Echocardiographic approach to the decision-making process for tricuspid valve repair

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Objective: Commonly used procedures to repair functional tricuspid regurgitation have a high failure rate. The present study was designed to lower this failure rate by reducing leaflet tethering via pericardial patch augmentation when the preoperative probability of recurrence was high.

Methods: Between 2001 and 2007, 210 patients with severe functional tricuspid regurgitation underwent tricuspid valve repair at the Day General Hospital. With respect to the type of repair, the patients were randomly divided into 4 groups: (1) De Vega in 52 patients; (2) ring annuloplasty in 53 patients; (3) De Vega and, if indicated by the preoperative tethering index (tethering distance > 8 mm or tethering area > 16 mm^2), pericardial patch augmentation in 53 patients; and (4) ring annuloplasty and, if indicated by the preoperative tethering index (tethering distance > 8 mm or tethering area > 16 mm^2), pericardial patch augmentation in 52 patients. The results of 1-month and 1-year postoperative tricuspid regurgitation were evaluated.

Results: Fifteen patients in group 3 and 15 patients in group 4 met the criterion for the complementary procedure. Postoperative tricuspid regurgitation was different between the groups ($P < .05$): 16.0% and 28.0% of patients in the De Vega group, 8.0% and 14.0% of patients in the ring annuloplasty group, 4.0% and 10.0% of patients in the De Vega + pericardial patch augmentation group, and 2.0% and 8.0% of patients in the ring annuloplasty + pericardial patch augmentation group had postoperative tricuspid regurgitation at 1-month and 1-year follow-up, respectively.

Conclusion: An assessment of preoperative tricuspid valve tethering to select patients suitable for augmentation contributes to a good surgical outcome in patients with severe functional tricuspid regurgitation. (J Thorac Cardiovasc Surg 2010;139:1483-7)

ACD

Functional tricuspid regurgitation (TR) appears in conjunction with left-sided valve disease and left ventricular dysfunction despite the presence of a structurally normal tricuspid valve (TV). Surgical repair of functional TR during the operation of left-sided heart disease is recommended because the persistence of significant TR begets a significant increase in postoperative morbidity and mortality.[1-3] Functional TR is thought to be caused by the dilatation of the TV annulus and tethering of the tricuspid leaflet, subsequent to right ventricular (RV) dilatation.[4-6] TR severity is related to both dilated TV annulus and leaflet tethering, which decrease the degree of leaflet overlap or coaptation at the tips.[6] If performed to reduce the TV annulus, however, these modalities might not be sufficient to correct functional TR, with more than mild residual TR occurring in up to 20% of patients early after annuloplasty and in more than 40% of patients after De Vega.[7-10] Unfortunately, the mechanism and determinants of residual TR after TV repair have not been fully investigated and thus remain unknown.

In light of a previous study demonstrating that the severity of preoperative TV leaflet tethering distance and area could predict significant residual TR after TV annuloplasty,[10] we sought to reduce the failure rate of TR repair by lessening leaflet tethering via pericardial patch augmentation when the preoperative probability of recurrence was high.

MATERIALS AND METHODS

Study Population

The present study included 293 consecutive patients, selected for functional TR repair at Day General Hospital. Patients with pacemaker wires across the TV, congenital heart disease, and inadequate visualization on echocardiography were excluded. The final population of this study was composed of 210 patients (74 men and 136 women at a mean age of 55.2 ± 10.0 years). The study protocol was approved by the institutional Ethics Committee on Human Studies at Day General Hospital.

Patients were examined using 2-dimensional transthoracic echocardiography (TTE) before and after cardiac surgery. Postoperative echocardiography was performed at a follow-up of 1 month and 1 year after cardiac surgery.

The main left-sided lesions were mitral valve in 143 patients, aortic valve in 1 patient, both mitral and aortic valves in 43 patients, and combined valve and coronary artery disease in 23 patients.

Eighty-seven patients (47.1%) had previous cardiac surgery: 55 for the mitral valve, 8 for the aortic valve, 12 for both mitral and aortic valves, and 12 for the mitral and TVs. Previous percutaneous mitral valvuloplasty had

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Abbreviations and Acronyms
RV = right ventricular
TEE = transesophageal echocardiography
TR = tricuspid regurgitation
TTE = transthoracic echocardiography
TV = tricuspid valve

been carried in 28 patients. A total of 151 patients (71.9%) had atrial fibrillation.

Patients were randomly divided into 4 groups by type of repair: (1) De Vega in 52 patients; (2) ring annuloplasty in 53 patients; (3) De Vega and, and if indicated by the preoperative tethering index (tethering distance > 8 mm or tethering area > 16 mm^2), pericardial patch augmentation in 53 patients; and (4) ring annuloplasty and, if indicated by the preoperative tethering index (tethering distance > 8 mm or tethering area > 16 mm^2), pericardial patch augmentation in 52 patients.

Echocardiographic Measurements

In this prospective study, all the echocardiograms were obtained by 2 blinded cardiologists. Two-dimensional TTE was performed as routine before and after cardiac surgery with Vivid 7 (GE Medical Systems, Waukesha, WI). In the 4-chamber view, RV end-systolic and end-diastolic areas were measured via planimetry and tracing the endocardial outline of the RV and the plane of the TV. RV fractional area change was calculated as end-diastolic area minus end-systolic area divided by end-diastolic area × 100.[11,12] TV annulus diameter was measured in the apical 4-chamber view as the distance between the points of reflection of the septal and mural endocardium on the anterior and septal tricuspid leaflets, respectively. The TV coaptation depth and tethering area were measured by tracing between the atrial surface of the leaflets and the tricuspid annular plane at the time of maximal systolic closure (Figure 1). TR severity was assessed via color Doppler flow mapping of the spatial distribution of the regurgitant jet within the right atrium. TR jet area on the color flow mapping (Figure 2) and the right atrium in the same frame were measured by planimetry, and the ratio of the maximal regurgitant area to right atrium area (%TR) was thereafter obtained. In accordance with previous studies,[6,13,14] residual TR after TV annuloplasty was graded as mild if it occupied less than 20%, moderate if it was between 20% and 34%, and severe if it was greater than 34% on follow-up echocardiography. Left ventricular ejection fraction was also obtained by using Simpson's rule methods from apical 4- and 2-chamber views. After TV systolic velocity was recorded with continuous-wave Doppler, RV systolic pressure was calculated by Modified Bernoulli gradient + estimated right atrium pressure based on the inferior vena cava pattern.

It should be noted that transesophageal echocardiography (TEE) was done in all the patients. However, because TR can vary significantly and be underestimated during surgery and after anesthesia, we chose TTE over TEE so that the patients would be under a normal and stable condition.

Surgical Procedure

The operations were performed through a median sternotomy with extracorporeal circulation. TV repair was carried out subsequent to the surgical correction of the mitral or aortic valve. Myocardial protection was achieved with antegrade or retrograde cardioplegia.

Patients with aortic lesions (n = 48) underwent aortic prosthetic valve replacement (mechanical prostheses in 38 patients and bioprostheses in 10 patients). Patients with mitral lesions (n = 185) underwent mitral prosthetic valve replacement (n = 120; mechanical prostheses, 82 and bioprostheses, 38) or mitral valve repair (n = 65; flexible ring annuloplasty, 57; mitral commissurotomy, 20; thinning of the subvalvular apparatus, 12; and leaflet augmentation, 13).

An autologous piece of pericardium was harvested immediately after median sternotomy and immersed in 3% glutaraldehyde for 15 minutes. The patients were placed on standard cardiopulmonary bypass with bicaval cannulation, and standard blood cardioplegic arrest was initiated with antegrade and retrograde cardioplegia. In cases of an enlarged left atrium, the mitral valve was replaced via a left atriotomy, which was followed by a right atriotomy to repair the tricuspid valve. On the other hand, when the left atrium was small, the mitral valve was replaced through the interatrial groove via right atriotomy and subsequently the tricuspid valve was repaired. Annuloplasty sutures with 2-0 Ethibond were used to bring the valve closer to the surgical field. A curvilinear incision was thereafter made in the anterior leaflet parallel to the anterior annulus, from commissure to commissure, leaving 1 to 2 mm of leaflet tissue. The secondary order chordae of the leaflet were cut to confer mobilization.

The autologous patch was then generously fashioned to a suitable size; great care was exercised to ensure that the length of the patch was at least the same as the commissure to commissure distance and that the width of the patch was 8 to 12 mm (depending on which part of the leaflet was more shortened) in an effort to restore the coaptation zone between the leaflets and avert leaflet prolapse. Once appropriately sized, the patch was sewn into the defect of the anterior leaflet with 2 running 5-0 Prolene sutures. A complete ring annuloplasty procedure or De Vega was subsequently performed in the patients. For annular ring procedure, the Carpentier-Edwards ring (Baxter Healthcare Corp, Santa Ana, Calif) was used. The length of the base of the septal leaflet (intertrigonal distance) determined the size of the ring. All the rings were downsized by 2 sizes.

De Vega repair was performed by a partial purse-string reduction of the anterior and posterior leaflet annulus. The judgment regarding the degree of annular reduction was based on the degree of annular reduction using the ring annuloplasty sizers designed for the tricuspid valve (with the rule of undersizing the ring by 2 sizes).

The completed repair restored the intraventricular zone of coaptation, which was confirmed at the time of repair by filling the RV with saline through a bulb syringe and visually inspecting the leaflets in conjunction with intraoperative TEE.

Statistical Analysis

All the results are expressed as mean ± standard deviation. The nominal and continuous variables were compared using the chi-square test and analysis of variance, respectively. A post hoc comparison was made via the

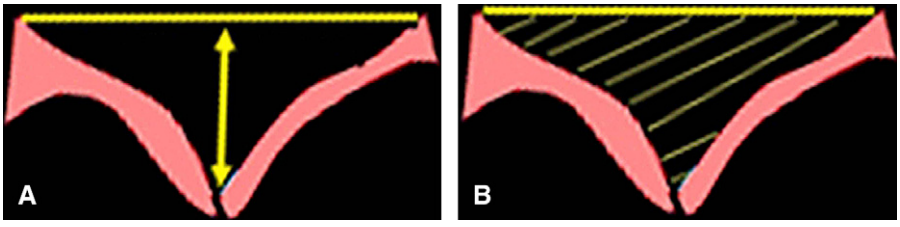

FIGURE 1. The TV coaptation depth (A) and tethering area (B) were measured by tracing between the atrial surface of the leaflets and the tricuspid annular plane at the time of maximal systolic closure.

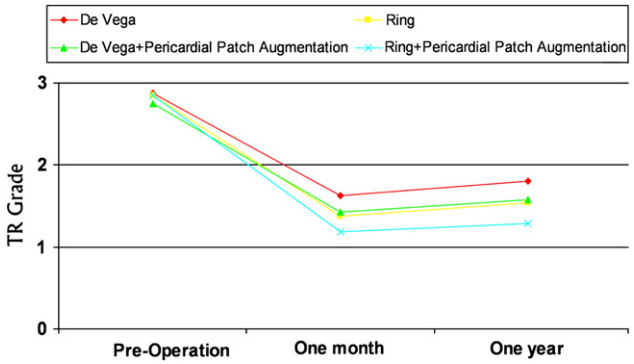

FIGURE 2. Comparison of preoperative and postoperative TR among the 4 groups. *TR,* Tricuspid regurgitation.

Bonferroni test. In addition, a general linear model was used to compare the repeated measurements of the differences in postoperative TR in the 4 groups.

RESULTS

There were 10 (4.8%) hospital mortalities, the causes of death being heart failure in 6, respiratory insufficiency in 2, and multiorgan failure in 2. With regard to the 4 groups of patients, hospital mortality occurred in 3.8% of the De Vega group (2/52), 5.7% of the ring annuloplasty group (3/53), 5.7% of the De Vega + pericardial patch augmentation group (3/53), and 3.8% of the ring annuloplasty + pericardial patch augmentation group (2/52). Fifty patients survived in each group. The difference in the mortality rates among the 4 groups was not statistically significant ($P > .05$).

There was no difference among the 4 groups in male-to-female ratio, age, ejection fraction, New York Heart Association Class, mitral valve surgery, and aortic valve surgery ($P > .05$) (Table 1), and there was no statistically significant difference in RV systolic pressure, annulus, RV fractional area, right atrial area, and preoperative TR ($P > .05$) (Table 1).

At 1-year follow-up, mitral valve repair failure developed in 3 patients: 1 in the De Vega group, 1 in the De Vega + pericardial patch augmentation group, and 1 in the ring annuloplasty + pericardial patch augmentation group. Only the latter had severe TR at 1-year follow-up. We found no correlation between mitral valve repair failure and TR recurrence.

Severe postoperative TR was different among the groups at follow-up. It should be noted, however, that this difference in TR between the groups with and without the patch was not large (Figure 3): 16.0% and 28.0% patients in the De Vega group, 8.0% and 14.0% in the ring annuloplasty group, 4.0% and 10.0% in the De Vega + pericardial patch augmentation group, and 2.0% and 8.0% in the ring annuloplasty + pericardial patch augmentation group had postoperative TR at 1-month and 1-year follow-up, respectively. There was a significant difference between groups 1 and 4 ($P < .05$). The mean TR was 1.6 ± 0.753 in the De Vega group, 1.38 ± 0.63 in the annuloplasty group, 1.42 ± 0.575 in the De Vega + pericardial patch augmentation group, and 1.18 ± 0.438 in the annuloplasty + pericardial patch augmentation group.

DISCUSSION

TV regurgitation with the concomitant disease of the mitral or aortic valve, or both, has been consistently associated with a high mortality rate and an increased risk of early- and late-phase adverse events.[15,16]

Previous studies have demonstrated that despite continuing advances in the diagnosis and management of valvular heart disease, TV surgery remains challenging.[17-19] Most series have reported the operative mortality for TV replacement to be between 14.3% and 24.5%,[15,20-24] and as a result TV repair has remained the preferred choice for patients with TR. TV repair can become even more complicated if there is an associated abnormality of the valve and subvalvular apparatus. Annuloplasty sometimes does not

TABLE 1. Comparison of the characteristics in the 4 groups before surgery

Variable	De Vega	Annuloplasty	De Vega + pericardial	Ring + pericardial	*P* value
Sex (M/F)	20/32	18/35	21/32	18/34	.932
Age (mean ± SD)	55.0 ± 0.5	55.9 ± 10.3	56.0 ± 10.0	54.7 ± 10.0	.879
LVEF (%) (mean ± SD)	40.4 ± 7.5	44.0 ± 9.5	43.8 ± 9.1	42.5 ± 8.9	.117
RVFA (%) (mean ± SD)	29.8 ± 4.8	28.2 ± 5.1	28.3 ± 5.3	28.7 ± 5.0	.299
RA-A (cm^2) (mean ± SD)	31.2 ± 8.3	32.9 ± 8.2	31.2 ± 8.4	33.8 ± 8.6	.275
RVSP (mm Hg) (mean ± SD)	54.4 ± 8.9	53.9 ± 9.1	53.6 ± 9.0	52.2 ± 8.6	.624
Annulus (cm) (mean ± SD)	36.4 ± 4.5	36.3 ± 4.0	36.9 ± 3.9	37.9 ± 5.6	.292
TET-A (cm^2) (mean ± SD)	15.3 ± 6.1	13.6 ± 5.5	15.0 ± 5.9	15.4 ± 6.7	.418
TET-D (cm) (mean ± SD)	6.3 ± 2.4	5.9 ± 2.1	6.8 ± 2.4	6.7 ± 2.3	.132
Preoperative TR (%) (mean ± SD)	2.88 ± 0.32	2.85 ± 0.36	2.75 ± 0.43	2.85 ± 0.36	.325
NYHA (mean ± SD)	2.9 ± 0.8	2.8 ± 0.8	2.9 ± 0.8	2.7 ± 0.9	.667
MV surgery (%)	85.5	88.7	89.3	88.9	.921
AV surgery (%)	23.6	20.8	23.2	22.2	.985

LVEF, Left ventricular ejection fraction; *RVFA,* right ventricular fractional area change; *RA-A,* right atrial area; *RVSP,* right ventricular systolic pressure; *TET-A,* tethering area; *TET-D,* tethering distance; *TR,* tricuspid regurgitation; *SD,* standard deviation; *NYHA,* New York Heart Association; *MV,* mitral valve; *AV,* aortic valve.

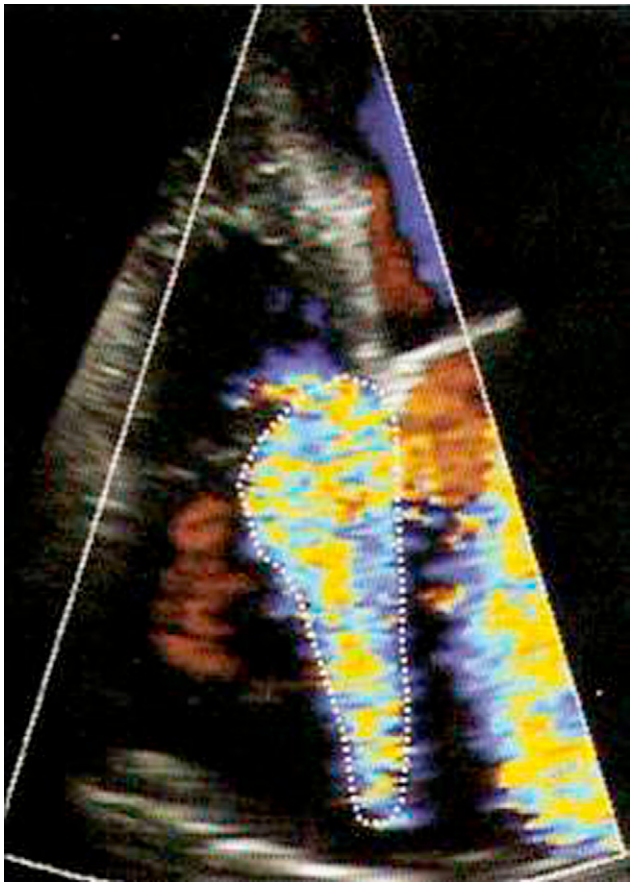

FIGURE 3. Measurement of TR jet area.

completely resolve this problem, and severe residual TR may persist. Therefore, averting severe residual TR is a great challenge that many cardiac surgeons face.

Residual TR of more than grade 2 early after tricuspid annuloplasty is believed to be a significant risk factor for late TV reoperation.[25] In Fukuda and colleagues' study,[10] residual TR was rated as severe in 7.4% and moderate in 15% of 216 patients. The incidences of severe residual TR were 6.7% and 14% in patients with ring and non-ring annuloplasty, respectively.[10]

McCarthy and colleagues[7] reported that the prevalence of 3+ or 4+ residual TR was 14% in 790 patients. Onoda and colleagues[8] measured postoperative TR after Carpentier ring annuloplasty and observed moderate TR in 29% of 31 patients. Rivera and colleagues[9] reported that significant residual TR, assessed through clinical findings or right ventriculography, was observed in 22% of 81 patients. They also found the incidence of significant TR to be lower in patients with the Carpentier ring (10%) than in those with De Vega non-ring (43%) annuloplasty.

In our study, the incidence of severe residual TR was 16.0% in those who underwent De Vega and 8.0% in those who had ring annuloplasty, both without pericardial patch augmentation.

TV annulus dilatation and leaflet tethering are regarded as important mechanisms in the development of functional TR.[4-6] Changes in the RV geometry are thought to cause the displacement of the papillary muscles, resulting in the tethering of the TV leaflet. The ideal TV annuloplasty or De Vega would resolve the incomplete TV coaptation instigated by both TV annular dilatation and leaflet tethering, but sometimes these modalities are not sufficient to correct a highly tethered TV.[10]

Attempts were made in the present study to identify TV tethering, as was described by Fukuda and colleagues,[10] and to resolve it via pericardial patch augmentation. Consequently, augmentation was carried out in conjunction with the procedure in those with a high tethering index (15 of the 53 patients in the De Vega group and 15 of the 52 patients in the annuloplasty group), which yielded far better results by comparison with the patients who underwent De Vega and ring annuloplasty alone. Residual TR decreased to 4.0% persons in the De Vega+pericardial patch augmentation group and to 2.0% persons in the ring annuloplasty+pericardial patch augmentation group.

Leaflet augmentation can resolve residual TR after repair; nevertheless, it is time-consuming and not suitable for all patients, because more often than not there is another valvular involvement or the procedure is a redo. Furthermore, an increased pump-time can prove pernicious to these already high-risk patients. It is, therefore, advisable that we determine before surgery whether the patient has a high probability of repair failure so that we can perform augmentation in conjunction with the routine modality.

In light of Fukuda and colleagues' study,[10] we selected these patients on the basis of their tethering distance and tethering area and succeeded in achieving excellent results with little significant residual TR. This study demonstrates that relieving TV tethering in patients with severely tethered valve may significantly reduce the probability of TV repair failure.

Limitations

This study was based on the evaluation of residual TR in tricuspid valve augmentation in patients with highly tethered TV; consequently, the patients should have been followed up and evaluated for the recurrence of TR. Longer observation periods are required to validate the effectiveness of this method of patient selection and durability of this technique.

CONCLUSIONS

To reduce the rate of tricuspid valve repair failure, both leaflet tethering and annular dilatation should be considered. Moreover, a thorough assessment of preoperative TV tethering is essential to define the surgical indication of augmentation in patients with functional TR.

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