Comparison of Ring and Suture Annuloplasty in the Treatment of Tricuspid Regurgitation

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Abstract

Background: Significant TR is common in patients with cardiac disease and because of its prognostic importance, TV came to the spotlight in the last decades. Functional TR is mostly treated when undergoing left-sided valve surgery, whereas idiopathic TR surgery is uncommon. The aim of this study is to compare the durability of tricuspid valve annuloplasty techniques, and to explore the optimal method for TV repair surgery. Methods: 1005 patients who underwent tricuspid valve repair from February 2012 to March 2019, were retrospectively studied. The patients had tricuspid valve repair while receiving surgery for other cardiac conditions. The study population was divided into Suture group (n=483, 48.1%), and Ring group (n=522, 51.9%). Data variation between and within the groups was analyzed with Mann-Whitney U test, Wilcoxon rank-sum test, and Radit analysis. Results: At two-year follow-up, in the Suture group, none/trace TR subjects were 63.9%, and 1.4% had severe TR; In the Ring group were: 63.9% none/trace, and 0.6% severe. Both groups' two-year follow-up TR status was significantly different with preoperative TR status ($p<0.05$). At two-year follow-up, Suture group had 63.9% none/trace and 1.4% severe; and Ring group had 63.9% none/trace and 0.6% severe TR and there was no significant difference between the groups ($p>0.05$). Conclusions: Both annuloplasty techniques have good short-term outcomes. However, suture annuloplasty deteriorates faster than ring annuloplasty, making the latter to be the ideal technique for TV repair.

Original Article

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Methods: 1005 patients who underwent tricuspid valve repair from February 2012 to March 2019, were retrospectively studied. The patients had tricuspid valve repair while receiving surgery for other cardiac conditions. The study population was divided into Suture group (n=483, 48.1%), and Ring group (n=522, 51.9%). Data variation between and within the groups was analyzed with Mann-Whitney U test, Wilcoxon rank-sum test, and Radit analysis.

Results: At two-year follow-up, in the Suture group, none/trace TR subjects were 63.9%, and 1.4% had severe TR; In the Ring group were: 63.9% none/trace, and 0.6% severe. Both groups' two-year follow-up TR status was significantly different with preoperative TR status ($p<0.05$).

At two-year follow-up, Suture group had 63.9% none/trace and 1.4% severe; and Ring group had 63.9% none/trace and 0.6% severe TR and there was no significant difference between the groups ($p>0.05$).

Conclusions: Both annuloplasty techniques have good short-term outcomes. However, suture annuloplasty deteriorates faster than ring annuloplasty, making the latter to be the ideal technique for TV repair.

Keywords: Tricuspid regurgitation, Ring annuloplasty, Suture annuloplasty.

Background

Tricuspid Regurgitation (TR) is a disease of the right atrioventricular valve. Trace or mild TR is a common finding even in healthy people; with an occurrence rate of about 1% in the general population.[1] In a structurally normal tricuspid valve (TV) apparatus, mild TR can be considered a normal variant.[2]

For decades, TR has been considered a benign disease with a long asymptomatic period. As a consequence, it has been relatively neglected and did not receive enough attention. Data showed that significant (moderate or greater) TR is common, with a 0.5% incidence on the general population, with an increasing prevalence after the age of 75 years, particularly in women and in the presence of atrial fibrillation (AFib),[3] and is associated with a poor prognosis. Because of its prognostic value in conditions such as ischemic heart disease, mitral valve regurgitation, AFib, and heart failure, TV has risen from the "forgotten valve" to the spotlight in the last decades.

TR can be classified into different morphologic categories:**Primary (or organic) TR** is caused by congenital or acquired defects of the TV apparatus; **Secondary (or functional) TR** is caused by deformation of the TV apparatus secondary to dilation of the TV annulus, leaflet tethering, and right ventricular (RV) remodeling as a result of left-sided heart disease and pulmonary hypertension (PH);**Isolated (or Idiopathic) TR,** is another class of TR and it is related to intra-cardiac device leads, AFib and right atrial (RA) remodeling. In 80% of adults with significant TR, the incompetence is caused by acquired right ventricular and annular dilation rather than inherent valve pathology.[4]

Functional TR is mostly treated when undergoing left-sided valve surgery, whereas isolated TV surgery is rarely performed, but is recommended in patients with severe TR that are either symptomatic or have progressive RV remodeling.

Generally, in patients with primary TR, repair mainly depends on the degree of valve damage. Replacement may show better results over repair in TR cases with severe valve lesions. For functional TR, there is currently a clear tendency towards valve repair.

Tricuspid annuloplasty has been the most common technique used for surgical correction of TR. TV annuloplasty typically consists of annular size reduction with ring or suture techniques to bring closer the leaflets and restore coaptation. First suture repair techniques were described more than 50 years ago by Jerome Kay and Norberto De Vega. Both techniques are currently been used in clinical practice, despite recent studies suggesting better long-term results of ring annuloplasty over suture annuloplasty.[5] [6] [7] There is still a hot debate on the indication, feasibility, long-term outcome, and cost-benefit balance between the TV repair procedures among cardiac surgeons. The great advantage of suture annuloplasty is that it is technically more simpler, less time consuming and less costly; however, suture techniques carry a higher risk of recurrent TR, according to studies.[8] Monika et al,[9] did not detect tissue tearing by the purse-string suture in the De Vega annuloplasty, and considered suture annuloplasty a valid treatment option for TR. Ring annuloplasty gained a lot of support from studies,[2] however, there are reports of increased annular dehiscence with ring repair technique.[6]

Methods and Materials

A retrospective study of 1005 patients who underwent TV repair surgery at the First Affiliated Hospital of Zhengzhou University, from July 2012 to August 2019.

All the patients had TV repair when undergoing surgery for other cardiac conditions. Among the subjects, 662 (66%) patients had concomitant left-sided valve surgery (AVR, AVP, MVR, MVP); 274 (27.2%) patients had combined TV repair and various congenital heart defects repair, such as ASD, VSD, TOF, PS and ECD; 48 (4.8%) patients simultaneously underwent aortic artery interventions (Bentall procedure) and coronary artery bypass graft surgery; and the remaining 21(2%) patients had other less common procedures such as left atrial myxoma resection and aortic sinus rupture repair. Table 2 contains the proportions of different cardiac procedures performed at the time of TV repair.

Data collection and selection criteria

All the patients who underwent TR repair in our center from Feb 2012 to March 2019 were collected and using the hospital admission numbers, we searched carefully for all in-hospital and outpatient follow-up echocardiographic reports. The patients who did not have preoperative and postoperative follow-up echoes from our hospital were excluded from this study, and 1005 patients met the selection criteria, therefore constitute the study population of the present research. Patients who had TV replacement were equally not included in this study. Overall heart function was evaluated solely with an echocardiogram done in our center. The Hospital Ethics Committee approved the retrospective review of medical records in accordance with the protection of patient confidentiality, and consented the use of the data for publication; patients were not identified and individual consent was not obtained.

Surgical Procedure

All the surgeries were performed with the patients under general anesthesia and tracheal intubation. The sternotomy was performed with a sternal saw. Cardiopulmonary bypass (CPB) was established routinely: Bicaval cannulation, moderate systemic hypothermia, local ice-cooling (for longer CPB time cases), and cardioplegia for myocardial arrest.

The patients who received suture annuloplasty techniques (Kay 62(6.2%) and classical or modified De Vega 421(41.9%)) were designated Suture group, and those who underwent ring annuloplasty (522(51.9%)) were designated Ring group.

Follow-up

There were three postoperative periods in the follow-up of this study: immediate postoperative (within one-month); one-year and two-year after the operation. Echocardiographic parameters (TR grade and right

atrial diameter) for each patient preoperatively and at all follow-up time points were saved on the data bank for analysis.

Statistical Analysis

IBM SPSS Statistics version 21.0 was used for statistical analysis. The non-normally distributed data were analyzed using the Mann-Whitney U test and Wilcoxon rank-sum test. Radit analysis was performed to study data variations within the groups. Normally distributed data were analyzed using student's *t-test* to compare and study the relationships of continuous variables between the groups. Categorical variables were presented as counts and percentages. The differences in categorical variables between patient groups were evaluated with the Chi-square test or Fisher exact test as appropriate. A $p\text{-}value < 0.05$ was considered to be significant.

Results

In a universe of 1005 patients who underwent concomitant TV repair, 483 (48.1%) received suture annuloplasty (Suture group) and 522 (51.9%) received ring annuloplasty (Ring group). The student's t-test was used to analyze the patients' demographics. The mean age at the time of surgery was 47.9 ±15.0 years (Ring group (50.6±12.7 years); Suture group (45.0±16.7)) and was significantly different between the groups ($p<0.05$). The study population was made of 376 (Ring group n=201 (53.5%), Suture Group n=175 (46.5%)) men and 629 (Ring group n=321 (51.0%), Suture Group n=308 (49.0%)) women. Gender was not statistically different between the groups ($p>0.05$). TR grades were scored as none/trace (1), mild (2), moderate (3), and severe (4). The patients' preoperative baseline characteristics are shown in table 1.

Radit analysis was performed for data variation within the groups. TR status in all the postoperative three time points of follow-up differed significantly with preoperative TR status within the Suture group. Among the 483 patients in the Suture group, 6 (1.2%) presented with none/trace TR, 189 (39.1%) had mild TR, 220 (45.5%) had moderate TR and 68 (14.1%) had severe TR, preoperatively. One-month after the surgery results showed 382 (79.1%) none/trace, 97 (20.1%) mild, 4 (0.8%) moderate and there was no severe TR among the subjects. The two time points (preoperative and postoperative One-month) TR grades were significantly different ($p<0.05$) (compare figures 1 and 2).

At one-year time point, there were 366 (75.2%) patients with none/trace TR, 108 (22.2%) mild, 11 (2.2%) moderate and 1 (0.2%) patient with severe TR. Although one-year time point TR status was significantly different from preoperative TR status ($p<0.05$), it did not differ significantly from the postoperative one-month period ($p>0.05$). Compare figure 3 with figures 1 and 2.

At two-year follow-up, the number of none/trace TR subjects was 309 (63.9%), 146 (30.1%) mild, 21 (4.4%) moderate, and 7 (1.4%) severe, showing a statistically significant difference not only to preoperative TR ($p<0.05$) but also to the postoperative periods of one-month ($p<0.05$) and one-year ($p<0.05$). Compare figure 4 with figures 1, 2, and 3.

The changes within the Ring group in the study four time periods were quite similar to the Suture group. Preoperative TR grades for the 522 patients in the Ring group were as follows: 1 (0.1%) none/trace, 96 (18.3%) mild, 250 (47.8%) moderate and 175 (33.5%) severe; At one-month follow-up, there were 378 (72.2%) none/trace, 128 (24.5%) mild, 12 (2.2%) moderate and 4 (0.8%) severe TR. Postoperative one-month and preoperative TR statuses within the Ring group were significantly different with a $p<0.05$.

At one-year time point, 370 (70.8%) patients had none/trace TR, 138 (26.3%) mild, 13 (2.5%) moderate and 1 (0.2%) patient with severe TR. These values differed significantly with preoperative TR status ($p<0.05$), but were similar with postoperative One-month time period ($p>0.05$). At two-year time point, TR grades distribution were: 334 (63.9%) none/trace, 156 (29.9%) mild, 28 (5.4%) moderate and 4 (0.6%) severe. This was significantly different with preoperative TR ($p<0.05$), One-month ($p<0.05$) and One-year ($p<0.05$). postoperative one-month.

Right Atrium diameter was another parameter analyzed in this study. Within the suture group, preoperative

mean RA diameter was 39.6±9.4 mm; after TV repair mean RA diameter was 34.3±6.9 mm, 32.6±7.6 mm, and 27.0±10.9 mm, one-month, one-year, and two-year, respectively. There was a significant statistical difference of each time point with the other three time points ($p<0.05$). In the same way, within the Ring group, preoperative mean RA diameter was 42.5±10.5 mm; after TV repair, mean RA diameter was 37.3±8.0 mm, 34.3±8.6 mm and 27.8±11.7 mm, one-month, one-year, and two-year, respectively; and each study time point significantly differed with the other three time points ($p<0.05$). Table 4 has the mean RA diameters for each group at the different time points with T and p values.

Data variation between the groups was analyzed using the Mann-Whitney U test and Wilcoxon rank-sum test. Preoperative TR grades were distributed as follows: in the Suture group (n=483), 6 (1.2%) patients had none/trace TR; 189 (39.1%) mild; 220 (45.5%) moderate; and 68 (14.1%) severe; in the Ring group (n=522), there was 1 (0.1%) patient with none/trace TR; 96 (18.3%) mild; 250 (47.8%) moderate; and 175 (33.5%) severe. There was a statistically significant difference in TR grades between the two groups preoperatively ($p<0.05$).

One-month after the procedure, echocardiographic follow-up showed 382 (79.1%) of the patients had none/trace TR, 97 (20.1%) mild, 4 (0.8%) moderate, and there was no severe TR in the Suture group; whereas, 378 (72.2%) patients had none/trace TR, 128 (24.5%) mild, 12 (2.2%) moderate, and 4 (0.8%) severe TR in the Ring group. TR severity was significantly different in both groups at one-month follow-up, with a$p<0.05$.

One-year follow-up TR grade distribution in the Suture group was: 363 (75.2%) none/trace, 108 (22.2%) mild, 11 (2.2%) moderate, and 1 (0.2%) severe; in the Ring group there were 370 (70.8%) none/trace, 138 (26.3%) mild, 13 (2.5%) moderate, 1 (0.2%) severe TR patient. There were similar TR grades in the two groups ($p>0.05$).

At two-year follow up, Suture group experienced the following changes: 309 (63.9%) none/trace, 146 (30.1%) mild, 21 (4.4%) moderate and 7 (1.4%) severe; and Ring group had 334 (63.9%) none/trace, 156 (29.9%) mild, 28 (5.4%) moderate and 4 (0.6%) severe TR. Equally, there was no significant difference between the two groups in this follow-up period ($p>0.05$). Table 3 and figures 1, 2, 3, and 4 illustrate TR changes across the study four time periods between the two groups.

Right Atrium diameter analysis between the groups showed a preoperative mean RA diameter of 39.6±9.4 mm in the Suture group, and 42.5±10.5 mm in the Ring group. The two groups' preoperative RA diameter was significantly different ($p<0.05$). At One-month follow-up, RA diameter significantly differed between the two groups (Suture group 34.3±6.9 mm; Ring group 37.3±8.0 mm;$p<0.05$); the same results were seen at one-year follow-up, Suture group 32.6±7.6 mm; Ring group 34.3±8.6 mm ($p<0.05$). However, at two-year, there were no statistical difference between the Suture group (27.0±10.9 mm) and Ring group (27.8±11.7 mm) regarding right atrial diameter ($p>0.05$).

Discussion

Data have shown that about 20% of patients having cardiac surgery have significant TR. American and European guidelines agree that severe TR should be treated in patients undergoing left-sided cardiac surgery.[2] Concomitant surgical intervention is also recommended for moderate TR with annular dilation of [?]4 cm and history of RV failure.[10] There is an old debate among experts about the optimal time for surgery and the kind of TV intervention. Should repair be favored over replacement? Is ring annuloplasty better than suture annuloplasty?

Despite the gaps in the guidelines and lack of a global consensus, some habits have been established over the years. Valve repair is typically preferred to avoid the risks of long-term anti-coagulation, valve thrombosis, or bio-prosthetic valve degeneration.[11] In addition, a repair can be accomplished rapidly during concomitant left-sided valve surgery. However, for primary TR, repair mainly depends on the degree of valve damage; replacement may show better results over repair in TR cases with severe valve lesions.[12] For functional TR, there is currently a clear tendency favoring valve repair. Although Marquis-Gravel et al. demonstrated a

higher occurrence of persistent severe TR after TV repair (13%) compared with TV replacement (2.%);[13] preference for repair over replacement is obvious, particularly when there is a high possibility that a good post-operative native valve function can be achieved.[14]

The ultimate goal of any TR repair technique is to restore leaflet coaptation. Severe TR frequently presents with annular dilation, and recent studies[15] suggest that ring annuloplasty be considered in such patients. Navia et al[8] did a retrospective analysis of 2277 patients who underwent TV surgery; they found a lower rate of recurrent TR with a ring annuloplasty compared with De Vega annuloplasty. On the other hand, the higher rate of annular dehiscence after the implantation of a rigid ring was reported in a study by Pfannmueller and colleagues.[6]

In the present study, we compared the results of echocardiographic evaluation between the patients that underwent suture annuloplasty and those that underwent ring annuloplasty.

TR status at different time points within the study groups showed statistically significant differences.

In the Suture group, for example, the proportion of none/trace TR changed from 1.2% preoperative to 79.1%, 75.2%, 63.9% postoperative, one-month, one-year, and two-year time periods, respectively; the same group had 14.1% preoperative severe TR that postoperatively changed to 0.0%, 0.2% and 1.4% in one-month, one-year and two-year respectively. With exception of one-year follow-up compared to one-month follow-up ($p>0.05$), each follow-up time point is significantly different from the previous time points ($p<0.05$).

On the other hand, the proportion of none/trace TR in the Ring group changed from 0.1% preoperatively to 72.2%, 70.8%, 63.9%, one-month, one-year, and two-year time period, respectively; the same group had 33.5% preoperative severe TR that changed postoperatively to 0.8%, 0.2% and 0.6% at one-month, one-year and two-year, respectively. Similarly, except for one-year compared to one-month follow-up ($p>0.05$), each time point was significantly different from the previous time points ($p<0.05$). The suture group showed greater change towards worse TR grades over time compared to the Ring group (table 3).

Right Atrium diameter measurements in the four time points followed similar changes with TR severity.

Within the Suture group, mean RA diameter progressively became smaller at all follow-up time points, and each time point was statistically different from the previous ones ($p<0.05$). The same pattern was observed within the Ring group. RA diameter at any time point was statistically different from each of the previous time points ($p<0.05$).

Data analysis between the groups showed a statistically significant difference in the preoperative TR grades. The Ring group was significantly worse than the Suture group TR status *($p<0.05$).* 40.3% of patients in the suture group had only trace or mild TR, whereas in the Ring group this accounts for 18.4%. Severe TR was 14.0% of all the Suture group, in contrast, it accounts for 33.5% in the Ring group. Besides, RA diameter (table 4) equally showed statistical differences between the two groups ($p<0.05$). This can be explained by the fact that, generally, more severe cases of TR receive ring annuloplasty. These patients normally present with pulmonary hypertension, severe annular dilation, and right heart remodeling. Being a retrospective study, this research could not manipulate preoperative variables or interfere with patient selection criteria.

There is also a difference in age between the two groups *($p<0.05$),* and this is because ring annuloplasty is mostly performed in older patients whereas suture annuloplasty is mostly reserved for younger ones. There is no difference observed concerning gender distribution between the groups *($p>0.05$).*

At One-month follow-up, both groups' TR status improved significantly. 79.1% of the patients in the Suture group presented with none/trace TR, in the Ring group 72.2% showed none/trace TR. The severe TR cases at this time point are below 1.0% in each group (0.0% for the Suture group and 0.8% for the Ring group). The two groups significantly differed One-month postoperative *($p<0.05$),* with the Suture group having better outcomes. We believe this difference is the result of better preoperative conditions in the Suture group (less severe TR grades and younger age). The two groups equally experienced a reduction in the RA diameter, which is significantly better than preoperative condition ($p<0.05$).

At one-year after the surgery, 75.2% of the patients in the Suture group presented with none/trace TR, in the Ring group 70.8% showed none/trace TR. Severe TR was 0.2% in the Suture group and 0.2% in the Ring group. TR status showed no statistically significant difference between the groups *(p>0.05).* Despite the Suture group having a better outcome at one-month, the outcome at one-year was similar for both groups, showing a progressive deterioration of the suture techniques as time passes. But concerning RA diameter, further reduction was seen in the two groups.

Just like at one-year, two-year follow-up TR status showed no statistically significant difference between the groups ($p>0.05$). At this time point, none/trace TR proportion is equal in both groups (63.9%). Severe TR was 1.4% and 0.6% in the Suture group and Ring group, respectively. At the two-year follow-up, RA diameter equally did not differ between the groups ($p>0.05$).

The improvement of TR status, after surgical repair, was accompanied by a reduction in RA diameter in both groups at the three follow-up time points. One-month and one-year mean RA diameters were all significantly different in the two groups ($p<0.05$). However, at two-year, the mean RA diameter was similar in the two groups. This confirmed the idea that Suture group TR status deteriorated faster than the Ring group, causing previously different mean RA diameters to become similar at two years follow-up. These findings coincided with the variation of TR grades at two years follow-up. Many studies have reported similar findings in regards to the outcome and durability of suture annuloplasty.[16] [17]

We believe that ring annuloplasty had better outcomes at two-year follow-up, in part, because prosthetic rings could better restrict annular dilation, keep its diameter relatively constant, and slowdown the progress of TR. Moreover, modern rings have a 3D shape, which tries to replicate native TA geometrical structure. This enables it to fit in the annulus in a constant systolic position, restore its physiologic shape, prevent annular deformation, and warrant a harmonized functioning of the prosthetic and native TA.[18] This cannot be achieved with suture annuloplasty. Besides, the classical De Vega technique has the disadvantage of suture detachment[19]from the tissue, thus failing to promote proper leaflet coaptation and prevent future annular dilation.

Conclusion

Both annuloplasty techniques have good short-term outcomes, resulting in the improvement of TR status accompanied by a reduction of the RA diameters. However, long-term durability with suture annuloplasty is not as good as ring annuloplasty. Our study finds greater and faster deterioration of TR grades among the patients in the Suture group over time. Whereas the deterioration in the Ring group is slower and stable across three time periods of follow-up, therefore we suggest the use of ring annuloplasty for TV repair.

Limitations

The findings of the present study may be limited by the fact that our conclusions are derived exclusively from the analysis of echocardiographic parameters, and also because of the relatively short follow-up time (2 years). Future studies, in which combined ultrasound and clinical data are analyzed, and with longer follow-up periods, can, in a better way, redeem the limitations of the present study.

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Disclosures

The authors declares that there is no conflict of interest.

References

1. Topilsky Y, Maltais S, Medina Inojosa J, Oguz D, Michelena H, Maalouf J, Mahoney DW, et al. Burden of Tricuspid Regurgitation in Patients Diagnosed in the Community Setting. *JACC Cardiovasc Imaging.*2019;12(3):433-42.
2. Arsalan M, Walther T, Smith RL 2nd, Grayburn PA. Tricuspid regurgitation diagnosis and treatment.*Eur Heart J.* 2017;38(9):634-8.
3. Bohbot Y, Chadha G, Delabre J, Landemaine T, Beyls C, Tribouilloy C. Characteristics and prognosis of patients with significant tricuspid regurgitation. *Arch Cardiovasc Dis.* 2019;112(10):604-14.
4. Singh JP, Evans JC, Levy D, Larson MG, Freed LA, Fuller DL, et al. Prevalence and clinical determinants of mitral, tricuspid, and aortic regurgitation (the Framingham Heart Study). *Am J Cardiol.* 1999;83(6):897-902.
5. McCarthy PM, Bhudia SK, Rajeswaran J, Hoercher KJ, Lytle BW, Cosgrove DM, et al. Tricuspid valve repair: durability and risk factors for failure.*J Thorac Cardiovasc Surg.* 2004;127(3):674-85.
6. Pfannmuller B, Doenst T, Eberhardt K, Seeburger J, Borger MA, Mohr FW. Increased risk of dehiscence after tricuspid valve repair with rigid annuloplasty rings. *J Thorac Cardiovasc Surg.* 2012;143(5):1050-5.
7. Tang GHL. Tricuspid Clip: Step-by-Step and Clinical Data. *Interv Cardiol Clin.* 2018;7(1):37-45.
8. Navia JL, Nowicki ER, Blackstone EH, Brozzi NA, Nento DE, Atik FA, et al. Surgical management of secondary tricuspid valve regurgitation: annulus, commissure, or leaflet procedure? *J Thorac Cardiovasc Surg.*2010;139(6):1473-82.e5.
9. Kunova M, Frana R, Toušek F, Mokráček A, Pešl L. Tricuspid annuloplasty using De Vega modified technique – Short-term and medium-term results. *Coretvasa.*2016;58:379-83.
10. Buzzatti N, De Bonis M, Moat N. Anatomy of the Tricuspid Valve, Pathophysiology of Functional Tricuspid Regurgitation, and Implications for Percutaneous Therapies.*Interv Cardiol Clin.* 2018;7(1):1-11.
11. McCartney SL, Taylor BS, Nicoara A. Functional Tricuspid Regurgitation in Mitral Valve Disease. *Semin Cardiothorac Vasc Anesth.*2019;23(1):108-22.
12. Al-Hijji M, Fender EA, El Sabbagh A, Holmes DR. Current Treatment Strategies for Tricuspid Regurgitation. *Curr Cardiol Rep.* 2017;19(11):106.
13. Marquis-Gravel G, Bouchard D, Perrault LP, Pagé P, Jeanmart H, Demers P, et al. Retrospective cohort analysis of 926 tricuspid valve surgeries: clinical and hemodynamic outcomes with propensity score analysis.*Am Heart J.* 2012;163(5):851-8.
14. Kilic A, Saha-Chaudhuri P, Rankin JS, Conte JV. Trends and outcomes of tricuspid valve surgery in North America: an analysis of more than 50,000 patients from the Society of Thoracic Surgeons database.*Ann Thorac Surg.* 2013;96(5):1546-52.
15. El-Eshmawi A, Pandis D, Adams DH, Tang GH. Tricuspid valve surgery: repair and replacement. *Minerva Cardioangiol.* 2018;66(6):700-12.
16. Bernal JM, Gutiérrez-Morlote J, Llorca J, San José JM, Morales D, Revuelta JM. Tricuspid valve repair: an old disease, a modern experience. *Ann Thorac Surg.*2004;78(6):2069-74.
17. Huang X, Gu C, Men X, Zhang J, You B, Zhang H, et al. Repair of functional tricuspid regurgitation: comparison between suture annuloplasty and rings annuloplasty.*Ann Thorac Surg.* 2014;97(4):1286-92.
18. Carpentier A, Deloche A, Hanania G, Forman J, Sellier P, Piwnica A, et al. Surgical management of acquired tricuspid valve disease. *J Thorac Cardiovasc Surg.*1974;67(1):53-65.
19. Belluschi I, Del Forno B, Lapenna E, Nisi T, Iaci G, Ferrara D, et al. Surgical Techniques for Tricuspid Valve Disease. *Front Cardiovasc Med.* 2018;5:118.

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