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A comparison of three tricuspid annuloplasty techniques: Suture, ring, and band

Üç triküspid anüloplasti tekniğinin karşılaştırılması: Sütür, halka ve bant

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ABSTRACT

Background: This study aims to compare three different tricuspid annuloplasty techniques using suture, ring, and band.

Methods: Between January 2010 and December 2015, a total of 231 consecutive patients (78 males, 153 females; mean age 50.3±15.9 years; range, 34 to 66 years) who underwent tricuspid valve annuloplasty using three different techniques were retrospectively analyzed. Tricuspid valve repair was performed with de Vega annuloplasty technique (n=62, 26.8%), flexible ring (n=76, 32.9%) or Teflon strip (n=93, 40.3%). Postoperative data including vital signs, echocardiographic reports, functional status, and the rate of re-do surgeries were recorded.

Results: Cardiopulmonary bypass times were statistically significantly shorter in the de Vega annuloplasty group (p<0.001). There was no significant difference among the groups in terms of the in-hospital mortality. Late postoperative tricuspid regurgitation grades, systolic pulmonary artery pressure, and right atrial diameters showed significant improvements, compared to baseline, in ring and strip annuloplasty groups.

Conclusion: Our study results demonstrate that suture-based approaches should be avoided. Instead of performing routine tricuspid ring annuloplasty, Teflon strip annuloplasty may be considered an alternative method in most cases, particularly due to controversy in selection of true ring size and high cost of this surgical material in the real-life setting.

Keywords: Annuloplasty, band, ring, suture, tricuspid valve.

ÖZ

Amaç: Bu çalışmada sütür, halka ve bant ile üç farklı triküspid anüloplasti tekniği karşılaştırıldı.

Çalışma planı: Ocak 2010 - Aralık 2015 tarihleri arasında, üç farklı teknik ile triküspid kapak anüloplastisi yapılan toplam 231 ardışık hasta (78 erkek, 153 kadın; ort. yaş 50.3±15.9 yıl, dağılım, 34 to 66 yıl) retrospektif olarak incelendi. Triküspid kapak tamiri de Vega anüloplasti tekniği (n=62, %26.8), esnek halka (n=76, %32.9) veya Teflon strip (n=93, %40.3) ile yapıldı. Vital bulgular, ekokardiyografi raporları, fonksiyonel statü ve yeniden cerrahi oranı dahil olmak üzere ameliyat sonrası veriler kaydedildi.

Bulgular: Kardiyopulmoner baypas süreleri, de Vega anüloplasti grubunda istatistiksel olarak anlamlı düzeyde daha kısa idi (p<0.001). Gruplar arasında hastane içi mortalite açısından anlamlı bir fark yoktu. Halka ve strip anüloplasti gruplarında geç ameliyat sonrası triküspid yetmezliği dereceleri, sistolik pulmoner arter basıncı ve sağ atriyum çapları başlangıca kıyasla anlamlı düzeyde düzelme gösterdi.

Sonuç: Çalışma sonuçlarımız, sütür bazlı yaklaşımların terk edilmesi gerektiğini göstermektedir. Bilhassa uygun halka boyutunun seçimine ilişkin tartışmalar ve gerçek yaşamda bu cerrahi materyalin yüksek maliyeti nedeniyle, triküspid halka anüloplastinin rutin uygulanması yerine, birçok olguda Teflon strip anüloplasti alternatif bir yöntem olarak düşünülebilir.

Anahtar sözcükler: Anüloplasti, bant, halka, sütür, triküspid kapak.

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The tricuspid valve (TV) regurgitation usually occurs secondary to left heart valve diseases in consequence of right ventricular volume and pressure overload and dilation of cardiac chambers and, thus, TV annular dilation and right ventricular enlargement.[1] Tricuspid regurgitation (TR) rarely occurs from other TV pathologies such as rheumatic, congenital, endocarditis and myxomatous degeneration.[2] Most patients with TR suffer from fatigue and reduced exercise capacity due to decreased cardiac output. They also experience the classical symptoms of right-sided heart failure as a result of elevated right atrial pressures, such as ascites, hepatomegaly, peripheral edema, decreased appetite, and abdominal fullness. Tricuspid regurgitation may even lead to biventricular heart failure and death.

According to the American College of Cardiology (ACC)/American Heart Association (AHA) 2014 Practice Guideline for the management of patients with valvular heart disease, valve repair surgery, particularly at the time of left-sided valve surgery, is the recommended treatment for TR.[3] The main TV repair technique is annuloplasty in the presence of a dilated annulus with normal leaflets and chordal structures to reduce the annular size and enhance leaflet coaptation surface. To date, different annuloplasty techniques have been defined such as de Vega/Kay annuloplasty, ring annuloplasty with a rigid or flexible band and Teflon strip band annuloplasty.[4-6] Some surgeons perform TV annuloplasty with de Vega/Kay technique, owing to its easy-to-use nature, while others prefer using annuloplasty ring, as it is safe, effective, and reliable surgical procedure.[7,8]The optimal annuloplasty technique for TR is still debated, since there are advantages or disadvantages for each one.

In this study, we aimed to present our early and mid-term results of three different tricuspid annuloplasty techniques including de Vega, ring, and Teflon strip band annuloplasty.

PATIENTS AND METHODS

This retrospective study included a total of 231 consecutive patients (78 males, 153 females; mean age 50.3±15.9 years; range, 34 to 66 years) who underwent TV annuloplasty using three different techniques between January 2010 and December 2015. Tricuspid valve repair was performed using de Vega annuloplasty technique (n=62, 26.8%), flexible ring (n=76, 32.9%) or Teflon strip (n=93, 40.3%). All patients underwent tricuspid annuloplasty in addition to other cardiac procedures. The decision of tricuspid intervention was based on the European Society of Cardiology (ESC) guidelines which suggests performing TV annuloplasty in severe TR undergoing left-sided valve surgery and in moderate TR with dilated annulus (maximum systolic tricuspid annulus [TA] >40 mm, four-chamber view). Tricuspid regurgitation was secondary to mitral valve (MV) disease (n=179, 77.5%), aortic valve disease (n=30, 13%), or atrial septal defect (n=22, 9.5%). Those with congenital tricuspid anomalies, rheumatic or organic disease of the leaflets, active endocarditis, and previous cardiac surgery were excluded from the study. A written informed consent was obtained from each patient. The study protocol was approved by the institutional Ethics Committee of Türkiye Yüksek İhtisas Training and Research Hospital. The study was conducted in accordance with the principles of the Declaration of Helsinki.

Baseline demographic and clinical characteristics of the patients and postoperative data including vital signs, echocardiographic reports, functional status, and rate of re-do surgery were obtained from either hospital records or telephone interview. Postoperative echocardiography was mostly performed before discharge and at one year after the operation.

Surgical technique

All operations were performed by the three senior surgeons in our institute. All patients in the study underwent TV surgery under general anesthesia via a standard median sternotomy using cardiopulmonary bypass (CPB), mild systemic hypothermia (33°C), and warm blood cardioplegia. We often performed tricuspid annuloplasty at the end of the operation subsequent to the main procedure (mitral reconstruction/replacement, or aortic valve reconstruction/replacement). Tricuspid annuloplasty was performed during cardioplegic arrest. The TV was exposed through an oblique right atriotomy. Both leaflets and all chordal structures were examined in all patients by the surgeon. Surgeon's discretion and device availability determined the preference of annuloplasty technique upon intraoperative evaluation of the valve.

De Vega annuloplasty was performed in a standard fashion and sutures were not tied following passing them through the annulus. Adjusting the annular reduction size was accomplished by titrating the tightness of the sutures under saline test until achieving satisfactory competence. Once the regurgitation was eliminated, sutures were secured in place.

The sizing for ring annuloplasty was performed by both measuring intercommissural distance of the septal leaflet and the surface area of anterior leaflet using the official sizers obtained from the

Table 1. Baseline demographic and clinical characteristics of patients

	De Vega (n=62)					Ring (n=76)					Band (n=93)					
	n	%	Mean±SD	Median	Min-Max	n	%	Mean±SD	Median	Min-Max	n	%	Mean±SD	Median	Min-Max	*p*
Age (year)			50.1±11.8					47.8±16.5					52.2±17.7			0.08
Gender																
Male	16	25.8				33	43.4				29	31.2				0.07
Body surface area (m^2)			1.8±0.2					1.75±0.2					1.7±0.2			0.21
NYHA functional class			2.5±0.5					2.5±0.5					2.6±0.7			0.78
Main pathology																0.74
Mitral regurgitation/stenosis	50	80.6				59	77.6				70	75.3				
Aortic regurgitation/stenosis	7	11.3				8	10.5				15	16.1				
Atrial septal defect	5	8.1				9	11.8				8	8.6				
Atrial fibrillation (%)	37	59.7				33	43.4				51	54.8				0.14
LV diastolic diameter (mm)			50.7±6.7					51.2±7.8					51±7.4			0.69
LV systolic diameter (mm)				39.9	26-48				40.9	28-62				39.8	28-47	0.83
LV ejection fraction (%)				53.6	40-65				55.9	32-65				53.4	30-65	0.11
Left atrial diameter (mm)				50.3	35-76				47.5	29-73				49.8	30-78	0.1
Right atrial diameter (mm)				50.9	40-68				51.6	42-62				51.6	40-68	0.56
Systolic PA pressure (mmHg)				50.9	35-65				51.7	25-90				49.6	25-87	0.58
Tricuspid regurgitation grade																0.84
I	2	3.2				4	5.3				2	2.2				
II	21	33.9				27	35.5				39	41.9				
III	37	59.7				43	56.6				48	51.6				
IV	2	3.2				2	2.6				4	4.3				

SD: Standard deviation; Min: Minimum; Max: Maximum; NYHA: New York Heart Association; LV: Left ventricular; PA: Pulmonary artery.

supplier. The exact decision for the size was given considering the level of annular dilatation in the preoperative period and intraoperative examination of the valve.

Determination of the band annuloplasty size was quite similar with the ring annuloplasty. Following the measurements of the intercommissural distance of the septal leaflet and the surface area of anterior leaflet, the circumference of the sizer was used to measure the length of Teflon band. The width of the Teflon strip was usually prepared 5 to 7 mm to enable satisfactory suture support and annular stabilization. Once the Teflon band size was determined as explained above, single polyester sutures were placed similar to the ring annuloplasty. The number of sutures was variable, but mostly was seven.

At the end of the procedure, TV leaflets were evaluated in all patients by saline infusion test to confirm whether sufficient coaptation was obtained after annuloplasty.

Echocardiographic assessment

Echocardiographic examinations were performed with 2-4 MHz phased array transducer attached to a Vivid S5 echocardiography system (GE, Horten, Norway) by a single cardiologist who was blinded to clinical data of each patient. A M-mode standard two-dimension left parasternal long axial echocardiographic examination was performed in accordance with the criteria of the American Society of Echocardiography. The left ventricular ejection fraction (LVEF), was measured using the method based on the Simpson's rule. Examinations were performed in all study patients before surgery, before discharge from the hospital, and at the late postoperative period during outpatient visits.

Statistical analysis

Statistical analysis was performed using the SPSS version 15.0 software (SPSS Inc., Chicago, IL, USA). Continuous variables were expressed in mean ± standard deviation (SD), while categorical variables were expressed in number and frequency. The Kolmogorov-Smirnov test was used to test the distribution patterns. For categorical variables, comparisons between the groups were made using the chi-square test or Fisher's exact test, where appropriate. The independent-samples Student's t-test was used for normally distributed continuous variables. Statistical significance was determined using the Kruskal-Wallis test and the Wilcoxon-Mann-Whitney U test, where appropriate. A p value of <0.05 was considered statistically significant.

RESULTS

The mean follow-up was 32.5 (range, 6 to 49) months. Table 1 shows baseline demographic and clinical characteristics and echocardiographic findings of all patients. There was no significant difference in the age, gender, body surface area, baseline New York Heart Association (NYHA) functional class, or echocardiographic findings including left ventricular end-diastolic diameter (LVEDD) and left ventricular end-systolic diameter (LVESD), LVEF, left and right atrial diameters, systolic pulmonary artery pressures (SPAP), and TR grades among the three groups.

Table 2 shows operative data of all patients. Cross-clamp and CPB times were significantly shorter in the de Vega annuloplasty group ($p<0.001$). There was no significant difference among the groups in terms of concomitant procedures and postoperative complications. However, postoperative need for positive inotropic support, duration of mechanical ventilation, and length of intensive care unit and hospital stay were significantly higher in the de Vega annuloplasty group.

There were no intraoperative mortality. The in-hospital mortality rate was 2.6% (n=6/231). The reason for in-hospital mortality was reported as low cardiac output in three patients, respiratory failure in one patient, and sepsis in two patients. There was no significant difference among the groups in terms of the in-hospital mortality; however, the de Vega annuloplasty group had significantly highest late-mortality rates ($p=0.01$, Table 2).

Early postoperative results showed that the grade of TR improved in all patients. Echocardiographic assessment before discharge revealed that there was no significant difference among the groups in terms of TR grades and residual TR ($p>0.05$). None of the patients underwent early or late reoperation due to recurrent TR.

Table 3 shows a comparison of preoperative and late postoperative echocardiographic findings of three groups. Late postoperative LVEF, LVEDD, LVESD, and left atrial diameters significantly improved, compared to baseline values in all groups of patients. Additionally, in the de Vega annuloplasty group, there was no significant difference between the baseline and postoperative follow-up values of TR grades, SPAP, and right atrial diameters. However, postoperative late echocardiographic parameters of ring annuloplasty

Table 2. Operative data

	De Vega (n=62)				Ring (n=76)				Band (n=93)				
	n	%	Median	Min-Max	n	%	Median	Min-Max	n	%	Median	Min-Max	*p*
Cross-clamp time (min)			83.2	59-151			93.5	53-167			95.5	47-163	0.002*
Cardiopulmonary bypass time (min)			109.1	90-213			127	76-206			128.4	78-202	<0.001**
Concomitant procedure													
Mitral valve repair	29	46.8			48	63.2			52	55.9			0.15
Mitral valve replacement	32	51.6			19	25			26	28			0.002*
Aortic valve repair	2	3.2			10	13.2			5	5.4			0.05
Aortic valve replacement	13	21			7	9.2			16	17.2			0.14
Coronary artery bypass grafting	4	6.5			15	19.7			16	17.2			0.07
Atrial septal defect closure	8	12.9			16	21.1			24	25.8			0.15
Maze procedure	13	22			8	10.5			21	22.6			0.09
Duration of mechanical ventilation (hour)			22.5	4-120			11.9	5-25			14.1	4-100	<0.001**
Intensive care unit stay (days)			2.5	1-10			1.49	1-5			2.1	1-25	<0.001**
Hospital stay (days)			8.4	5-23			7.1	5-30			7.8	4-32	0.001*
Postoperative need for positive inotropic agents	34	54.8			25	32.9			33	35.5			0.02*
Postoperative complications													
Pleural effusion	9	14.5			4	5.3			7	7.5			0.14
Arrhythmia	8	12.9			6	7.9			6	6.5			0.36
Bleeding or tamponade	5	8.1			4	5.3			2	2.2			0.22
Infection	5	8.1			5	6.6			4	4.3			0.61
In-hospital death	2	3.2			2	2.6			2	2.2			-
Late death	4	6.5			1	1.3			-	-			0.01*

Min: Minimum; Max: Maximum; * p<0.05; ** p<0.001. Significant values were obtained by Kruskal-Wallis test for continuous variables, and chi-square or Fisher's exact tests for categorical variables.

Table 3. Preoperative and late postoperative echocardiographic findings

	De Vega (n=62)									Ring (n=76)									Band (n=93)								
	Baseline				Follow-up					Baseline				Follow-up					Baseline				Follow-up				
	n	%	Mean±SD	Median (Min-Max)	n	%	Mean±SD	Median (Min-Max)	*p*	n	%	Mean±SD	Median (Min-Max)	n	%	Mean±SD	Median (Min-Max)	*p*	n	%	Mean±SD	Median (Min-Max)	n	%	Mean±SD	Median (Min-Max)	*p*
Tricuspid regurgitation grade									0.32									0.006*									0.014*
0, trivial	-	-			-	-				-	-			7	9.2				-	-			19	20.4			
I	2	3.2			6	9.7				4	5.3			59	77.6				2	2.2			64	68.8			
II	21	33.9			30	48.4				27	35.5			10	13.2				39	41.9			10	10.8			
III	37	59.7			25	40.3				43	56.6			-	-				48	51.6			-	-			
IV	2	3.2			1	1.6				2	2.6			-	-				4	4.3			-	-			
Systolic PA pressure (mmHg)				50.9 (35-65)				46.9 (28-68)	0.06				51.7 (25-90)				35.2 (25-50)	<0.001**				49.6 (25-87)				31.7 (21-46)	<0.001**
LV ejection fraction (%)				53.6 (40-65)				56.8 (40-65)	0.02*				55.9 (32-65)				59 (35-65)	0.02*				53.4 (30-65)				57.1 (35-65)	0.03*
LV diastolic diameter (mm)			50.7±6.7				45.6±5.6		<0.001**			51.2±7.8				47.7±7.5		<0.001**			51±7.4				40.4±6.1		<0.001**
LV systolic diameter (mm)				39.9 (26-48)				36.8 (26-46)	<0.001**				40.9 (28-62)				37.8 (26-51)	<0.001**				39.8 (28-47)				32.6 (25-46)	<0.001**
Left atrial diameter (mm)				50.3 (35-76)				46.1 (37-60)	<0.001**				47.5 (29-73)				41.9 (29-60)	<0.001**				49.8 (30-78)				43.8 (28-62)	<0.001**
Right atrial diameter (mm)				50.9 (40-68)				48.8 (34-61)	0.06				51.6 (42-62)				40.1 (31-52)	<0.001**				51.6 (40-68)				40.9 (30-50)	<0.001**

SD: Standard deviation; Min: Minimum; Max: Maximum; LV: Left ventricular; PA: Pulmonary artery; * $p<0.05$; ** $p<0.001$. Significant values were obtained by chi-square or Fisher's exact tests for categorical variables and paired sample t-test or Wilcoxon t-test for continuous variables.

and band annuloplasty groups showed a significant improvement in TR grades, SPAP, and right atrial diameters, compared to baseline values.

There were no cases of significant tricuspid stenosis according to postoperative echocardiography reports.

DISCUSSION

The present study demonstrated that TV annuloplasty using ring or Teflon band yielded a significant improvement in TR grades, SPAP, and right atrial diameters, compared to baseline values, while the de Vega technique failed to demonstrate such a benefit.

Historically, functional TR has been treated conservatively.[9,10] However, it has been reported that moderate-to-severe late functional TR ensues after isolated MV surgery.[11,12] Although performing concomitant TV annuloplasty for mild-to-moderate functional TR remains a controversial issue, concomitant TV annuloplasty is recommended for severe TR at the time of MV surgery to prevent progressive heart failure and poor survival.[13-16] The 2014 ACC/AHA valvular heart disease practice guidelines give a Class I indication for TV repair in any patient with severe TR undergoing MV surgery.[3] In case of moderate functional TR and a dilated TA (>40 mm) in a patient undergoing left-sided surgery with a Class IIa recommendation for TV repair, annuloplasty has been also suggested according to the 2014 ACC valvular heart disease guidelines and also the 2012 ESC management of valvular heart disease guidelines.[3,17]

In general, TV repair is favored over replacement for prohibiting the potential thrombotic complications associated with either mechanical or bioprosthetic valves. In addition, TV repair appears to provide improved mid-term survival (up to 10 years after surgery) compared to TV replacement.[18] In secondary TR, the leaflets of TV are normal and the common finding is a coaptation defect due to annular dilatation. Accordingly, the surgical reconstruction has been mostly addressed to the commissural or annular level. To date, different methods for repairing TV have been recommended according to the anatomic level of surgery.[19] However, there is no consensus on performing TV repair either by a suture-based or a prosthetic ring annuloplasty technique.[20]

There are various less commonly used surgical methods which have been described for the management of functional TR. Posterior annular bicuspidization initially described by Kay et al.[8] is

performed by placing a pledget-supported mattress suture placed from the posteroseptal commissure to the anteroposterior commissure along the posterior annulus for posterior annular bicuspidization. Focal posterior tricuspid annuloplasty was shown as an effective method in selected cases by Deloche et al.[21] Castedo et al.[22] also described edge-to-edge (Alfieri-type) repair. De Vega style including partial purse-string suture techniques to reduce the anterior and posterior portions of the annulus is accepted as another approach.[8] Some series demonstrated that both de Vega and Kay annuloplasties yielded good short-term and long-term results.[5,23] However, some other authors attempted to investigate these results whether high incidence of recurrent postoperative TR was defined at follow-up, particularly in patients with pulmonary hypertension and severe tricuspid annular dilatation.[24,25] A prosthetic ring annuloplasty has been suggested as a solution for recurrent TR of suture-based techniques. In the preliminary clinical trials, annuloplasty accompanied by prosthetic ring demonstrated an improved mid-term performance compared to annuloplasty in which suture-based techniques were only used with a significant higher freedom from moderate and severe TR.[25] Some other studies also confirmed these results and these results seem to recommend an annuloplasty ring in patients undergoing TR repair to prevent recurrence and adverse long-term sequelae, particularly in those with pulmonary hypertension and more severe TR.[2,20,26] Those suture-based annuloplasty techniques have advantages of being simple, cheap and quick; however, effectiveness is still a point of debate compared to ring annuloplasty techniques. Our study demonstrated more effective relief from TR with both ring and Teflon band annuloplasty technique in terms of TR grades, SPAP, and right atrial diameters in a similar patient group.

Although rigid ring TV annuloplasty is accepted as the most optimal treatment modality for functional TR by most of authors, a controversy exists regarding the size selection for the TV annuloplasty. Some have recommended using oversized rings in TV annuloplasty for precaution of subsequent tricuspid stenosis.[2,25] A mathematical approach associated with a ratio between the anterior, posterior, and septal segments as a parameter in tricuspid ring sizing has been also suggested by others. The ring size selection is also a controversial topic. Besides the true ring size selection, high cost of this surgical material can be accepted as a restrictive factor in usage for routine clinical practice. Therefore, in our clinic, we often use Teflon strip band annuloplasty technique first described by Rastan[6] In this method, even there is no use of flexible band or rigid annuloplasty ring, more durable and stable reconstruction is achieved compared to suture-only-based techniques such as de Vega and Kay annuloplasties. Using this method, the anteroposterior portion of the TA is sutured to a semi-circular nonelastic strip of the Teflon by double needle sutures. Since the radius of this strip is shorter than the radius of the valve ring, the TA would be narrowed after the sutures are tied. Owing to its simplicity, firmness and maintenance of the valvular ring elasticity, this method seems to be advantageous to all similar procedures. In the literature, however, there are no data regarding the mid- and long-term results of this TV repair technique. In the immediate postoperative period, echocardiographic TR improved significantly in all groups. However, our study results showed, for the first time, that Teflon strip annuloplasty was more effective than the de Vega method for controlling functional TR in the mid-term postoperative period. On the other hand, we found that there was no statistically significant difference for controlling TR in the mid-term postoperative period between the ring annuloplasty and Teflon strip annuloplasty. Tricuspid valve annuloplasty with a Teflon band has an additional advantage of cost, compared to ring annuloplasty. There is no need for additional equipment for sizing due to the determination of band length can be easily achieved using standard annuloplasty sizers as described previously.

On the other hand, the retrospective design of the study paves the way for some limitations including patient selection biases which is a common problem in surgical sciences. The relatively short follow-up period is also another limitation. Although recurrences and technical failures are commonly experienced in the early periods of recovery, longer duration of follow-up is recommended for a more conclusive result.

In conclusion, at the time of left-sided heart surgery concomitant surgical repair of moderate-to-severe tricuspid regurgitation should be considered standard of treatment modality, since this approach has been shown to improve functional class, perioperative outcomes, and survival rates. Our study results demonstrate that suture-based approaches should be avoided. Instead of performing routine tricuspid ring annuloplasty, Teflon strip annuloplasty may be considered to be an alternative method in most cases, particularly due to controversy in selection of true ring size and high cost of this surgical material in the real-life setting.

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