

Adjustable Segmental Tricuspid Annuloplasty: Technical Advantages and Midterm Results

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Background. Adjustable segmental tricuspid annuloplasty is a new recently published procedure. The purpose of this prospective study was to present the technical advantages of this new tricuspid annuloplasty and analyze its early and midterm results.

Methods. Between January 2004 and December 2006, 17 patients who had moderate or severe pure functional tricuspid regurgitation (TR) underwent adjustable segmental tricuspid annuloplasty. The mean age of the patients was 64.3 ± 10.4 years and the majority were female (94%). All patients had recent preoperative transthoracic echocardiography (TTE). Three postoperative TTE were performed: (I) before the hospital discharge; (II) between 3 and 6 months after surgery; and (III) at a mean 30.4 ± 13.8 months of follow-up. We studied the tricuspid valve, right ventricle, and left ventricle.

Results. No hospital mortality was reported. Progressive overall clinical improvement was observed. Serial

postoperative TTE revealed the following: (1) 13 patients with mild or less than mild TR, 1 patient with residual moderate TR, 1 patient with early moderate TR related to poor left ventricular function, and 1 patient with late severe TR due to a transvenous pacemaker lead; (2) the indexed tricuspid annulus diameter normalized in all patients; (3) pulmonary hypertension gradually regressed; and (4) right ventricular end-diastolic diameter and inferior vena cava diameter gradually decreased throughout the study.

Conclusions. Adjustable segmental tricuspid annuloplasty is an improved and efficient procedure for functional TR because it is more selective, more adjustable and more resistant. It may be adversely influenced by poor left ventricular function and by the presence of a pacemaker lead.

(Ann Thorac Surg 2009;87:1148–53)

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The clinical importance of tricuspid regurgitation (TR) has been underestimated. Misconceptions regarding TR have perpetuated the belief that TR is a functional rather than an organic disorder, and is produced by pulmonary hypertension (PHT) and by dilatation of the right ventricle (RV) and tricuspid annulus as a consequence of mitral valve diseases. Various techniques have been described to repair functional TR including bicuspidization annuloplasty [1], the original De Vega tricuspid annuloplasty [2], the “over and over” suture technique [3], and the modified De Vega annuloplasty [4]. Occasionally, the sutures may pull out the friable tissue of the tricuspid annulus and cause guitar-string syndrome. To obviate this complication, several modifications of the original De Vega annuloplasty have been advised including the following: the use of a strip of Teflon to reduce the anteroposterior tricuspid annulus [5]; the interposition of 10 to 12 Teflon pledgets in each suture stitch [6]; the use of 5 to 6 Teflon pledgets in every stitch step in the segmental tricuspid annuloplasty [7]; and the use of a 2-0 polypropylene suture to encircle the anteroposterior segment of the annulus in a spiral fash-

ion in the modified semicircular constricting tricuspid annuloplasty [8]. According to the authors, all these techniques can achieve a durable and stable repair of TR, with a considerable decrease in early and late mortality.

Adjustable segmental tricuspid annuloplasty is a new semicircular suture annuloplasty, recently published [9]. It is based on the pathophysiology and pathogenesis of functional TR, and it only repairs the dilatation of the tricuspid annulus. In this article we present the technical advantages of this new annuloplasty and analyze its early and midterm results.

Patients and Methods

We designed a prospective clinical study on a small group of patients to analyze the immediate, early, and midterm results of this new tricuspid annuloplasty. The study was approved by our Institute’s Ethics Committee and this procedure was explained to every patient and their consent was obtained. Between January 2004 and December 2006 different surgeons performed tricuspid ring annuloplasty on 47 patients (71.2%), De Vega annuloplasty on 2 patients (3%), and one surgeon performed adjustable segmental tricuspid annuloplasty on 17 patients (25.8%). The mean age of patients was 64.3 ± 10.4 years (range, 44 to 78 years) and the majority were female

Accepted for publication Jan 14, 2009.

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(n = 16, 94.1%). All patients had atrial fibrillation. Five patients (29.4%) had previous cardiac surgery; 2 patients (11.7%) had closed mitral commissurotomy, 2 patients (11.7%) had open mitral commissurotomy, and 1 patient (5.9%) had mitral valve replacement. Two patients (11.7%) had an emergency operation; the first, because of endocarditis and thrombosis of the mitral prosthesis with low left ventricular ejection fraction (LVEF < 0.30) and the second, because of severe ischemic mitral valve regurgitation in the presence of cardiogenic shock. The mean New York Heart Association (NYHA) functional class was 3.0 ± 0.4 and the mean logistic European System for Cardiac Operative Risk Evaluation (EuroSCORE) was $15.9 \pm 17.4\%$. The mean degree of functional TR was 3.5 ± 0.5 (53% of patients had severe TR and 47% of patients had moderate TR). A percentage of 41.2% of patients had severe PHT (> 60 mm Hg), 53% had moderate PHT (45 to 60 mm Hg), 23.5% had severe dilatation of the tricuspid annulus (indexed tricuspid annulus diameter; ITAD > 21 mm/m²), and 70.6% had moderate dilatation of the tricuspid annulus (ITAD 15 to 20 mm/m²). The concomitant procedures included mitral valve replacement in 12 patients (70.6%), mitral valve repair in 1 patient (5.9%), mitral and aortic valve replacement in 1 patient (5.9%), mitral valve replacement and coronary artery bypass grafting in 1 patient (5.9%), and closure of an atrial septal defect with autologous pericardial patch in 2 patients (11.7%). The mean cardiopulmonary bypass time was 91.6 ± 22.5 minutes and the mean aortic cross-clamp time was 54.0 ± 18.8 minutes.

Two-dimensional and Doppler transthoracic echocardiography (TTE) was performed in a standard manner by an expert cardiologist and reviewed by another one using a commercially available echocardiography device (GE Medical System Vivid 7 and Philips Medical System ATL 5000 [Bothell, WA]). All patients had recent preoperative TTE (no more than 2 months prior to surgery). Three postoperative TTEs were performed: (I) before the hospital discharge; (II) between 3 and 6 months after surgery; and (III) at a mean 30.4 ± 13.8 months of follow-up (range 3.7 to 47.8 months). Criteria for exclusion included (1) congenital tricuspid valve (TV) disease; (2) organic TV disease; (3) endocarditis of the TV; (4) severe enlargement of RV or poor right ventricular function; (5) patients with an implanted transvenous pacemaker; and (6) patients who had received TV repair or replacement. The following echocardiographic parameters were obtained: (1) in the tricuspid valve, the degree of functional TR (none: degree 0, trivial: degree 1, mild: degree 2, moderate: degree 3, and severe: degree 4) by measurements of the regurgitant jet area to right atrium area ratio, the vena contracta, the effective regurgitant orifice area, the systolic flow reversal in the hepatic veins, the pulmonary artery systolic pressure (PASP), and the indexed tricuspid annulus diameter; (2) in the right ventricle, the right ventricular end-diastolic diameter, the inferior vena cava diameter, and the right ventricular function; and (3) in the left ventricle, the left ventricular end-diastolic diameter, and the LVEF.

Surgical Technique

The details of this new annuloplasty have been described elsewhere [9]. All patients were operated through median sternotomy under cardiopulmonary bypass at normothermia. Double venous cannulation was used. Myocardial protection consisted of antegrade and retrograde cold blood cardioplegia. After the concomitant procedure was performed and the aortic cross-clamp was taken off, the right atrium was opened obliquely and the TV was carefully explored in a beating heart. The tricuspid annulus was identified, and the distance between the anteroseptal and posteroseptal commissures was measured using a 32 or 34 Carpentier tricuspid valve annuloplasty sizer. Two 2-0 Ethibond sutures (Ethicon, Somerville, NJ) with a Teflon pledget were used for double suture lines. The first suture was placed in the region of the posteroseptal commissure and threaded along the tricuspid annulus where the posterior leaflet is attached. The second suture was placed in the region of the anteroseptal commissure and threaded along the tricuspid annulus where the anterior leaflet is attached. The two separate sutures met in the middle, close to the anteroposterior commissure, and were held together using a wider Teflon pledget pointing toward the 12 o'clock position. The sutures were then passed through a short rubber tourniquet to equalize and adjust the pursing force at both ends of the same suture. The tourniquets were lowered to touch the tricuspid annulus and both sutures were marked with a small vascular clip just above the tourni-

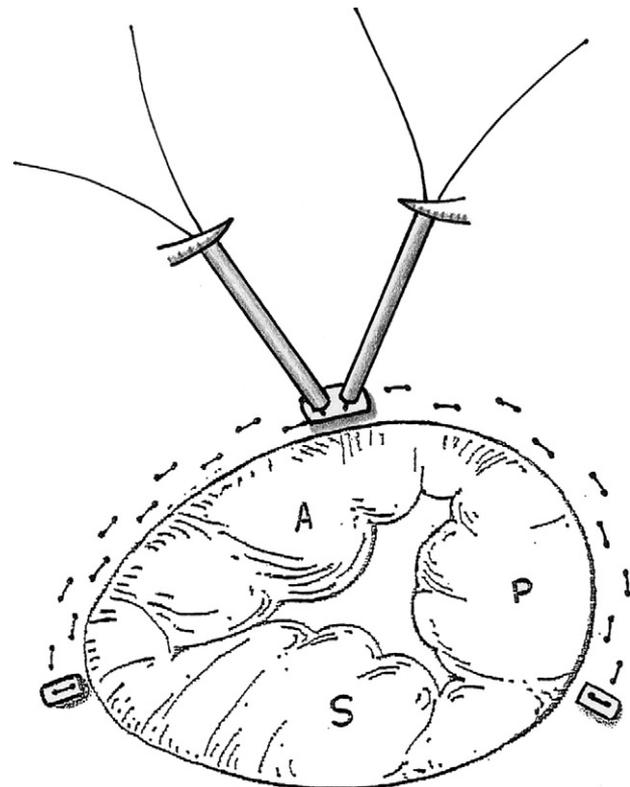


Fig 1. Schematic presentation of the selective, adjustable, and commissural tricuspid annuloplasty.

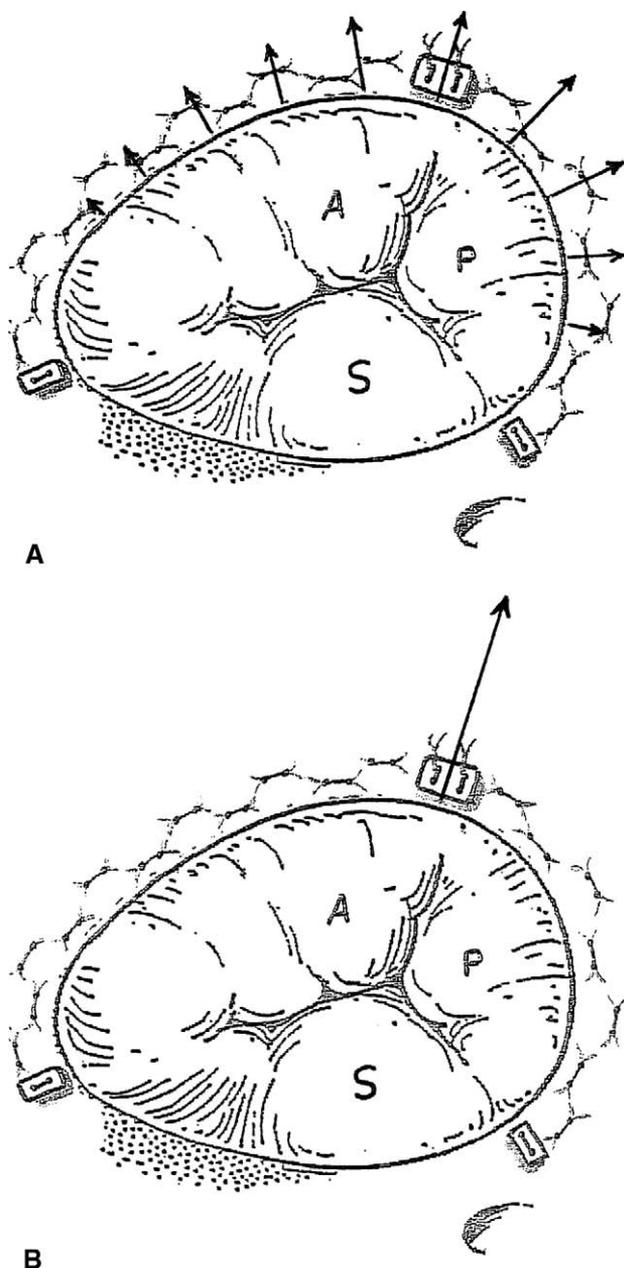


Fig 2. (A) Forces of distension. (B) The sum of forces of distension passing over the wide Teflon.

quet (Fig 1). The pulmonary artery was cross-clamped and a warm saline solution was injected into the RV through the tricuspid valve. While the first suture was cinched until coaptation of the anterior tricuspid leaflet with the other leaflets was achieved, the middle pledget turned clockwise and pointed up toward the 1 o'clock position and down along the anteroposterior commissure. The second suture was cinched nearly one-third of that applied to the first suture (ie, the correlation between the anterior and posterior annular dilatation) [10]. The corresponding Carpentier tricuspid valve annuloplasty sizer was reintroduced inside the tricuspid annulus to prevent tricuspid stenosis caused by overcorrec-

tion. The pulmonary artery was declamped, the vascular clips were removed, and the sutures were tied in sequence. The competence of the tricuspid valve was retested, as described previously.

Technical Advantages

Adjustable segmental tricuspid annuloplasty is an improved suture annuloplasty that only repairs the dilatation of the tricuspid annulus in pure functional TR. Like all other tricuspid suture annuloplasties, it is a simple, low-cost, fast, and safe procedure, which does not cause hemolytic anemia, endocarditis, or thromboembolism [11], and does not interfere with the physiologic motion of the tricuspid annulus. In addition, adjustable segmental tricuspid annuloplasty has certain advantages: (1) it is more resistant, as the sum of the forces of distension is passed over a wide Teflon patch (Fig 2A; 2B); (2) it is segmental, because it divides the forces of distension over two double sutures (Fig 3) in order to avoid the guitar-string syndrome; (3) it is more selective, because it acts specifically on the anteroposterior segment, the most dilated portion of the tricuspid annulus; (4) it is more adjustable, as the pursing forces can be adapted to the most dilated segment of the annulus; (5) it is commissural, as the pursing forces act in the middle of the anteroposterior segment, near the anteroposterior commissure allowing the complete closure of this commissure; and finally (6) this new tricuspid annuloplasty purses the double sutures in the same direction to avoid tearing of the endocardial surface, and uses a tourniquet on each double suture to achieve a gradual and equal pursing at each end of the suture (Fig 1).

Statistical Study

All values were expressed as mean \pm SD or as percentages. To study the efficiency of the adjustable segmental tricuspid annuloplasty, we measured the ITAD and the relationship between the degree of preoperative and postoperative functional TR at three intervals. The repair was considered successful when the ITAD had normalized and remained stable and no trivial or mild residual

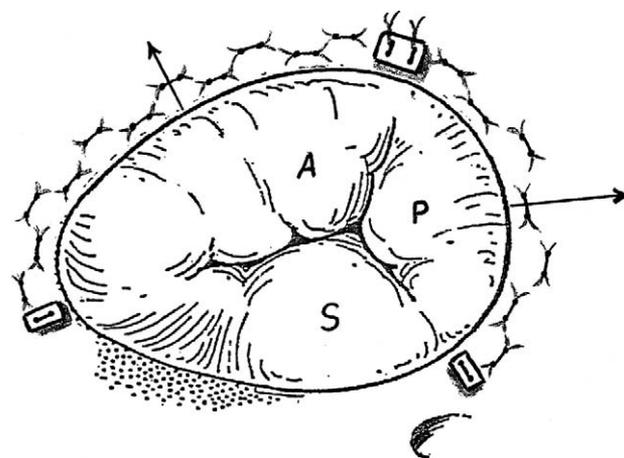


Fig 3. Segmental: The forces of distension are distributed over two separate sutures.

Table 1. Echocardiographic Results of the Adjustable Segmental Tricuspid Annuloplasty in Functional Tricuspid Regurgitation Repair

	Preoperative TTE (recent study) n (%)	Postoperative Transthoracic Echocardiography			p
		(I) (1.8 ± 1.4 weeks) n (%)	(II) (3 to 6 months) n (%)	(III) (30 ± 14 months) n (%)	
FTR					
degree 0	0	0	0	2 (11.8%)	<0.001
degree 1	0	3 (17.6%)	6 (35.2%)	6 (35.2%)	
degree 2	0	13 (76.5%)	9 (53%)	5 (29.4%)	
degree 3	8 (47%)	1 (5.9%)	2 (11.8%)	2 (11.8%)	
degree 4	9 (53%)	0	0	1 (5.9%)	
mean degree	3.5 ± 0.5	1.9 ± 0.5	1.7 ± 0.6	1.6 ± 1.0	
PASP					
normal	0	1 (5.9%)	2 (11.8%)	3 (17.6%)	0.002
mild	1 (5.9%)	8 (47%)	9 (53%)	8 (47%)	
moderate	9 (53%)	6 (35.3%)	4 (23.5%)	4 (23.5%)	
severe	7 (41.1%)	2 (11.8%)	2 (11.8%)	1 (5.9%)	
ITAD					
normal	0	2 (11.8%)	5 (29.4%)	6 (35.3%)	<0.001
mild	1 (5.9%)	15 (88.2%)	11 (64.7%)	10 (58.9%)	
moderate	12 (70.6%)	0	1 (5.9%)	0	
severe	4 (23.5%)	0	0	0	

FTR = functional tricuspid regurgitation; ITAD = indexed tricuspid annulus diameter; PASP = pulmonary artery systolic pressure; TR = tricuspid regurgitation; TTE = transthoracic echocardiography, recent study (no more than 2 months prior to surgery).

TR was observed on the postoperative echocardiography. The statistical analyses were performed using the SPSS software package, version 12.0 (SPSS Inc, Chicago, IL). The *p* values were calculated using the program Epi Info (United States Department of Health and Human Services, Centers for Disease Control and Information) 6.04d [12] and differences were considered statistically significant at *p* less than 0.05. We calculated the success rate and the corresponding 95% confidence interval [CI 95%] using an exact method based on a binomial distribution [13]. The midterm survival was analyzed using the Kaplan-Meier method.

Results

There was no hospital mortality. Postoperative complications were observed in 3 patients (17.6%) including atrial fibrillation with slow ventricular response requiring permanent transvenous pacing, acute renal failure secondary to antibiotic treatment for thrombosis and endocarditis of mitral valve prosthesis, and large right pleural effusion requiring thoracic drainage.

On the first postoperative TTE, 16 patients (94%) had mild or less than mild TR and 1 patient (5.9%) had moderate TR. Serial postoperative TTE studies revealed a progressive decrease in the severity of TR. The mean degree of TR was 1.6 ± 1.0 at the end of the study, versus 3.5 ± 0.5 preoperatively (*p* < 0.001). Figure 4 shows the outcomes of this new tricuspid annuloplasty for moderate and severe TR. The PHT regressed gradually throughout the study. The proportion of patients with severe PHT decreased from 41.2% to 5.9%, and the proportion of patients with moderate PHT decreased from 53% to 23.5% (*p* < 0.002). The indexed

tricuspid annulus diameter normalized in all patients (*p* < 0.001). Table 1 summarizes the echocardiographic results of the adjustable segmental tricuspid annuloplasty in the repair functional TR. In addition, we observed immediate and progressive decreases in right ventricular end-diastolic diameter (*p* < 0.09) and in inferior vena cava diameter (*p* < 0.001), which persisted throughout the study. On the other hand, changes were observed neither in right ventricular function, nor in left ventricular function or in left ventricular end-diastolic diameter.

In further analyses, we found no statistically significant effects attributable to severe PHT (> 60 mm Hg), severe dilatation of the tricuspid annulus (ITAD > 21 mm/m²), poor left ventricular function (LVEF < 0.30), or presence of transvenous pacemaker lead on the outcomes of this new tricuspid annuloplasty. The success rate of adjust-

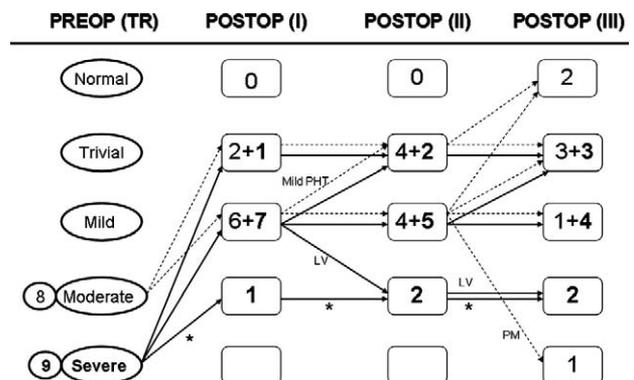


Fig 4. Results of the adjustable segmental tricuspid annuloplasty in moderate and severe TR.

Table 2. Experiences of Various Surgical Groups in Semicircular Tricuspid Suture Annuloplasties

Author	Year	Type of Annuloplasty	No. of Patients	Follow-up (Months)	Failure of Annuloplasty (%)
Grondin [15]	1975	De Vega	17	11.5	23
Rábago [16]	1980	De Vega	150	6-30	5.9
Brugger [17]	1982	De Vega	76	30	4.2
Rivera [18]	1985	De Vega	83	64	34
Pasaoglu [19]	1990	De Vega	195	42	2
Holper [20]	1990	De Vega	97	56	33.8
Hashimoto [21]	1993	Arai	43	60	7
Peltola [22]	1996	De Vega	30	10-71	43.7
Tager [23]	1998	De Vega	43	57	11.5
Bernal [24]	2004	Revuelta	139	81	4.5
McCarthy [25]	2004	All	790	48-168	14
Goksin [8]	2006	Sagban	25	17.8	4.2
Antunes [26]	2007	Antunes	442	24-192	0.007

able segmental tricuspid annuloplasty in stabilizing the tricuspid annulus was (95% CI 94 to 100) and in the repair of functional TR was (95% CI 88 to 94).

Patient Follow-Up

Telephone contact was established with each patient and follow-up was 100% complete. The mean follow-up period after surgery was 30.42 ± 14 months (range, 4 to 48 months). A progressive overall clinical improvement was observed, with a decrease in mean NYHA functional class from 3.0 ± 0.4 preoperatively, to 1.3 ± 0.6 at the end of follow-up (p < 0.005). Treatment with diuretics was discontinued or reduced in 71% of patients. Only one noncardiac death was documented at 4 months of follow-up. The survival rate at the end of the study was 94%. Figure 5 shows the Kaplan-Meier survival curve and the number of patients at risk.

Comment

The management of functional TR and choice of most appropriate surgical techniques remain debated among various surgical teams. An ideal tricuspid annuloplasty

should take into consideration the anatomic and functional characteristics of the normal and pathologic TV. It should be cost-effective, easy to perform, and safe; preserving the normal function of the TV and free of complications such as thromboembolism or heart block, durable, and free of long-term of recurrence of TR.

Bicuspidization techniques do not act on the portion where the anterior leaflet is inserted; therefore do not prevent the subsequent dilatation of the anterior annulus, if the hemodynamic status allows for this. On the other hand, plication of the posterior annulus might interfere with the functional symmetry of the subvalvular apparatus and tension on the extremities of the plicated segment might tear the endocardial surface.

The original De Vega annuloplasty and its variants purse the posterior annular segment considerably more than the anterior segment. Excessive tension on a continuous and single suture can cause recurrent TR due to the bowstring “guitar-string” phenomenon. On the other hand, pursing the suture in an opposite direction might tear the endocardial surface of the posteroseptal region. Antunes and Girdwood [6] incorporated oval Teflon pledgets in each stitch of the double suture to protect only the outside surface of the endocardium. Segmental tricuspid annuloplasty exposes the zones situated between the stitches to new and progressive distension if the hemodynamic status allows. On the other hand, it evenly purses the anteroposterior annulus [7]. Semicircular constrictive annuloplasty purses the sutures just at the anteroposterior commissure, so it does not completely close this commissure [8]. The foreign material used in the vanishing De Vega annuloplasty is absorbed within 6 months after surgery, and is replaced by loose collagenous tissue that enables the expansion of the tricuspid annulus to its original circumference. It is particularly applicable in children and patients with functional TR and low pulmonary arteriolar resistance [14].

Because only two original De Vega tricuspid annuloplasties were performed in our institution during the period of this study, we reviewed the experiences of other surgical groups in semicircular tricuspid suture annuloplasties (which are summarized in Table 2) to serve as a historic

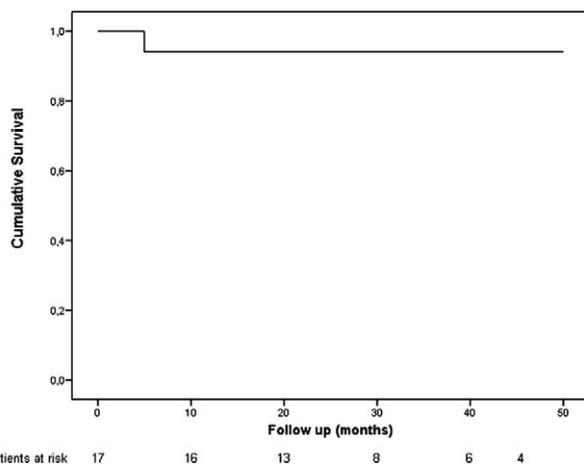


Fig 5. Patients survival curve analyzed by the Kaplan-Meier method.

control group. The effectiveness of the original De Vega annuloplasty reported by these various groups of investigators has been variable. The best results were obtained by Pasaoglu and colleagues [19], and the worst by Peltola and colleagues [22]. Antunes and Barlow [26] performed a modified De Vega annuloplasty on 442 patients, of whom only 3 required reoperation for severe residual or recurrent TR. McCarthy and colleagues [25] observed residual TR in 14% of 790 patients who underwent different tricuspid annuloplasties. The risk factors for annuloplasty failure were severe preoperative TR, poor left ventricular function, presence of a permanent transvenous pacemaker lead, and a repair procedure other than ring annuloplasty.

Adjustable segmental tricuspid annuloplasty is an improved suture annuloplasty that repairs only the dilatation of the tricuspid annulus. However, it could be combined with another type of repair to address the mixed TR. This new annuloplasty is segmental, commissural, more selective, more adjustable, and more resistant in the presence of TR associated with severe dilatation of the tricuspid annulus, severe PHT, or both. Its success rate in stabilizing of the tricuspid annulus was 94% to 100% and in the repair of functional TR was 88% to 94%.

However, it is noteworthy that recurrences of TR observed in 3 patients were related to a permanent transvenous pacemaker lead implanted after surgery, tethering of the septal leaflet produced as a consequence of poor left ventricular function, and anterior leaflet prolapse undetected on preoperative echocardiography. We do not recommend this new annuloplasty for patients with poor right ventricular function and (or) prominent tricuspid valve tethering.

In conclusion, adjustable segmental tricuspid annuloplasty is an improved annuloplasty procedure for functional TR because it is segmental, commissural, more selective, more adjustable, and more resistant in the presence of TR associated with severe dilatation of the tricuspid annulus, severe PHT, or both. These results may make this tricuspid annuloplasty the procedure of choice in underprivileged countries. Like all tricuspid annuloplasties, it may be adversely influenced by poor left ventricular function or by the presence of a permanent transvenous pacemaker lead. We are awaiting the long-term results of this new annuloplasty, which we are continuing to perform, in a larger number of patients.

This study was conducted without grant support. The authors thank Francisco Rodriguez for providing the biostatistical analysis used in this article and the technician Montse Ampuero for her valuable contribution in collecting the echocardiographic data.

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