-45.5)	42.4 (36.3-51.2)	.15	0.33	0.08	0.52

ANOVA, Analysis of variance; LV, left ventricular; IQR, interquartile range; LA, left atrial; TR, tricuspid regurgitation; RA, right atrial; TV, tricuspid valve; RV, right ventricular.

Changes of Echocardiographic Data and Effect of Tricuspid Annuloplasty on Them

Table 3 shows echocardiographic data at 1 year follow-up, the results of Wilcoxon signed rank test, and interaction. Figure 3 shows the improvement of each echocardiographic parameter between the preoperative and 1-year follow-up periods, according to group. The results of Wilcoxon signed rank test are shown in the same colors as graphs. In both groups, TR severity evaluated according to the TR jet area/RA area ratio was reduced significantly at 1 year after surgery. In terms of TR grade, the TR severity of group non-T remained mild whereas that of group T changed from moderate to trivial. The RV diameter in diastole and systole showed different changes according to group: that of group non-T showed a tendency to increase, whereas that of group T significantly decreased over time.

The results of 2-factor analysis of variance with repeated measures on echocardiographic parameters are also shown in Figure 3. First, the left heart dimensions including LV diameter in systole and diastole, left atrial diameter, and LV ejection fraction did not show significant interaction. Second, the parameters of TR, including pressure gradient, jet area, and their ratio showed significant interaction. Finally, concerning RV parameters, tricuspid valve tethering height and RV fractional area change did not show interaction. On the contrary, the RV diameter in systole and diastole showed significant interaction.

Propensity Score Matching

Because of the retrospective nature of the study, there were some differences in patient characteristics. We examined how each difference in background affected our

results. The sample size was too small to conduct subgroup analysis for each factor. Therefore, we conducted propensity score matched analyses using covariates that are clinically important (mitral valve surgery, aortic valve surgery, concomitant coronary artery bypass grafting, history of atrial fibrillation, LV ejection fraction, TR jet area, RA area, and the TR jet area/RA area ratio), yielding 16 matched pairs. The preoperative characteristics after adjustment are shown in Table 2. There was no significant difference between groups. The 1-year follow-up data, the results of the Wilcoxon signed rank test between preoperative and 1-year follow-up periods, and interaction are shown in Table 4. Figure 4 shows the improvement of each echocardiographic parameter between the preoperative and 1-year follow-up periods, according to groups. The significant interactions between time and tricuspid annuloplasty were seen in RV diameter even after adjustment (in diastole: $P = .0008$, in systole: $P = .001$).

DISCUSSION

The main findings of this study was that tricuspid annuloplasty concomitant with left-sided valve surgery had a positive effect on the improvement of postoperative RV geometry 1 year after surgery, whereas RV remodeling was observed in patients who underwent only left-sided valve surgery. Tricuspid annuloplasty did not show a significant effect on the improvement of RV function 1 year after surgery. The same results were also seen after propensity score matched analyses. In most previous reports regarding the recovery of RV dimensions and function, tricuspid annuloplasty was performed concomitantly with mitral valve surgery. However, multivariate analysis

◇ Group non-T: without (n = 43), and ○ Group T: with tricuspid annuloplasty (n = 35)

◇ Group non-T: without (n = 43), and ○ Group T: with tricuspid annuloplasty (n = 35)

FIGURE 3. The effect of tricuspid annuloplasty concomitant with left-sided valve surgery on each echocardiographic parameter calculated using 2-factor analysis of variance with repeated measures. The results of Wilcoxon signed rank test are shown in the same colors. A, The results for the left heart dimensions and function. B, The results (only Wilcoxon signed rank test) for the parameters regarding tricuspid regurgitation (TR). C, The results for the right heart dimensions and function. LV, Left ventricular; Pre, preoperative; RA, right atrial; RV, right ventricular; TV, tricuspid valve.

◇ Group non-T: without (n = 43), and ○ Group T: with tricuspid annuloplasty (n = 35)

FIGURE 3. (Continued).

showed that tricuspid annuloplasty had beneficial effects on RV reverse remodeling regardless of the type of left-sided valve disease, LV ejection fraction, presence of atrial fibrillation, and concomitant coronary artery bypass grafting. In addition, we found that RV reverse remodeling after tricuspid annuloplasty can be seen at

1 year postoperatively, whereas RV remodeling progressed in patients who did not undergo tricuspid annuloplasty. These findings are new to the literature, and support an aggressive approach to perform tricuspid annuloplasty before TR becomes more complicated, with leaflet tethering caused by RV dilatation.

TABLE 4. One year follow-up echocardiographic data after adjustment

	1 y follow-up data			Wilcoxon signed rank test		ANOVA
	Group non-T (n = 16)	Group T (n = 16)	P value	Group non-T (n = 16)	Group T (n = 16)	Interaction
LV diameter in diastole, mm (IQR)	46 (39-50)	42 (39-48)	.69	0.0003	0.002	0.16
LV diameter in systole, mm (IQR)	30 (26-34)	29 (26-33)	.84	0.001	0.007	0.29
LA diameter, mm (IQR)	41 (36-51)	39 (35-45)	.37	0.007	0.003	0.78
LV ejection fraction, % (IQR)	61 (56-65)	61 (54-67)	.88	0.96	0.7	0.55
TR pressure gradient, mm Hg (IQR)	24 (19-28)	23 (0-28)	.7	0.001	0.002	0.35
TR jet area, cm ² (IQR)	1.7 (1.0-2.4)	1.0 (0.05-1.88)	.03	0.01	<.0001	0.02
RA area, cm ² (IQR)	14.3 (11.5-17.0)	15.9 (12.4-18.2)	.56	0.03	0.06	0.57
TR jet area/RA area ratio (IQR)	0.11 (0.07-0.18)	0.07 (0.00-0.11)	.01	0.02	<.0001	0.02
TV tethering height, mm (IQR)	3.9 (3.2-5.5)	3.6 (2.7-4.3)	.16	0.65	0.18	0.83
RV diameter in diastole, mm (IQR)	32 (28-37)	28 (26-32)	.03	0.07	0.007	0.0008
RV diameter in systole, mm (IQR)	21 (25-27)	16 (18-24)	.003	0.09	0.005	0.001
RV fractional area change, % (IQR)	39.1 (31.1-42.7)	47.7 (39.1-53.2)	.01	0.53	0.01	0.21

ANOVA, Analysis of variance; IQR, interquartile range; LV, left ventricular; LA, left atrial; TR, tricuspid regurgitation; RA, right atrial; TV, tricuspid valve; RV, right ventricular.

◇ Group non-T: without (n = 16), and ◇ Group T: with tricuspid annuloplasty (n = 16)

◇ Group non-T: without (n = 16), and ◇ Group T: with tricuspid annuloplasty (n = 16)

FIGURE 4. Echocardiographic changes after adjustment for preoperative and surgical differences using propensity score matching (16 pairs). A, The results for the left heart dimensions and function. B, The results for the parameters regarding tricuspid regurgitation (TR). C, The results for the right heart dimensions and function. LV, Left ventricular; Pre, preoperative; RA, right atrial; RV, right ventricular; TV, tricuspid valve.

◇ Group non-T: without (n = 16), and ○ Group T: with tricuspid annuloplasty (n = 16)

FIGURE 4. (Continued).

Clinicians have been conservative in performing tricuspid annuloplasty concomitant with left-sided valve surgery, in particular with mitral valve surgery, because some reports showed that mitral valve surgery alone could reduce TR.^{10,11} That belief has gradually changed, because many authors revealed a high incidence of recurrent and progressive TR.¹²⁻¹⁵ Other authors also showed that postoperative TR affects long-term outcomes, including mortality and morbidity,^{14,16-21} and current guidelines have shown a more aggressive attitude toward additional tricuspid annuloplasty. This attitude is supported by the facts that additional use of tricuspid annuloplasty positively affects the mid- and long-term outcomes including survival^{1,13,14,22-24} and that it does not increase surgical risks,^{2,18,25-27} whereas reoperation in patients with severe TR which was untreated in the previous left-sided valve surgery has high mortality.^{5,18,28,29} Furthermore, recent reports suggested that eliminating preoperative TR has a positive effect on improving RV dimensions and function, and on controlling recurrent TR.^{3,8,9} Van de Veire et al reported that mitral valve surgery alone in patients with mild or less TR but with TAD caused progressive TR, increased TR pressure gradient, and RV remodeling postoperatively, whereas tricuspid annuloplasty concomitant with mitral valve surgery in patients with significant TR or TAD achieved RV reverse remodeling as well as reduction of TR and

pressure gradient at 2-year follow-up.¹ In our study, similar results were obtained with regard to RV reverse remodeling at 1 year after surgery, which shows that the geometric improvement of the right ventricle starts from the early phase of the postoperative course. TR did not progress regardless of tricuspid annuloplasty. However, TR was controlled at the level of less than trivial in group T, whereas TR remained mild in group non-T. This finding explains the reason for the differences in geometric improvement during the time course. The volume overload caused by TR affects the right ventricle differently, although the preoperative RV diameter was almost the same. After releasing volume overload postoperatively, the RV diameter was reduced only in group T. This difference was produced because the right ventricle is a volume-dependent chamber. Nevertheless, we agree that medical treatment using diuretics is a reasonable alternative to control volume overload as long as TR is stably maintained at mild or less severity.

Chikwe et al compared patients who underwent mitral valve repair alone with those who underwent mitral valve repair and tricuspid annuloplasty.⁹ They revealed that additional use of tricuspid annuloplasty induced improvement of RV function. The proportion of patients with RV dysfunction became almost the same between the 2 groups at 3 to 5 years after surgery, although that proportion was significantly higher in patients with mitral valve repair alone preoperatively. Desai et al also reported the

continuous improvement of RV function in patients with 3+ or 4+ TR if tricuspid annuloplasty was performed concomitantly with mitral valve repair.³ This effect persisted, and RV function recovered up to almost the normal level at 3 years after surgery. This finding showed that RV function is reversible.

From these previous reports and the results of this study, our speculation for the recovery of RV dimensions and function is that, after relieving pressure overload through left-sided valve surgery and volume overload through tricuspid annuloplasty, the RV dimensions can be improved and TR regulation can be maintained for 1 year. This might lead to the improvement of RV function thereafter.

Study Limitation

This study is limited by its retrospective and observational nature, as well as the small sample size. Because echocardiographic data were reviewed retrospectively, the readers were not blinded to what procedures had been performed. In the patient selection, 18 patients were excluded because they were followed-up in other hospitals. This exclusion due to unavailability of follow-up data might potentially lead to selection bias.

To assess the effects of small sample size and differences in background, we performed propensity score matched analyses; the results ensured that our speculation was valid from the viewpoint of statistical methodology. However, we cannot assess unknown confounding factors or generalize the results of this study on the basis of only 78 patients. Moreover, propensity score matching produced only 16 pairs. The disappearance of significant differences in preoperative characteristics after propensity score matching might be because of its smaller sample size. Another limitation is that we could not reveal the association between RV reverse remodeling and clinical outcomes because of the small sample size and short follow-up period.

Nevertheless, the findings of this study strongly support the benefit of tricuspid annuloplasty concomitant with left-sided valve surgery. A prospective multicenter randomized control trial is necessary to update the recommendations of current guidelines.

CONCLUSIONS

Among patients with mild or more preoperative TR, RV reverse remodeling was not achieved with left-sided valve surgery alone 1 year after surgery. Tricuspid annuloplasty concomitant with left-sided valve surgery might potentially achieve not only favorable TR regulation but also RV reverse remodeling.

Conflict of Interest Statement

Authors have nothing to disclose with regard to commercial support.

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Key Words: tricuspid regurgitation, tricuspid annuloplasty, right ventricular remodeling, right ventricular function