Minimally Invasive Isolated Tricuspid Valve Repair: the Trend for Redo Tricuspid Valve Surgery

Xiaoyi Dai
the First Affiliated Hospital, College of Medicine, Zhejiang university
Peng Teng
The First Affiliated Hospital, College of Medicine, Zhejiang University
Sihan Miao
the first affiliated hospital, college of medicine, Zhejiang university
Wei Si
First Hospital of Zhejiang Province: Zhejiang University School of Medicine First Affiliated Hospital
Qi Zheng
Zhejiang Provincial First Hospital: Zhejiang University School of Medicine First Affiliated Hospital
Ke Qin
First Hospital of Zhejiang Province: Zhejiang University School of Medicine First Affiliated Hospital
Liang Ma (ml1402@zju.edu.cn)
Department of Cardiovascular Surgery, the First Affiliated Hospital, College of Medicine, Zhejiang University https://orcid.org/0000-0001-8054-4582

Research article

Keywords: Tricuspid valve repair, Minimally invasive, Redo, Surgery

Posted Date: April 19th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-410036/v1

Abstract

Background: Tricuspid regurgitation after left-sided valve surgery was associated with terrible outcomes and high perioperative mortality for redo surgical treatment. In current years, minimally invasive redo isolated tricuspid valve repair is increasingly performed in our institution to address tricuspid regurgitation.

Methods: Thirty-seven consecutive patients with previous left-sided valve surgery underwent minimally invasive redo isolated tricuspid valve repair in our institution between November 2017 and December 2020. Twenty-nine patients(78.4%) were women and the mean age of patients was 58.4±8.5 years. Follow-up was 100% complete with a mean follow-up time of 16.8±9.4 months.

Results: Both the in-hospital and 30-day mortalities were 2.7%. The overall NYHA class had improved significantly during the follow-up(p□0.001). The grade of TR had decreased before discharge(p□0.001) and during the follow-up(p□0.001) compared with the preoperative level although severe TR was recurrent in one patient.

Conclusions: Minimally invasive redo isolated tricuspid valve repair has remarkable early and midterm outcomes, may be the preferred surgical option to address tricuspid regurgitation after previous left-sided valve surgery when it is feasible.

Background

Tricuspid regurgitation(TR), associated with terrible outcomes, is affecting more than 1.6 million people in the USA[1]. The prevalence of moderate-to-severe TR is estimated to be as high as 0.55% and up to 3% after 75 years old and it becomes increasingly common after rheumatic heart disease[2, 3], which was prevalent in China. As a result, many patients have undergone the left-sided valve surgery, including mitral valve replacement(MVR), aortic valve replacement(AVR) or both. When symptomatic TR occurred, they had to choose conservative therapy instead of reoperation in the past due to the fear of re-median sternotomy and the high perioperative mortality of isolated tricuspid valve surgery[4, 5].

With the advancement of surgical approaches, minimally invasive access via a light lateral thoracotomy has been applied in cardiac surgeries, making these patients more willing to accept redo surgery. The strategies of isolated tricuspid valve surgery includes tricuspid valve replacement(TVR) and tricuspid valve repair(TVr), which one is better remaining inconclusive. Although TVR has been widely applied in researches have been reported[6–9],some researchers deem that TVr would be the trend in the future[6, 10]. Minimally invasive isolated TVr is increasingly performed in our institution to address TR after previous left-sided valve surgery. Herein, we share our experience and aim to evaluate the early and midterm outcomes of minimally invasive redo isolated TVr.

Patients And Methods

Between November 2017 and December 2020, a total of 37 patients underwent minimally invasive redo isolated TVr via a light lateral thoracotomy in our institution. All patients who had undergone previous left-sided valve surgery(including concomitant tricuspid valvuloplasty)(Table 1) accepted isolated TVr due to symptomatic TR meeting the inclusion criteria. Twenty-nine patients(78.4%) were women and the mean age of patients was 58.4 ± 8.5 years. The Ethics Committee of the First Affiliated Hospital, College of Medicine, Zhejiang University approved this retrospective study and individual patient informed consent was not required.

Table 1
Previous left-sided valve surgeries

Previous surgery	All patients(n = 37)
MVR	15 (40.5%)
MVR + AVR	19 (51.4%)
MVR + TVP	1 (2.7%)
MVR + AVR + TVP	1 (2.7%)
AVR	1 (2.7%)
MVR: mitral valve replacement; AVR: aortic valve replacement; TVP: tricuspid valvuloplasty.	

Surgical procedure

All operations were performed on the standard procedure but slightly different according to surgeon's preference. Patients were positioned supine with a 30° elevation on the right side. After the heparinization level reached the target, cardiopulmonary bypass(CPB) was established through femoral arterial and venous cannulation. The femoral artery was usually cannulated with a 16 or 18Fr arterial perfusion cannula(Edwards Lifesciences, USA) and the femoral vein was cannulated with a 22 or 24Fr venous cannula(Edwards Lifesciences, USA). Then adjusted the position of femoral venous cannula until its proximal end arrived at the inferior vena cava ostium with the detection of transesophageal echocardiography.

A 4-6cm right anterolateral thoracotomy was performed over the fourth intercostal area and then simply separated the adhesions from the anterior chest wall(if any). When the activated clotting time value≥480s, CPB was started and complete venous drainage was achieved with vacuum-assistance. The right atrium was incised directly together with the pericardium instead of separating the pericardial adhesions due to the previous cardiac surgery. Kept the balance of arterial inflow and venous drainage to ensure the venous return plane in the right atrium was below the tricuspid annulus.

In order to expose the surgical filed better, a shunt tube[11](generally 34Fr, 12cm) made by common vena caval drainage cannula would be used sometimes. One end of that was placed into the superior vena

cava and the other end was connected to the head of the femoral vein cannula. The blood flow in the right atrium was significantly reduced by draining the superior and inferior vena cava separately through the shunt tube.

With the assistance of thoracoscopy, all procedures of TVr were performed on the beating heart with normothermic CPB. Based on the surgeon's preference, a SOVERING™ band(Sorin Group Italia S.r.l, Italy) or an Edwards MC3 annuloplasty ring(Edwards Lifesciences, USA) of suitable size(28# to 34#) was always implanted to correct the annular dilation by continuous suture usually, simultaneously plicating the posterior leaflet annulus. Following that, saline was injected into the right ventricle to test valvular competence. If the tricuspid leaflets coaptation was still unsatisfactory, then we would apply the "edge-to-edge" suture of the anterior and septal leaflets[12] or stitch together the midpoint of the free edges of the tricuspid leaflets producing a "clover" shaped valve[13].

Follow-up

After discharge, all patients or their family members were contacted by telephone and inquired about the recent physical conditions to evaluate the New York Heart Association(NYHA) functional class. The follow-up was 100% complete with a mean time of 16.8 ± 9.4 months(range, 3–40 months). Additionally, we asked all patients for a periodical echocardiography to detect the grade of TR, whether it was performed in the local hospital or our institution. The most recently postoperative echocardiographic report was available in 77.8% of the surviving patients(n = 36) with a mean follow-up time of 15.3 ± 10.4 months(range, 1–39 months).

Statistical analysis

Categorical variables were presented as frequency distributions and percentages, and continuous variables were expressed as mean ± standard deviation. The Wilcoxon signed rank test was used to compare the difference between the preoperative and follow-up NYHA class and TR grade. A *p*-value less than 0.05 was considered to be statistically significant. All statistical analyses were performed by IBM SPSS Statistics for Windows, Version 26.0(IBM Corp., Armonk, NY, USA).

Results

The baseline information and clinical characteristics of patients are depicted in the Table 2. The average time to previous cardiac surgery was 13.1 ± 5.0 years, among that the longest time was 25 years. Twenty-six patients(70.3%) belonged to NYHA class III and IV. Almost all patients(91.9%) had developed atrial fibrillation, making it the most common comorbidity. Most patients complained about chest tightness/anhelation and legs edema, and hepatomegaly and ascites detected by abdominal ultrasound were found in 16(43.2%) and 4 patients(10.8%) respectively. All patients had moderate-severe(21.6%) or severe(78.4%) TR and the mean tricuspid annular plane systolic excursion(TAPSE) was 16.6 ± 3.0 mm, suggesting the severe degeneration of right ventricular function.

Table 2
Baseline characteristics

Variables	All patients(n = 37)
Age(years)	58.4 ± 8.5 (32 to72)
Time to last operation(years)	13.1 ± 5.0 (2 to 25)
Female	29 (78.4%)
NYHA class III and IV	26 (70.3%)
Comorbidities	
Permanent pacemaker	4 (10.8%)
Hypertension	8 (21.6%)
Diabetes mellitus	4 (10.8%)
Coronary artery disease	3 (8.1%)
Atrial fibrillation	34 (91.9%)
Anemia	13 (35.1%)
Physical examination	
Chest tightness/anhelation	26 (70.3%)
Legs edema	26 (70.3%)
Hepatomegaly	16 (43.2%)
Ascites	4 (10.8%)
Echocardiography	
LVEF (%)	63.1 ± 7.3
PASP (mmHg)	46.8 ± 8.9
TAPSE (mm)	16.6 ± 3.0
Grade of TR	
Moderate-severe	8 (21.6%)
Severe	29 (78.4%)
Laboratory data	
TB (μmol/L)	20.6 ± 16.2

NYHA: New York Heart Association; LVEF: left ventricular ejection fractions; PASP: pulmonary artery systolic pressure; TAPSE: tricuspid annular plane systolic excursion TB: total bilirubin; BUN: blood urea nitrogen; Cre: creatinine

Variables	All patients(n = 37)
BUN (mmol/L)	7.6 ± 2.3
Cre (μmol/L)	77.0 ± 24.2
NYHA: New York Heart Association; LVEF: left ventricular ejection fractions; PASP: pulmonary artery systolic pressure; TAPSE: tricuspid annular plane systolic excursion TB: total bilirubin; BUN: blood urea nitrogen; Cre: creatinine	

Table 3 presents the detailed intraoperative and postoperative outcomes of patients. Except one patient(2.7%) died quickly after the surgery due to acute myocardial infarction intraoperatively and further heart and kidney dysfunction, other 36 patients(97.3%) accepted minimally invasive redo TVr successfully. The mean operation time was 151 ± 47.7 minutes and CPB time was 61.3 ± 21.7 minutes. No one conversed to sternotomy but 4 patients(10.8%) underwent re-exploration for bleeding, all of which were caused by incomplete hemostasis during the surgery. Prolonged ventilation, defined as requirement for ventilator assistance more than 72 hours, was needed in 4 patients(10.8%). Patients stayed at intensive care unit(ICU) for 3.4 ± 2.2 days and the duration of postoperative hospital stay was 9.7 ± 3.8 days. All postoperative complications including III° atrioventricular block(AVB), cerebral infarction and hemodialysis appeared in the same patient. Thirty-six patients(97.3%) were discharged finally and had an uneventful recover in the subsequent 30-day follow-up, so the in-hospital mortality and 30-day mortality were both 2.7%.

Table 3
Surgical details and postoperative outcomes

Variables	All patients(n = 37)
Operation time(min)	151.4 ± 47.7
CPB time(min)	61.3 ± 21.7
Drainage volume(ml)	333.1 ± 251.7
Re-exploration for bleeding	4 (10.8%)
Conversion to sternotomy	0
Prolonged ventilation	4 (10.8%)
Duration of ICU stay(d)	3.4 ± 2.2
Duration of hospital stay(d)	9.7 ± 3.8
Complications	
III°AVB	1 (2.7%)
Cerebral infarction	1 (2.7%)
Hemodialysis	1 (2.7%)
In-hospital mortality	1 (2.7%)
30-day mortality	1 (2.7%)
CPB: cardiopulmonary bypass; ICU: intensive care unit; AVB: atrioventricular block.	

Table 4 shows the preoperative NYHA class of all patients(n = 37) and the present NYHA class of the surviving patients(n = 36). Overall, NYHA class had improved during the follow-up(p<0.001). Significant improvement of NYHA class was found in 26 patients(72.2%) compared with their preoperative status whereas the deterioration to NYHA class IV from II was seen in 1 patient(2.8%).

Table 4
Preoperative and follow-up NYHA functional Class

NYHA class	I	II	III	IV
Preoperative(n = 37)	2 (5.4%)	9 (24.3%)	20 (54.1%)	6 (16.2%)
Follow-up(n = 36)	18 (50.0%)	12 (33.3%)	4 (11.1%)	2 (5.6%)

Table 5
Echocardiographic results before surgery, before discharge and at follow-up

Grade of TR	1+	2+	3+	4+
Preoperative (n = 37)	0	0	8 (21.6%)	29 (78.4%)
Predischarge (n = 36)	28 (77.8%)	8 (22.2%)	0	0
Follow-up (n = 28)	19 (67.9%)	6 (21.4%)	2 (7.1%)	1 (3.6%)

The most recent echocardiographic data with a mean follow-up time of 15.3 ± 10.4 months is available in 77.8% of the surviving patients(n = 36), which is collected in Table 5 with the preoperative and predischarge echocardiographic results. TR was graded as 1 + for mild, 2 + for moderate, 3 + for moderate-severe and 4 + for severe. Before hospital discharge, it could be readily seen that the grade of TR had decreased significantly(p<0.001) and there was no patient of ≥ 3 + TR. However, residual moderate TR was detected in 8 patients(22.2%) after TVr, 87.5% of whose follow-up echocardiographic data was retrieved, revealing that the grade of TR was decreasing in 4 patients(57.1%), stable in 2 patients(28.6%) but worsening to 4 + in 1 patient(14.3%). Overall, the grade of TR had decreased during the follow-up(p<0.001) compared with the preoperative level, although recurrent severe TR was seen in 1 patient, who chose conservative treatment instead of reoperation to address recurrent TR.

Discussions

Currently, TVR has been more widely adopted while TVr is regarded as the first choice in our institution. Our experience with this patient series demonstrates that patients undergoing minimally invasive redo isolated TVr have remarkable early and midterm outcomes, suggesting that TVr may be the preferred surgical option when it is feasible.

When it came to the isolated tricuspid valve surgery, the appropriate surgical timing was always an unavoidable topic. We advocated that surgical intervention was generally prohibited when TAPSE < 15mm or PASP > 60mmHg. Diuretic-based medical treatment was given to these patients to relieve the volume overload of the right ventricle and the surgery was not supposed to be carried out until the right heart function had improved to meet the surgical indications.

The reported perioperative mortality of redo isolated TV surgeries ranged from 4.2–37%[4, 5, 14, 15] while ours was only 2.7%, which may be credited to the advancement of minimally invasive access, accumulation of surgeons' experience and improvement of perioperative management. It was reported that some postoperative outcomes of TVR, including the 30-day mortality, the rates of permanent pace maker implant and stroke were higher than those of TVr[16]. This study showed that TVr seemed to have a slight advantage over TVR in the rate of postoperative complications compared with the similar research[7]. In addition, the CPB time and operation time required for TVr were relatively shorter, the possible reasons were as follows: 1)the venous drainage assisted with our self-made shunt tube

simplified the procedure and improved the operative efficiency by avoiding the vena cava exposition and snare, and the time-consuming superior vena cava cannulation; 2)the time required for an annuloplasty ring implantation was shorter than that for a prosthetic valve naturally. The shorter CPB and operation time might lead to the less duration of ICU stay and hospital stay. However, the sample sizes of these studies were not large enough, so the results should be extrapolated with caution.

TVr had excellent performance in addressing TR and improving heart function. The recurrence rate of severe TR before discharge in this study was zero, much lower than the ever reported 12.5%—14%[5, 15], which was attributed to the immature repair techniques and non-optimal annuloplasty rings at that time in a large extent. Our redo TVr procedure also showed considerable midterm outcomes in maintaining tricuspid competency for only one patient recurred severe TR in the follow-up, which may be related to uniformly-stressed continuous suture, not easy to avulse from the annulus. Although the TR recurrence rate of redo TVr had been reported higher in short term[15, 17], whether the bioprosthetic valve with limited durability was more favorable in maintaining tricuspid competency in long term had not been well proven. Additionally, most patients improved their NYHA class greatly but approximately one quarter did not after TR correction, which might be related to the late timing of surgical intervention.

The choice of TVR or TVr has generated much debate. It was reported that there was no significant difference in postoperative NYHA class improvement and right ventricular function maintenance between redo TVR and TVr[17]. Thus, we preferred TVr to TVR due to the high risks of prosthetic thrombosis, excessive anticoagulation, bioprosthetic valve degeneration and the higher rate of postoperative atrioventricular block[16, 18]. Moreover, TVr retained all the chordae chordomas of the TV and preserved a better structural integrity of the right ventricle. However, we have to choose TVR in patients with severe leaflet damage, extreme annular dilation or previous failed TVr.

At present, the selection of mechanical valve versus bioprosthetic valve in TVR remains controversial. Actually, four redo mechanical TVRs had been performed in our institution in the early years, when the bioprosthetic valve degeneration was considered as a tricky situation in relatively young patients due to the percutaneous tricuspid intervention technique was immature. Pfannmüller[15] held the view that if TVR was inevitable, biological prostheses should be routinely used regardless of patient age, even in patients with previously implanted mechanical valves to avoid excessive anticoagulation. We approved his concept, which was also supported by some researches[6–8] with high application rate of biological prostheses. In fact, the mechanical valve was more prone to thrombosis in the tricuspid position due to the lower pressures and velocities[19] whereas the bioprosthetic valve obtained better durability therefore. Additionally, it would be exceptionally difficult for pacemaker placement and right heart catheterization after a mechanical tricuspid valve implantation.

Study limitation

The study certainly has some significant limitations. The population is small because lots of symptomatic TR patients after previous left-sided valve surgery are inclined to conservative treatment

instead of undergoing the redo isolated TV surgery, which also results in the failure of univariable and multivariable logistic regression analysis for operative mortality and composite adverse outcomes. Another limitation is the short follow-up time and no deaths during this period, incapable to predict the 5-year survival. What's more, the retrieved echocardiographic data only represents the early effect of TVr but the long-term effect is what we truly care about. Besides, we cannot assess the procedure comprehensively due to some important data like the values of PASP and TAPSE are mostly missing. However, to our best know, our cohort represents one of the largest series of minimally invasive redo isolated TVr via a right thoracotomy reported to date.

Conclusions

Minimally invasive isolated redo TVr is a safe and effective procedure to address TR after previous left-sided valve surgery, with low perioperative mortality and remarkable early and midterm outcomes. When TVr is feasible, it can be regarded as the preferred surgical option.

Abbreviations

TR: Tricuspid regurgitation

TVR: Tricuspid valve replacement

TVr: Tricuspid valve repair

MVR: Mitral valve replacement

AVR: Aortic valve replacement

TVP: Tricuspid valvuloplasty

CPB: Cardiopulmonary bypass

NYHA: New York Heart Association

TAPSE: Tricuspid annular plane systolic excursion

ICU: Intensive care unit

AVB: Atrioventricular block

PASP: Pulmonary atrial systolic pressure

Declarations

Acknowledgements

Not applicable

Authors' contributions

(I) Study design: LM, XYD, PT; (II) Data collection and analysis: XYD, PT, SHM, WS; (III) Manuscript writing: XYD, PT, QZ, KQ;

Funding

None

Ethics approval and consent to participate

This study was approved by the Ethics Committee of the First Affiliated Hospital, College of Medicine, Zhejiang University(Hangzhou, China). It was a retrospective study and the individual patient informed consent was not required.

Consent for publication

All authors read and approved the final manuscript and agreed to submit it for consideration for publication in your journal.

Availability of data and materials

Not applicable

Competing interests

The authors declared that they had no competing interests.

References

1. Fender EA, Zack CJ, Nishimura RA. **Isolated tricuspid regurgitation: outcomes and therapeutic interventions**. *Heart* 2018; 104(10):798-806.
2. Topilsky Y, Maltais S, Medina Inojosa J, Oguz D, Michelena H, Maalouf J, et al. **Burden of Tricuspid Regurgitation in Patients Diagnosed in the Community Setting**. *JACC Cardiovasc Imaging* 2019; 12(3):433-442.
3. Zhu TY, Min XP, Zhang HB, Meng X. **Preoperative Risk Factors for Residual Tricuspid Regurgitation after Isolated Left-Sided Valve Surgery: A Systematic Review and Meta-Analysis**. *Cardiology* 2014; 129(4):242-249.
4. Chen J, Abudupataer M, Hu K, Maimaiti A, Lu S, Wei L, et al. **Risk factors associated with perioperative morbidity and mortality following isolated tricuspid valve replacement**. *J Surg Res* 2018; 221:224-231.

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):674-685.
6. Fang L, Li W, Zhang W, Gu W, Zhu D. **Mid-term results and risks of isolated tricuspid valve reoperation following left-sided valve surgery**. *Eur J Cardiothorac Surg* 2018; 53(5):1034-1039.
7. Lu S, Song K, Yao W, Xia L, Dong L, Sun Y, et al. **Simplified, minimally invasive, beating-heart technique for redo isolated tricuspid valve surgery**. *J Cardiothorac Surg* 2020; 15(1):146.
8. Chen J, Hu K, Ma W, Lv M, Shi Y, Liu J, et al. **Isolated reoperation for tricuspid regurgitation after left-sided valve surgery: technique evolution**. *Eur J Cardiothorac Surg* 2020; 57(1):142-150.
9. Dreyfus J, Flagiello M, Bazire B, Eggenspieler F, Viau F, Riant E, et al. **Isolated tricuspid valve surgery: impact of aetiology and clinical presentation on outcomes**. *Eur Heart J* 2020; 41(45):4304-4317.
10. Bashore TM, Serfas JD. **Isolated Tricuspid Valve Surgery**. *J Am Coll Cardiol* 2017; 70(24):2961-2963.
11. Wu S, Ma L, Li C, Ni Y. **Optimizing Venous Drainage for Minimal Access Right Atrial Procedures**. *Ann Thorac Surg* 2019; 108(5):e337-e338.
12. Castedo E, Canas A, Cabo RA, Burgos R, Ugarte J. **Edge-to-Edge tricuspid repair for redeveloped valve incompetence after DeVega's annuloplasty**. *Ann Thorac Surg* 2003; 75(2):605-606.
13. De Bonis M, Lapenna E, La Canna G, Grimaldi A, Maisano F, Torracca L, et al. **A novel technique for correction of severe tricuspid valve regurgitation due to complex lesions**. *Eur J Cardiothorac Surg* 2004; 25(5):760-765.
14. Kwon DA, Park JS, Chang HJ, Kim YJ, Sohn DW, Kim KB, et al. **Prediction of outcome in patients undergoing surgery for severe tricuspid regurgitation following mitral valve surgery and role of tricuspid annular systolic velocity**. *Am J Cardiol* 2006; 98(5):659-661.
15. Pfannmuller B, Misfeld M, Borger MA, Etz CD, Funkat AK, Garbade J, et al. **Isolated reoperative minimally invasive tricuspid valve operations**. *Ann Thorac Surg* 2012; 94(6):2005-2010.
16. Zack CJ, Fender EA, Chandrashekar P, Reddy YNV, Bennett CE, Stulak JM, et al. **National Trends and Outcomes in Isolated Tricuspid Valve Surgery**. *J Am Coll Cardiol* 2017; 70(24):2953-2960.
17. Scherptong RW, Vliegen HW, Winter MM, Holman ER, Mulder BJ, van der Wall EE, et al. **Tricuspid valve surgery in adults with a dysfunctional systemic right ventricle: repair or replace?** *Circulation* 2009; 119(11):1467-1472.
18. Hwang HY, Kim KH, Kim KB, Ahn H. **Treatment for severe functional tricuspid regurgitation: annuloplasty versus valve replacement**. *Eur J Cardiothorac Surg* 2014; 46(2):e21-27.
19. Mangoni AA, DiSalvo TG, Vlahakes GJ, Polanczyk CA, Fifer MA. **Outcome following isolated tricuspid valve replacement**. *Eur J Cardiothorac Surg* 2001; 19(1):68-73.