Original Article

Comparative study of tricuspid valve repair using ring vs. synthetic band in severe functional tricuspid valve regurgitation

Ashraf Elnahas, Yousry Shaheen, Dina Afifi, Ahmed Emara

Department of Cardiothoracic Surgery, Faculty of Medicine, Banha University, Banha, Egypt

Abstract

Background: Functional tricuspid valve regurgitation secondary to left-sided valve disease remains a common problem. There are different surgical techniques for tricuspid valve repair; however, the superiority of one approach over the other has not been proven. Our objective was to compare the short-term results of ring versus synthetic band annuloplasty to repair functional severe tricuspid regurgitation in patients with left-sided valve lesions.

Methods: This retrospective study includes 60 patients who underwent left-sided valve replacement with concomitant tricuspid valve repair for severe tricuspid regurgitation. Patients were divided into group A (n= 30), patients with rigid rings, and group B (n= 30), patients with synthetic bands.

Results: The preoperative demographic and clinical data were non-significant between both groups. In the preoperative data, the tricuspid annular plane systolic excursion (TAPSE) was significantly higher in the ring group (2.84 ± 0.53 vs. 2.3 ± 0.4, P< 0.001). Hospital stay was more prolonged in group B (10.05 ± 1.57 vs. 11.7 ± 2.76 days, P=0.006). There were no differences in other operative and postoperative data between groups. After a six-month follow-up, both groups had no significant difference regarding the clinical data or the degree of tricuspid valve regurgitation.

Conclusion: Tricuspid valve annuloplasty with a rigid ring or synthetic band for tricuspid regurgitation could have a good short-term outcome.

Introduction

Functional tricuspid regurgitation (FTR) is the most common cause of tricuspid valve (TV) disease. It results from changes in the geometry of the tricuspid annulus secondary to dilatation of the right ventricle. In almost all cases, this is a subsequent effect of increased pulmonary artery pressure as a back pressure from the left-sided valve lesions [1].

TV repair is recommended in patients indicated for left-sided valve surgery when the tricuspid regurgitation is severe, or the tricuspid annulus is dilatated over 40 mm [2].

Although some studies showed that a percentage of untreated FTR cases might regress or remain unchanged, about 40% may eventually deteriorate following left-sided valve surgery. [1] Furthermore, surgery for tricuspid regurgitation after left-side valve operations has a high mortality rate of up to 32% and a 5-year survival of less than 50% [3].

Corresponding author: Dina Afifi ✉ dinaafificts@hahoo.com

Several methods of tricuspid valve repair have been reported in the literature, with no proven superiority of one technique over the other. Therefore, our objective was to compare the short-term results of ring versus synthetic band annuloplasty for the repair of functional severe tricuspid regurgitation in patients with left-sided valve lesions.

Patients and Methods

This study was a retrospective comparative study and was conducted on 60 patients who underwent mitral or/and aortic valve replacement with concomitant tricuspid valve repair for severe functional tricuspid regurgitation. Data were retrieved between January 2017 and January 2022. Data were extracted from paper charts and a computer-based cardiac surgery registration system.

We have placed patients in two groups; Group A: (n=30) patients who underwent tricuspid annuloplasty using a rigid tricuspid ring. Group B (n= 30) included patients who underwent tricuspid annuloplasty using a fashioned prosthetic band of Dacron or Teflon.

We included patients of both sexes aged 18-70 years old. Patients had primary elective mitral or double valve surgery, with an ejection fraction > 40%. Patients with primary pulmonary hypertension, concomitant cardiac surgery, redo and emergency surgery, and those with other co-morbidities (renal or hepatic impairment) were excluded.

Surgical technique:

The surgical approach was through a conventional midline sternotomy. Cardiopulmonary bypass was initiated via aorto-bicaval cannulation after full heparinization. Then, a cross-clamp was applied, and the heart was arrested by infusing antegrade cold blood enriched cardioplegia with booster doses every 30-40 minutes intervals or a single dose of Histidine-tryptophan-ketoglutarate (HTK) solution (Custodiol®). Myocardial protection was assisted by systemic and topical cooling.

Table 1: Comparison of the demographic and preoperative data between patients who had ring vs. synthetic band

	Group A (n= 30)	Group B (n= 30)	P-value
Female	18 (60%)	17 (56.7%)	0.795
Age (years): Mean ± SD	38.71 ± 12.67	41.53 ± 13.87	0.414
BMI (kg/m²): Mean ± SD	28.35 ± 3.6	27.72 ± 2.87	0.456
NYHA class			
I	11 (36.7%)	10 (33.3%)	0.782
II	17 (56.7%)	20 (66.7%)	0.425
IV	2 (6.7%)	2 (6.7%)	>0.99
Atrial fibrillation	21 (70%)	22 (73.3%)	0.776
Mitral valve disease	20 (66.7%)	22 (73.3%)	0.576
Aortic valve disease	3 (10%)	2 (6.7%)	0.644
Double valve disease	7 (23.3%)	6 (20%)	0.756
LVESD: Mean ± SD	3.81 ± 0.82	4.02 ± 0.57	0.254
LVEDD: Mean ± SD	5.31 ± 0.76	5.21 ± 0.98	0.66
EF%: Mean ± SD	61.82 ± 5.30	59.26± 7.13	0.119
TAPSE: Mean ± SD	2.84 ± 0.53	2.3 ± 0.4	< 0.001
SPAP: Mean ± SD	67.74 ± 18.95	63.82±17.14	0.404
RV diameter: Mean ± SD	2.71 ± 0.36	2.66 ± 0.39	0.607

BMI: Body mass index; NYHA: New York Heart Association; LVESD: left ventricular end-systolic dimension; LVEDD: left ventricular end-diastolic dimension; EF: ejection fraction; SPAP: ejection fraction; RV: right ventricle

Surgical exposure of the mitral valve was achieved either by a left atriotomy incision in the Waterston groove or through a transeptal approach. The aortic valve was exposed through an oblique aortotomy incision. All patients underwent valve replacement using mechanical prostheses for the affected left-sided valves. After the required mitral or aortic procedure had finished, the aortic cross-clamp was removed, and tricuspid repair was performed without cardioplegia.

Tricuspid annuloplasty was performed through a right atriotomy incision after snaring the cavae. In group A, we used a rigid tricuspid ring sized according to the appropriate ring sizers. The ring was fixed to the annulus using interrupted 2/0 polypropylene sutures without Teflon pledgets. In group B, we used a strip of Dacron or Teflon fashioned in a length of 5-6 cm and 5 mm wide. It was fixed to the annulus with the same technique used for the ring. The suture bites were approximately 8-10 mm in length, skipping 5 mm between bites. Testing of the valve competency was done using a saline test to confirm the competence of the valve before closing the right atrium and unsnaring the cavae. If a satisfactory repair was achieved, we proceed towards weaning from cardiopulmonary bypass (CPB), protamine infusion, decannulation, hemostasis and sternal closure.

Study data

Preoperative data included demographic data, clinical data, and detailed echocardiographic measurements. Intra-operative data included the type of operation, cross-clamp and bypass times, and operative complications. Early postoperative data included postoperative ventilation time, intensive care unit (ICU) and hospital stay, postoperative complications, and clinical and echocardiographic data. We collected the clinical and echocardiographic data after six months.

Statistical analysis:

Data analysis was performed using SPSS statistical software version 20.0 (IBM Inc., Armonk, NY, USA). The unpaired student's "t" test was used for quantitative data which were expressed in means ± standard deviations. The chi-square (X^2) test was used for qualitative data which were expressed in proportions. The statistical difference was considered significant if the p-value was < 0.05.

Results

Patient's demographic and preoperative data:

We found no significant difference between the groups regarding the preoperative data. The number of males was 12 in group A versus 13 in group B. In group A, the mean age was 38.71 ± 12.67 years, and the mean body mass index (BMI) was 28.35 ± 3.6 kg/m2. In group B, the mean age was 41.53 ± 13.87 years, and the mean BMI was 27.72 ± 2.87 kg/m^2.

Table 2: Comparison of operative data between patients who had ring vs. synthetic band

	Group A (n= 30)	Group B (n= 30)	P-value
Total Bypass time (min): Mean ± SD	109.14 ± 18.74	117.77 ± 17.28	0.068
Cross clamp time: (min)Mean ± SD	87.76 ± 15.01	91.26 ± 14.80	0.366
Mitral valve size: Mean ± SD	30.06 ± 0.70	30.53 ± 1.33	0.092
Aortic valve size: Mean ± SD	20.7 ± 0.64	20.72 0.71	0.909
Tricuspid Ring size:			
28	5 (16.7%)		
30	16 (53.3%)		
32	6 (20%)		
34	3 (10%)		

Table 3: Comparison of postoperative data between patients who had ring vs. synthetic band

	Group A (n= 30)	Group B (n= 30)	P-value
Re-exploration for bleeding	4 (13.3%)	3 (10%)	0.692
Duration of mechanical ventilation (hours): Mean ± SD	8.58 ± 6.77	11.87 ± 7.4	0.075
ICU stay: (days): Mean ± SD	3.32 ± 0.94	3.59 ± 1.14	0.321
Hospital stay (days): Mean ± SD	10.05 ± 1.57	11.7 ± 2.76	0.006
Mitral valve Mean pressure gradient (PG) (mmHg): Mean ± SD	4.34 ± 1.2	4.7 ± 1.12	0.234
Aortic valve Mean PG (mmHg): Mean ± SD	17.3 ± 5.62	15.17 ± 2.35	0.06
Degree of tricuspid regurgitation:			
Mild	23 (76.7%)	22 (73.3%)	
Moderate	4 (13.3%)	4 (13.5%)	0.761
Severe	3 (10%)	4 (13.3%)	
EF (%) Mean ± SD	57.42 ± 4.22	58.32 ± 4.74	0.44
TAPSE: Mean ± SD	1.82 ± 0.21	1.93 ± 0.17	0.029
SPAP: Mean ± SD	48.32 ± 11.1	43.78 ± 9.72	0.097
RV diameter: Mean ± SD	2.73 ± 0.32	2.72 ± 0.33	0.905

CU: intensive care unit, PG: pressure gradient; EF: ejection fraction; TAPSE: tricuspid annular plane systolic excursion; SPAP: systolic pulmonary artery pressure; RV: right ventricle

Regarding dyspnea grading according to NYHA class, we did not find a significant difference between the ring and the band groups. None of the patients had lower limb edema or ascites in both groups.

In group A, 20 patients required valve replacement for the mitral valve, three for the aortic, and seven for both. In group B, 22 patients required valve replacement for the mitral valve, two for the aortic, and six for both. There was a highly significant difference in right ventricular (RV) function (TAPSE) between both, P value < 0.001. (Table 1)

Operative data:

The operative data included the total bypass time, ischemic time, mean size of prosthetic valve used, and different tricuspid ring sizes utilized in group A. These data were statistically non-significant between both groups, as shown in (Table 2).

Postoperative data:

Apart from the significant difference in hospital stay (P-value= 0.006), there was a non-significant difference among other data, such as re-exploration for bleeding, duration of ventilation, or ICU stay. The TAPSE was significantly higher in group B (P-value = 0.029). All patients of both groups had well-functioning prosthetic valves. Other data analyses between both groups showed a non-significant difference in the degree of tricuspid regurgitation, EF, SPAP, and RV dimension. (Table 3)

Follow-up data:

The follow-up period was between 6 and 14 months, with a mean of 8.2 months. There was no significant difference in clinical data between both groups, including the grade of dyspnea, lower limb edema, or readmission for right-side heart failure. Follow-up echocardiography revealed a mild increase in the pressure gradient across the left-side heart valves. The RV dimension and the pulmonary artery pressure are still high, with no significant difference in the degree of TR. There was a significant difference in TAPSE between both groups (P value 0.007). (Table 4)

High-risk group analysis:

Those defined to have moderate and severe TR at six months. We compared all the preoperative,

Table 4: Comparison of 6 months follow-up data between patients who had ring vs. synthetic band

	Group A (n= 30)	Group B (n= 30)	P-value
Dyspnea grade:			
Grade II	26 (86.7%)	24 (80%)	0.486
Grade III	4 (13.3%)	6 (20%)	
Lower limb edema	4 (13.3%)	6 (20%)	0.486
Readmission for right	0	0	
Mitral valve Mean PG (mmHg): Mean ± SD	5.14 ± 2.6	4.7 ± 1.12	0.398
Aortic valve Mean PG (mmHg): Mean ± SD	19.2 ± 5.38	17.65 ± 5.4	0.27
Degree of Tricuspid regurge			
Mild	22 (73.3%)	19 (63.3%)	0.416
Moderate	4 (13.3%)	4 (13.3%)	>0.99
Severe	4 (13.3%)	7 (23.3%)	0.316
EF%: Mean ± SD	60.5 ± 7.35	62.7 ± 5.81	0.203
TAPSE: Mean ± SD	1.6 ± 0.32	1.86 ± 0.40	0.007
SPAP: Mean ± SD	39.62 ± 7.21	43.24 ± 11.3	0.144
RV diameter: Mean ± SD	2.61 ± 0.52	2.7 ± 0.32	0.422

PG: pressure gradient; EF: ejection fraction; TAPSE: tricuspid annular plane systolic excursion; SPAP: systolic pulmonary artery pressure; RV: right ventricle

operative, and postoperative data, and patients with recurrent TR were older, with a high prevalence of double valve surgery and higher pulmonary artery systolic pressure. (Table 5)

Discussion

Surgical repair of severe TR is recommended during intervention for left-sided valves to improve the surgical outcome. After tricuspid annuloplasty using the De Vega technique, the tricuspid annular flexibility and contractility are not affected. [4] However, increased right ventricular pressure can cause these suture materials to become dehiscent with repair failure. Therefore, the concept of using tougher annuloplasty materials was introduced. The annuloplasty using a rigid ring such as Carpentier-Edwards was associated with decreased rates of regurgitation recurrence with questionable risk of affecting the right ventricular contractility and function. Other techniques have emerged under continuous research and evaluation, like using soft rings, fashioned pericardial strips, or synthetic bands. [5]

We found no significant difference between the ring and the band groups regarding the patient's demographic Data or the preoperative clinical data. These data were intended to be nearly uniform to eliminate their effect on the type of repair. This was the case in most studies

Table 5: comparison between the high-risk group and all patients

	High-risk group (n = 19)	All study patients (n = 60)	P value
Age (mean, years)	47.33 ± 7.21	40.12 ± 13.27	0.026
BMI (kg/m^2)	29.14 ± 2.25	28.04 ± 3.24	0.172
Double valve disease	9 (47.37%)	13 (21.67%)	0.029
Preoperative SPAP (mmHg)	76.56 ± 14.33	65.78 ± 18.05	0.02
RVD (cm)	2.81± 0.34	2.69 ± 0.38	0.223
SPAP after six months	53.33 ± 9.2	46.05 ± 10.41	0.008

BMI: body mass index; SPAP: systolic pulmonary artery pressure; RVD: right ventricular dimensions

similar to ours. We did not compare the other signs of right-side heart failure, like ascites and lower limb edema, as almost all patients were controlled by medical treatment before surgery.

There was a significant difference in RV function (TAPSE) between both groups (P-value < 0.001). This significance might explain the reason for choosing the rigid ring for repair. Furthermore, we have relatively higher measures for the mean systolic pulmonary arterial (67.74 ± 18.95 in group A versus 63.82 ± 17.14 mmHg in group B) compared to other studies, such as Carino and coworkers. They reported the mean of all patients was 45 mmHg. [3,4,6,7]

We found that both groups' total bypass time and ischemic time were non-significant, as we preferred to do the tricuspid repair after removing the aortic cross-clamp. Some authors observed longer operative time in the ring group and claim that this finding might add more complexity to the procedure. [8] Furthermore, Guenther and colleagues reported a highly significant difference in the cardiopulmonary bypass and the total cross-clamp time (P-value < 0.001) in favor of the non-ring group and found that this factor was a predictor of early mortality. [7] However, they did not clearly define whether the use of the ring annuloplasty was the cause of this prolonged time or not. Moreover, they have reported an increased rate of permanent pacemaker implantation in the ring group without confirming whether the cause of the heart block was because of the ring fixation.

In the early predischarge echo assessment, the TAPSE was higher in group B (p-value= 0.029). This could be explained early as the use of the rigid ring affects the tricuspid annular excursion.

The follow-up data after six months revealed a mild increase in the pressure gradient across the left-side heart valves. We have noticed an increased BMI in most patients after the six-month visit. The RV dimensions and the pulmonary artery pressure were less than the preoperative measures but still persistent in many patients to the degree that affected the RV function and

possibly the competence of repair. Although there was a non-significant difference in the degree of TR, the overall valve competence was affected.

The results of using a rigid ring in mitral valve repair have been criticized for the disability of dynamic annular contraction and the subsequent impairment of LV function. These findings allowed for the introduction of new concepts in mitral repair, starting from the semirigid ring through the soft ring and to the flexible bands. Moreover, these concepts have been inspired in the field of TV repair.

One of the interesting studies by Brown and colleagues was on 511 patients who underwent mitral valve repair using posterior band annuloplasty. The mean follow-up was 4.8 years, with 89% of patients having no or mild regurgitation at the last visit. [9] The long-term follow-up in many series was conducted to determine the actual benefit of the ring repair over other techniques. However, the use of synthetic bands was not studied for enough periods. Additionally, most previous studies have compared the ring repair with the conventional De Vega suturing technique.

When comparing the ring with suture (De Vega) repair, we looked at the study by Tang and associates of 702 patients; 209 of them had an annuloplasty ring, and 493 had mainly De Vega repair. The last echocardiographic examination (at 15 years postoperative) revealed that in the ring group, 30% of survived patients had moderate to severe TR, whereas, in the no-ring group, 36% had moderate to severe TR. However, they reported significantly better survival and event-free survival in the ring group. [10] Similarly, Guenther and collaborators analyzed 717 repairs (433 rings and 255 no rings) with a long-term follow-up period. At ten-year observation, the ten-year freedom from pacemaker implantation in the no-ring group was 91.8 ± 2% and 88 ± 2% in the ring Group (P = 0.013). The 10-year freedom from TV reoperation with a De Vega was 87.9 ± 3% compared to 98.4 ± 1% after the ring (P = 0.034). [7] Another study by Carino and colleagues compared the ring versus suture method and followed patients for up to 18

years. They found that the survival between the two groups was not different (P= 0.992). However, they concluded that ring repair had a better protective effect for TR than suture repair (P < 0.001). [6]

Although the ring repair has better results than the De Vega repair, in the long run, we believe that adding a synthetic band technique will give approximate results to the ring while avoiding its possible risk. Therefore, we looked at some similar techniques of ours. The study of Chang and colleagues evaluated the outcome of 217 patients repaired by pericardial strip against 117 patients who underwent conventional De Vega repair. At the eight-year follow-up, the recurrence-free survival was higher in the band group than that of the De Vega group (86.8% versus 71.9%; p - 0.039). [4]

Our study was similar to that conducted by Wang and colleagues. They conducted a meta-analysis to evaluate the flexible band versus the rigid ring for tricuspid annuloplasty. The study included five studies with 3,141 patients, of which 1,893 had a flexible band, and 1,248 had a rigid ring. They concluded that the rigid ring had significantly better freedom from grade ≥2 TR at five years but not at one year and three years. The overall freedom from grade ≥2 TR was better in the rigid ring group (P=0.005). There was no significant difference in overall rates of reoperation (P=0.232) and survival (P=0.086) between both groups. [11]

In agreement with the previous study, the work of Nosair and associates on comparing the ring group, which included 90 cases, and the synthetic band group of 80 cases with a follow-up mean of 67.2 ± 10.8 months, they found no significant differences in both groups regarding hospital morbidities or mortality. Additionally, there was a non-significant difference between the two groups degrees of TR or SPAP. However, there was a significant difference in the freedom from recurrent TR and the reoperation rates during the follow-up, which was lower in the ring group. [5]

Similarly, in a study by McCarthy and associates of 790 patients after TV repair for secondary TR, they reported an earlier recurrence of significant TR with the progression of the degree of regurgitation by time after pericardial and De Vega repairs (P= 0.002 and P= 0.06, respectively, compared with the rigid ring). [3]

The difference between the higher rates of tricuspid insufficiency and lower rates of reoperations might be referred to the high-risk surgery of this category of patients. Therefore, most of these patients are denied surgery and wrongly continue medical treatment as an alternative. [12]

We have investigated the risk factors for repair failure. We have agreed with other authors about these factors especially the persistence of pulmonary hypertension after surgery. We have noticed that the presence of multiple valve disease and the delay in surgery after the indicated time, together with advanced age, are markers for the persistence of pulmonary hypertension.

Abdelmohty and coworkers reported these factors as they studied De Vega's failure predictors. They found that the most significant predictor was the persistence of pulmonary arterial hypertension following surgery. Moreover, the preoperative condition of heart failure and the time between the indication of intervention and the time of surgery were also significant predictors. [13] Similarly, McCarthy and colleagues studied the risk factors for worsening tricuspid insufficiency after repair. These included the higher degree of regurgitation before the operation, the decreased ejection fraction of the left ventricle, the presence of a permanent pacemaker, the type of repair other than the ring, the ring size used, the systolic pressure of the RV, and the preoperative dyspnoea grade. [3]

Therefore, it is important to refer patients for valve surgery once indicated, as deferring surgery causes an increase in cardiac dimensions and an increase of pulmonary artery pressure to the extent that negatively impacts the outcome of surgery. Moreover, it is important to clarify the

morphology of the tricuspid valve with annular measurement to adequately plan the optimal repair or replacement type. Furthermore, understanding the patient's age, expected survival, co-morbidities, and risk factors of repair failure and shaping the tricuspid valve tackling strategy will improve the outcomes.

Study limitations

One of the limitations is the retrospective nature of the study due to the limited number of cases in which the rigid ring was used for repair. Moreover, we could not evaluate the effect of repair on morbidity and mortality as we collected data from only survived patients. Another limitation is the bias of the surgeon's preference. Furthermore, the short-term follow-up period of the cases is another limitation.

Conclusion

Using a synthetic band for tricuspid annuloplasty could have a good early outcome with nearly similar results obtained by the rigid ring.

Conflict of interest: Authors declare no conflict of interest.

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