

Cite this article as: Köksal C, Selçuk E, Kahveci G, Erdem H. A novel approach of tricuspid valve repair: mitralization of tricuspid valve. *Interact CardioVasc Thorac Surg* 2022; doi:10.1093/icvts/ivac049.

A novel approach of tricuspid valve repair: mitralization of tricuspid valve

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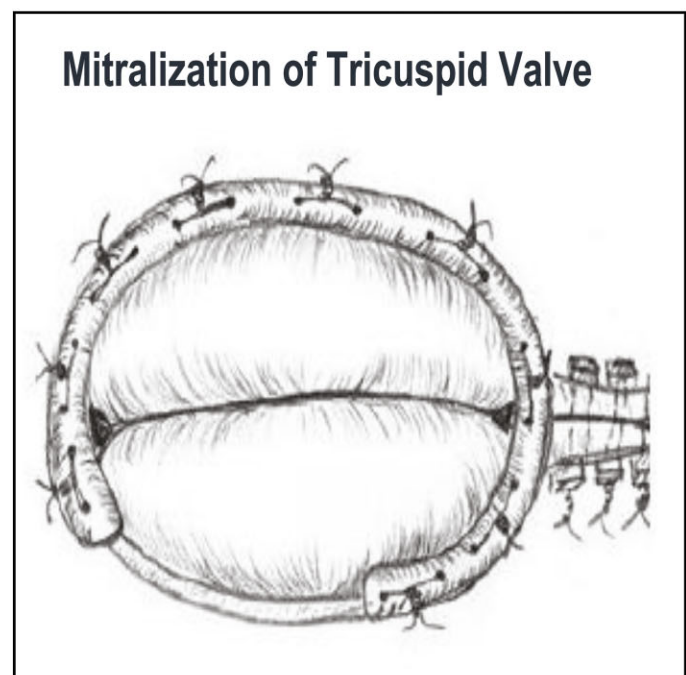
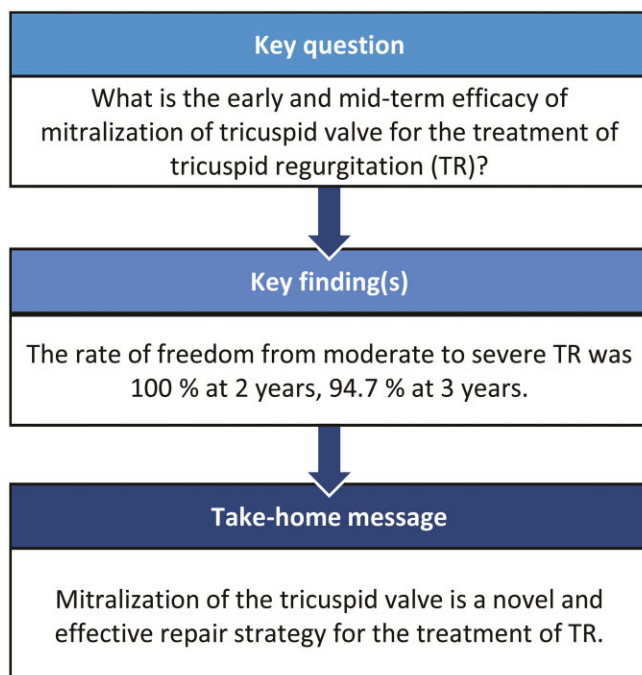
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Received 4 October 2021; received in revised form 14 February 2021; accepted 3 March 2022



Abstract

OBJECTIVES: This study presents the mid-term results of a novel tricuspid valve (TV) repair strategy defined as ‘mitralization of TV’ (resection and plication of the posterior leaflet, ring implantation, optional leaflet procedures) applied for the correction of tricuspid regurgitation (TR).

METHODS: Between 2017 and 2020, a total of 22 patients underwent concomitant TV repair using mitralization of the TV. Fourteen of the patients had functional TR (2 of them had severe tethering), 5 patients had prolapse and 3 patients had rheumatic involvement.

RESULTS: There was no in-hospital mortality. Moderate or severe TR was not observed in any patient in echocardiographic evaluations before discharge. The mean follow-up duration was 30.9 + 6.2 months. Moderate-to-severe TR-free survival was 100% in the second year and 94.7% in the third year.

CONCLUSIONS: Mitralization of the TV is a safe and effective treatment modality in terms of its mid-term results. This new technique provides an innovative perspective for the treatment of TR, especially in complex TV pathologies.

Keywords: Tricuspid regurgitation • Tricuspid valve repair • Treatment outcomes

ABBREVIATIONS

RV	Right ventricle
TR	Tricuspid regurgitation
TV	Tricuspid valve

INTRODUCTION

Moderate or severe tricuspid regurgitation (TR) is not an uncommon pathology, which is also characterized by poor prognosis [1]. A concomitant tricuspid valve (TV) repair during left-sided valve surgery has been shown to increase long-term survival without increasing operative mortality [2, 3]. A recent meta-analysis revealed that mild-to-moderate TR may also progress in the long term, despite the correction of left-sided heart pathologies [4]. Indications for TV interventions have expanded in line with current prognostic data. Today, achieving excellent valve performance and improving durability remain a major concern for all tricuspid repair methods [5, 6].

The overall rate of recurrent TR after successful repair in the long term has been reported to be around 40% [6, 7]. According to recent reports, rigid prosthetic ring annuloplasty has become popular rather than other techniques with good durability [6]. Although ring annuloplasty with three-dimensional rings is promising in terms of performance and durability, recurrent TR has been reported in 5–10% of patients in the early period [8, 9]. In addition, combinations of defined methods or novel repair methods are required to succeed in advanced TV repair in a certain group of patients. Various innovative solutions have been developed for the intraoperative management of this challenging patient group.

In our point of view, a novel standardized repair strategy is needed not only to ensure optimal durability in patients with isolated functional TR but also to provide excellent valve competence in patients with complex lesions such as extremely large annulus, organic involvement or prominent leaflet tethering. As a reflection of this approach, it may be reasonable to transform the TV into bicuspid form as the mitral valve is and consider the TV as an analogue of the mitral valve and apply a similar repair process to achieve perfection in TV repair results. In this study, we present preliminary clinical results of patients who have undergone TV repair with a novel methodological approach, which we defined as 'mitralization of the TV'.

MATERIALS AND METHODS

Study population and data source

This single-centre observational study included all patients who underwent TV repair via 'mitralization of the TV' between January 2017 and January 2020 at a high-level cardiac surgery centre. The decision for surgery was made with the consensus of at least 1 cardiac surgeon and 1 cardiologist. All preoperative and postoperative echocardiographic findings were double-checked by an independent echocardiographer. The demographic and clinical information of the patients was obtained from the hospital

database. All follow-up procedures of the patients were carried out by the same heart team.

Ethics statement

The Institutional Ethical Committee of Bezmialem Vakif University approved the study protocol (date: 16 February 2021/reference number: E-54022451-050.01.04-6355). Preoperative informed consent was obtained from all patients who underwent surgery. The study was conducted in accordance with the Declaration of Helsinki.

Procedural characteristics

All of the operations were performed during cardiopulmonary bypass with mild systemic hypothermia and the temperature of 28–32°C was used. The intermittent antegrade blood cardioplegia was used routinely in all patients. Additional retrograde cardioplegia was used optionally according to the surgeon's preference. Extracorporeal circulation was established through cannulation of the ascending aorta and selective bicaval for patients who underwent median sternotomy. Three patients were operated on with right mini-thoracotomy via direct vision. Peripheral cannulation was performed in these patients. Indications for TV repair were a grade of regurgitation \geq moderate, or an annular diameter of >40 mm in patients with less than moderate regurgitation. The novel technique was applied to patients who met the following criteria:

1. Functional TR with severe annular dilatation and/or tethering;
2. TV prolapse; and
3. Rheumatic involvement.

Tricuspid valve repair technique: mitralization of the tricuspid valve

TV repair was performed under a cross-clamp just after the mitral valve procedure was completed. Exposition of the TV is performed via conventional oblique right atriotomy. Then, the severity of annular dilatation, leaflets and subvalvular apparatus are carefully examined. Before starting the repair process, valve competence and any organic involvement are assessed with the on-table water test. First, the posterior leaflet is totally resected at the annulus level. Then, the posterior annulus is plicated with double pledget-supported sutures of 2-0 Ethibond (Ethicon, Inc, Somerville, NJ, USA) from the anteroposterior commissure to the posteroseptal commissure. These steps turn the TV into a bileaflet structure without any residual rim at the posterior part (Fig. 1). Then, three-dimensional rigid ring (Contour 3D annuloplasty ring, Medtronic, Minneapolis, MN, USA) is implanted to annular stabilization. The optimal ring size was determined by measuring the distance between the junctions of the septal leaflet with the ring sizer supplied by the manufacturer. The ring is fixed with interrupted intraannular sutures. If coaptation defect persists in the saline injection test despite these steps, additional leaflet procedures are applied. In our experience, the edge-to-edge repair alone was effective to fix all patients with residual regurgitation.

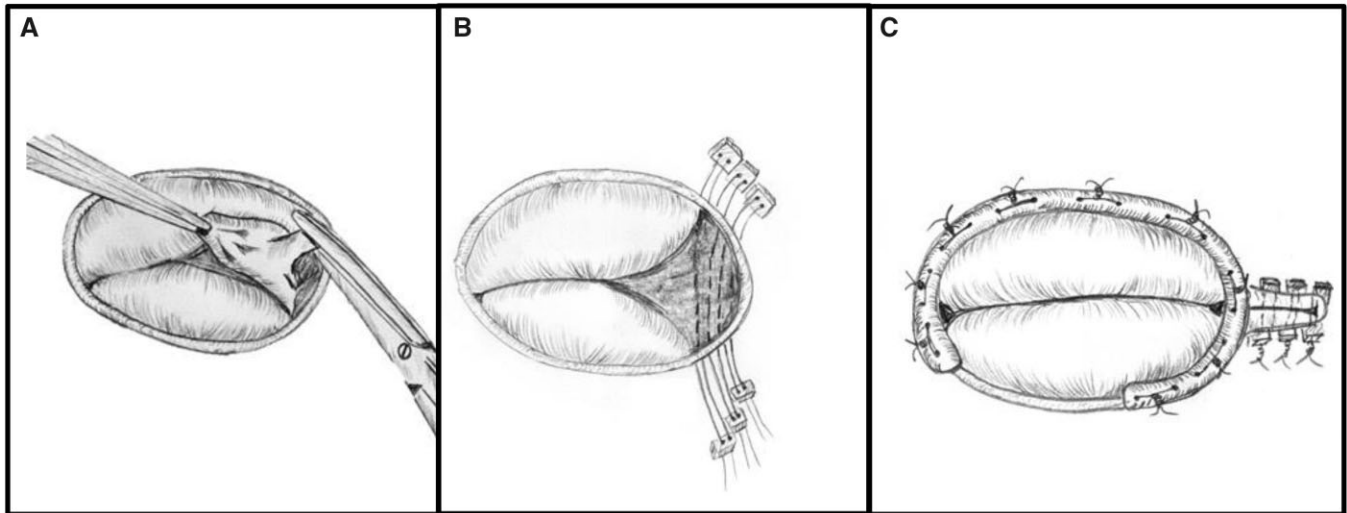
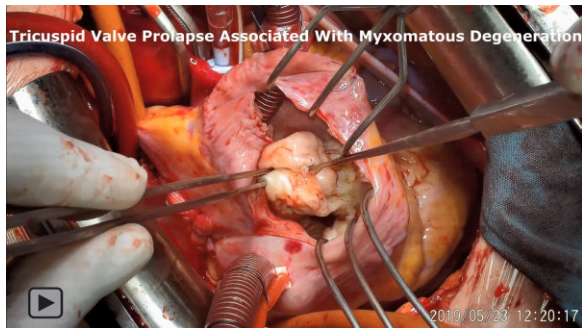


Figure 1: Mitralization of the tricuspid valve. (A) Posterior leaflet resection. (B) Plication of posterior annulus. (C) Ring annuloplasty.



Video 1: Mitralization of tricuspid valve for the repair of an incompetent myxomatous tricuspid valve.

After weaning from cardiopulmonary bypass, TV function is evaluated by transoesophageal echocardiography in terms of regurgitation or possible gradient. Video 1 shows the mitralization of the TV in a patient with myxomatous TV insufficiency and excessive leaflet tissue.

Analysis of results data collection and follow-up

In this study, intraoperative, postoperative and follow-up results of the patients were analysed. Early results include procedural success, in-hospital mortality and postoperative complications. Follow-up results are moderate-to-severe TR-free survival, reintervention and major adverse valve-related events. Postoperative events were compiled and analysed according to the 'Guidelines for reporting morbidity and mortality after cardiac valvular operations' [10].

All preoperative, intraoperative and pre-discharge echocardiographic evaluations were available for all patients. Serial echocardiographic evaluations were performed in all patients 3 months after discharge and annually thereafter. Additional echocardiographic evaluations performed at the discretion of the follow-up cardiologist were also included in the study. Evaluation and documentation of all echocardiographic parameters were done in line with the current recommendations of the European Cardiovascular Imaging Association [11]. TR recurrence was defined as at least moderate TR despite to repair.

Statistical analysis

Categorical variables were presented as counts and frequencies; continuous variables as mean (standard deviation); or median (interquartile range) as appropriate. SPSS version 23.0 (SPSS, Chicago, IL, USA) was used for all statistical analyses. Moderate-to-severe TR-free survival curve was shown with Kaplan–Meier plot.

RESULTS

Baseline characteristics

During the study period, 132 patients underwent TV surgery. TV surgery procedures performed during the study period are schematically illustrated in Fig. 2. A total of 22 consecutive patients who underwent TV repair via mitralization of the TV were evaluated during the study period. All patients underwent concomitant mitral valve procedures at the time of TV repair. Overall clinical and echocardiographic findings of all patients are summarized in Table 1.

Fourteen of the patients had functional TR secondary to annular dilatation triggered by left-sided heart disease. Two of these patients had severe tethering of the leaflets secondary to severe right ventricular dilatation in addition to annular dilatation.

Five patients had TV prolapse. Three of them had isolated posterior leaflet prolapse with excess tissue, 2 had prolapse in all leaflets. All patients with TV prolapse had myxomatous mitral valve disease. The remaining 3 patients had rheumatic TV disease characterized by commissural fusion and tethering. In patients with rheumatic involvement, commissurotomy was performed at the antero-septal and postero-septal levels before posterior leaflet resection.

In most of the patients, posterior leaflet resection, annular plication and ring implantation were sufficient to provide excellent valve competence. The edge-to-edge repair was applied as a bailout procedure in 5 patients, 3 of whom were patients with prolapse. Edge-to-edge repair was required to achieve optimum leaflet coaptation in 1 patient with rheumatic involvement after antero-septal commissurotomy and another patient with functional TR and severe annular dilatation. The mean cardiopulmonary bypass and ischaemic time for TV repair were 35 ± 7.5 and 25 ± 6 min, respectively.

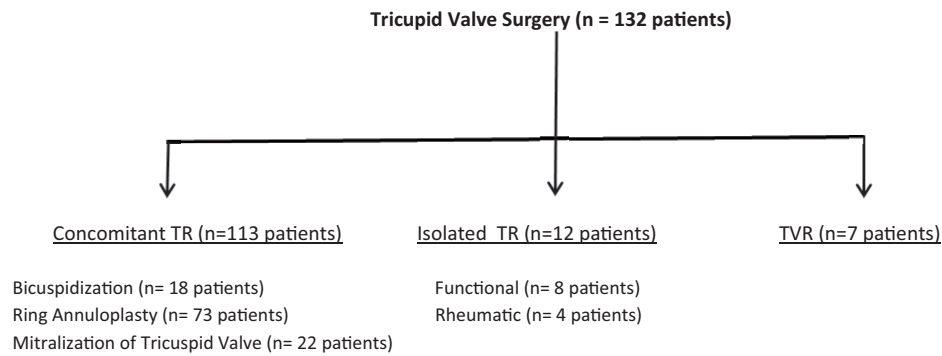


Figure 2: Tricuspid valve surgery procedures performed during the study period. TR: tricuspid valve repair; TVR: tricuspid valve replacement.

Early results

There was no in-hospital mortality in the study patients. Five patients needed a temporary pacemaker. No patient required permanent pacemaker implantation. The ratio of new-onset atrial fibrillation was 35.7% (5 of 14 patients). One patient underwent reoperation for bleeding. Prolonged intubation (>24 h) was observed in 1 patient. The pre-discharge echocardiogram showed no residual TR in 20 cases (90.9%) and mild TR in 2 (9.1%) patients.

Follow-up data

The mean follow-up duration was 30.9+6.2 months (range 16–442 months). No patients experienced major adverse valve-related events during this period. Only 1 patient had moderate TR at the end of the third year of follow-up. This patient was a patient with severe leaflet tethering due to right ventricular dilatation and accompanied by severe pulmonary hypertension. The patient is

being followed up with mild symptoms under diuretic therapy without any hospitalization requirement. Pulmonary arterial pressure significantly improved after surgery. Right ventricular fractional area change remained stable during follow-up. Table 2 shows the results of echocardiographic evaluations. None of the study patients had tricuspid stenosis in the early postoperative stage or during the follow-up period. Figure 3 summarizes moderate-to-severe TR-free survival.

DISCUSSION

This study presents the results of a total of 22 patients who underwent TV repair using the technique we defined as mitralization of the TV. According to early and mid-term results, mitralization of the TV is a safe and effective technique with good durability.

Besides the progression of ‘untouched’ TV regurgitation, late recurrence after successful repair may occur in certain group of the patients. Unresolved pulmonary hypertension after left-sided valve surgery, primer leaflet prolapse, atrial fibrillation, restricted leaflet motion due to right ventricle (RV) dysfunction, incomplete repair or low durability of the repair technique may cause chronic progressive RV overloading due to residual TR. Left ventricular dysfunction may also contribute to regurgitation after tricuspid annuloplasty due to ventricular interactions between the left ventricle and the RV [12, 13]. Ultimately, ongoing annular dilatation and changes in RV geometry may lead to failure of the configuration of a repaired TV. Therefore, excellent stabilization of RV basal and elimination of leaflet-origin residual TR are essential for high repair durability. Moreover, although the TV is no more a forgotten valve, enough attention and time are not spent, as we spend on the mitral valve.

As is known, the posterior tricuspid annulus is the most vulnerable part against RV dilatation and is responsible for the majority of annular dilatation [14]. In this technique, resection and plication of the posterior leaflet together with ring annuloplasty can provide better stabilization of the RV basal, especially in patients with severe pulmonary hypertension and/or large annulus diameter.

Moreover, we think that the mitral repair experiences can be well transferred to a TV after transforming it into a bicuspid valve in other words after mitralization. Ring annuloplasty is usually effective for the correction of secondary TR without the need for an additional leaflet procedure [6]. However, due to the complex mechanisms of TR in some patients, it is not possible to make satisfactory repairs with annuloplasty alone. We have experienced that in patients with very severe annular dilatation (especially in patients

Table 1: Baseline characteristics of the study patients

Characteristics	Patients (n = 22)
Age (years), mean ± SD	43.3 ± 9.9
Male sex, n (%)	12 (54.5)
NYHA class, n (%)	
I	1 (4.5)
II	5 (22.7)
III	13 (59.1)
IV	3 (13.6)
EuroSCORE II, mean ± SD (range)	2.8 ± 2.1 (0.87–8.2)
Index operation, n (%)	
Mitral repair	10 (45.5)
Mitral valve replacement	12 (54.5)
Mitral valve pathology, n (%)	
Degenerative	12 (54.5)
Rheumatic	10 (45.5)
Preoperative Afib, n (%)	8 (36.4)
Preoperative TR grade, n (%)	
Moderate	6 (27.3)
Severe	16 (72.7)
Annulus diameter, mm, mean ± SD (range)	48.5 ± 5 (40–55)
sPAP, mmHg, mean ± SD (range)	55.9 ± 11.1 (40–80)
sPAP >70 mmHg, n (%)	3 (13.6)
EF (%), mean ± SD	56.3 ± 5.2
30–50, n (%)	5 (22.7)
>50, n (%)	17 (77.3)

Afib: atrial fibrillation; EF: ejection fraction; NYHA class: New York Heart Association functional classification; SD: standard deviation; sPAP: systolic pulmonary artery pressure; TR: tricuspid valve regurgitation.

Table 2: Postoperative echocardiographic evaluation results

	Preoperative (n = 22)	Pre-discharge (n = 22)	Sixth month (n = 22)	First year (n = 22)	Second year (n = 21)	Third year (n = 19)
TR degree, n (%)						
None TR	0 (0)	20 (90.9)	20 (90.9)	19 (86.4)	18 (85.7)	16 (84.2)
Mild TR	0 (0)	2 (9.1)	2 (9.1)	3 (13.6)	3 (14.3)	2 (10.5)
Moderate TR	6 (27.3)	0 (0)	0 (0)	0 (0)	0 (0)	1 (5.3)
Severe TR	16 (72.7)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
sPAP, mmHg, mean \pm SD	55.9 \pm 11.1	43 \pm 9.1*	46.8 \pm 8.6*	44.7 \pm 7.4*	46.3 \pm 8.7*	45.9 \pm 8.8*
RV FAC, %, mean \pm SD	32.7 \pm 10.2	35.6 \pm 9.6	34 \pm 7.5	36 \pm 8.2	32 \pm 10.1	36 \pm 7.4

$P < 0.05$ versus preoperative value.

RV FAC: right ventricular fractional area change; SD: standard deviation; sPAP: systolic pulmonary artery pressure; TR: tricuspid valve regurgitation.

* $p < 0.05$.

with prominent leaflet tethering), ring undersizing alone sometimes does not provide sufficient coaptation. The TV, which has been transformed with bileaflet configuration, is made more suitable for the application of additional procedures such as bail-out edge-to-edge repair. In this way, this technique allows complete repair not only in patients with severe annular dilatation but also in the organic involvement of leaflets.

TV reoperations due to failure of repair are characterized by high rates of operative mortality and complications [15, 16]. In current practice, when patients are considered for TV reoperation, they are usually at the limit of inoperability due to right heart dysfunction. The application of the experience of left-sided transcatheter valve intervention to the TV has become a popular topic. Current data indicate that transcatheter TV insertions have positive results in terms of decreased mortality and increased functional capacity [17]. It has been shown that procedural failure is an important predictor of 1-year mortality [18]. The anatomical difficulties inherent in the TV and the delicate structure of the leaflets are the main problems for the success of transcatheter TV procedures. We speculate that currently available transcatheter

edge-to-edge procedures can be performed more easily on a mitralized TV compared to a native anatomy.

There are a limited number of reports on the repair of the TV by resection of the leaflet in TV endocarditis, transforming the valve into a bi-leaflet form. There was no patient with endocarditis in our series. However, we think that this technique may be useful in cases of endocarditis with posterior leaflet destruction [19, 20].

Conclusion

The concept of mitralization of the TV reflects both the anatomically transformation of the TV into a bileaflet structure and mitralization of the TV conceptually. Current TV repair techniques are feasible with acceptable long-term results and reproducible technical considerations, in the most of patients. We also frequently use both suture annuloplasty (bicuspidization) and ring annuloplasty techniques in our daily practice with satisfactory results. However, we think that more detailed repair methods such as the ones we use for the mitral valve are needed in a certain patient group at risk of tricuspid repair failure. Previously defined repair methods may not be curative in patients with persistent coaptation defect due to end-stage annulus dilatation or organic involvement. This novel technique is useful to create adequate coaptation of leaflets and also excellent annulus stabilization in this patient group. Although the present article only includes patients who underwent TV repair with concomitant mitral valve surgery, this method can also be applied in isolated TV surgeries. Another hypothetical advantage of the mitralization of the TV is that it allows easier transcatheter procedures with coaptation devices in possible late recurrent TV regurgitation.

Limitations

Undoubtedly, this study has some limitations with its current form. First, more detailed echocardiographic evaluations may be useful to reveal the real haemodynamic effects of this repair technique, especially in the long term. Unfortunately, we do not have further postoperative echocardiographic data other than standard measurements. Second, there is a need to conduct a comparative study to determine the superiority of this novel technique, which we used in complex TV repairs, over the previously described annuloplasty techniques. Although our results were satisfactory, its current form, it was not feasible to compare the results of patients of this study with any control group due to possible high selection bias. Because this

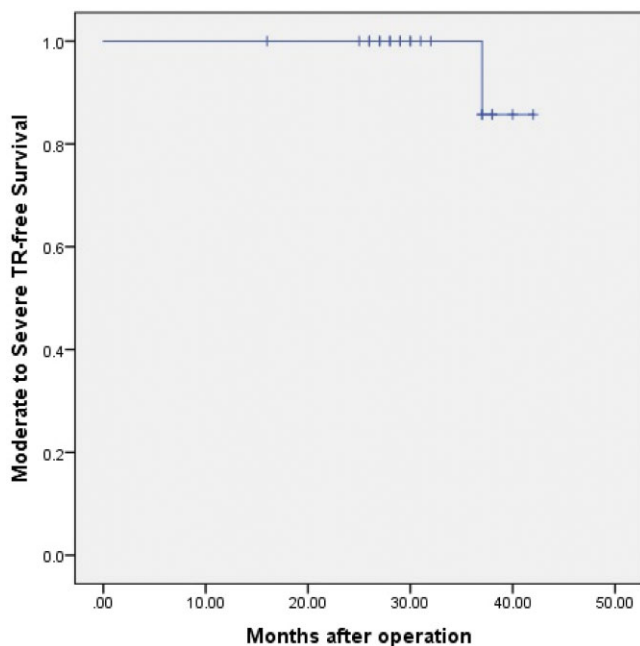


Figure 3: Moderate-to-severe tricuspid regurgitation-free survival. TR: tricuspid regurgitation.

technique was applied to patients requiring complex tricuspid repair techniques throughout the study period. In addition, single-centre nature of the study limits our evaluation of its reproducibility in daily surgical practice.

Conflict of interest: none declared.

Data Availability Statement

The data underlying this article will be shared on reasonable request to the corresponding author.

Author contributions

Cengiz Köksal: Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Project administration; Resources; Software; Supervision; Validation. **Emre Selçuk:** Data curation; Formal analysis; Funding acquisition; Methodology; Project administration; Validation; Writing—original draft; Writing—review & editing. **Gökhan Kahveci:** Conceptualization; Data curation; Formal analysis; Funding acquisition; Investigation; Methodology; Project administration; Validation; Visualization; Writing—original draft; Writing—review & editing. **Hasan Erdem:** Conceptualization; Data curation; Formal analysis; Funding acquisition; Investigation; Methodology; Project administration; Resources; Software; Supervision; Validation; Visualization; Writing—original draft; Writing—review & editing.

Reviewer information

Interactive CardioVascular and Thoracic Surgery thanks Paul Kurlansky, Sergey A Leontyev, Tsuyoshi Kaneko and the other, anonymous reviewer(s) for their contribution to the peer review process of this article.

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