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Original Article

Management of Severe Pulmonary Regurgitation and Severe Secondary Tricuspid Regurgitation

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ABSTRACT

Background: Management of severe functional tricuspid regurgitation (TR) at the time of pulmonary valve replacement in the setting of severe pulmonary regurgitation in adult congenital heart diseases has not been examined clearly.

Methods: Thirty-five patients with severe functional TR who were candidates for pulmonary valve replacement with congenital heart diseases were chosen. Baseline features and echocardiographic and clinical findings were compared between isolated pulmonary valve replacement, tricuspid valve repair, and pulmonary valve replacement groups.

Results: In the tricuspid valve repair group, TR was significantly improved compared with the isolated pulmonary valve replacement group in the early postoperative (P<0.001), short-term (P=0.009), and mid-term (P=0.035) follow-up periods. Functional capacity was improved in the tricuspid valve repair group (P=0.009) compared with the isolated pulmonary valve replacement group.

Conclusions: Our study has introduced the concomitant tricuspid valve repair as a safe approach in patients with severe functional TR at the time of pulmonary valve replacement. It can efficiently reduce TR severity in mid-term follow-up and improve the long-term functional capacity. However, there were no significant effects on mortality during the follow-up period. ***(Iranian Heart Journal 2022; 23(2): 34-41)***

KEYWORDS: Functional tricuspid regurgitation, Pulmonary valve regurgitation, Tricuspid valve repair, Pulmonary valve replacement

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Due to the improvement of surgical strategies, nowadays, more adults with congenital heart diseases are encountered in daily practice. Tetralogy of Fallot and its equivalent pulmonary stenosis constitute the most common congenital pulmonary valve diseases.[1] Pulmonary insufficiency, which is the major cause of reoperation in these patients, imposes chronic volume overload on the right ventricle (RV). Therefore, progressive RV dilatation, RV dysfunction, tachyarrhythmias, and tricuspid regurgitation (TR) happen.[2]

Congenital abnormalities of the tricuspid valve are rare in patients with tetralogy of Fallot.[3] Hence, secondary TR stands as the principal etiology.[4]

It is unclear whether isolated pulmonary valve replacement (PVR) can obviate tricuspid valve manipulation. On the other hand, it has been demonstrated that severe TR is associated with adverse clinical outcomes in different studies.[5,6]

Despite this challenge, little information is available on the management of severe functional TR accompanied by severe pulmonary insufficiency at the time of PVR. Therefore, this retrospective study was designed to assess the outcome of TR and clinical outcomes.

METHODS

Study Population

Among all the patients that underwent PVR between March 2004 and March 2018, we retrospectively investigated those who suffered from concomitant severe TR during PVR. We excluded patients with the primary etiologies of TR, those with significant pulmonary stenosis as the cause of PVR, previous tricuspid valve repair, PVR at the time of the total correction of tetralogy of Fallot, pulmonary atresia and the Rastelli procedure, complex cardiac surgeries, double-outlet RV, or other complex congenital diseases. Eventually, 35 patients (≥16 years old) were entered into our study with severe functional TR and the baseline congenital pathology of tetralogy of Fallot or after pulmonary stenosis commissurotomy who were candidates for PVR because of severe pulmonary insufficiency.

PVR was performed in symptomatic patients in the case of RV enlargement (RV end-diastolic volume index>150 mL/m^2) in cardiac magnetic resonance imaging or reduced RV function.[7]

The study was approved by the local ethics committee and the institutional review board. We did not impose any extra procedures or costs; therefore, written consent was waived.

Surgical Features

All the patients suffered from severe pulmonary regurgitation and severe functional TR. The type of the pulmonary valve inserted was according to the patient's condition and the surgeon's consideration. All the patients underwent tricuspid valve repair, and those who had tricuspid valve replacement were excluded from this study. Performing tricuspid valve repair or not, as well as its technique, was not randomized and were based on the surgeon's discretion. Ring annuloplasty was the dominant technique, followed by the De Vega annuloplasty and the bicuspidization method.

Echocardiographic Evaluation

Preoperative echocardiographic parameters were retrospectively assessed. Additionally, TR severity was determined according to the practical guidelines of echocardiography.[8,9] Furthermore, left ventricular ejection fraction, systolic pulmonary artery pressure, RV size and function, and the tricuspid valve annulus diameter were analyzed. Early postoperative, short-term (6 mon–1 y), and mid-term (1–3 y) echocardiographic data were reviewed.

Follow-up Evaluation

In-hospital outcomes consisted of mortality, new onset of tachyarrhythmia, intensive care unit (ICU) length of stay, and need for inotropic drugs in the ICU. Reoperation (PVR or tricuspid valve repair), tachyarrhythmia, and mortality were considered adverse cardiovascular events. The patients' clinical follow-up was

accomplished by medical charts or telephone contacts.

Statistical Analysis

The IBM SPSS software, version 21.0 (IBM, Armonk, NY, USA), was applied for statistical analysis. The mean ± the standard deviation, the median (interquartile range), and numbers (percentages) were reported as appropriate. The *t* test or the Mann–Whitney *U* test was used to compare continuous variables between the groups, while the χ^2 test or the Fisher exact test was applied for categorical and nominal variables. Freedom of mortality was assessed via the Kaplan–Meier analysis.

RESULTS

Baseline Characteristics

The mean age of the patients at the time of PVR was 35.6±10.1 years. Nineteen patients (54%) were male, and 49% of the patients' baseline congenital disease was tetralogy of Fallot. Concomitant tricuspid valve repair at the time of PVR was performed on 68.6% of the patients.

The baseline characteristics of the patients were compared between 2 groups of surgical procedures. No significant statistical differences were seen in sex (*P*=0.452), age (at the time of PVR) (*P*=0.659), and baseline congenital pathology (*P*=0.656) between these 2 groups. Similarly, baseline echocardiographic data did not exhibit meaningful variations between the patients who underwent PVR with tricuspid valve repair and those who underwent PVR alone. Further, RV size (*P*=0.264), RV function (*P*=0.780), tricuspid valve annulus diameter (*P*=0.488), and systolic pulmonary artery pressure (*P*=0.445) did not differ between the 2 groups (Table 1).

The principal technique of tricuspid valve repair was ring annuloplasty in 17 patients (70.8%). Five patients (20.8%) underwent the De Vega annuloplasty, and bicuspidization was performed on 2 patients (8.3%).

In-Hospital Outcomes

A significant improvement in TR severity was noticed in the patients who underwent concomitant tricuspid valve repair (*P*<0.001) compared with the group that underwent PVR alone. Identically, systolic pulmonary artery pressure significantly decreased (*P*=0.018). On the contrary, RV size (*P*=0.927), RV function (*P*=0.752), and left ventricular ejection fraction (*P*=0.895) showed no significant differences.

Concomitant tricuspid valve repair did not impose any further clinical risk in that it did not prolong the ICU length of stay (*P*=0.734) and inotropic drug use (*P*=0.693). Furthermore, no mortality took place, and none of the patients experienced a new-onset tachyarrhythmia in the ICU (*P*=0.21) (Table 2).

Follow-up Outcomes

TR severity improvement persisted in the short-term (6 mon–1 y) (*P*=0.009) and mid-term (1 y–3y) (*P*=0.035) follow-up periods in the patients of the tricuspid valve repair surgery group. Other echocardiographic findings showed no significant differences between the surgical groups (Table 3).

Functional capacity significantly improved in the concomitant tricuspid valve repair group compared with the isolated PVR group (*P*=0.009). However, tricuspid valve repair did not elevate the long-term tachyarrhythmia rate (*P*=0.582). Although mortality was greater in the isolated PVR group (*P*=0.046) compared with the tricuspid valve repair group, the Kaplan–Meier analysis for the assessment of mortality freedom did not prove this finding (log-rank test *P*= 0.067) (Fig.1).

Table 1: Baseline characteristics of the studied patients in the groups by type of surgery

	Isolated PVR (n = 11)	PVR With TV Repair (n = 24)	*P* value
Age at first surgery, y	16.93 ± 13.78	12.67 ± 10.39	0.317
Age at second surgery, y	34.48 ± 9.88	36.14 ± 10.38	0.659
Sex, n			0.452
Male	7 (20%)	12 (34.3%)	
Female	4 (11.4%)	12 (34.3%)	
Time interval between surgeries, y	17.53 ± 7.05	23.47 ± 9.16	0.067
Background Pathology, n			0.656
TOF	6 (17.1%)	10 (28.6%)	
PS	5 (14.3%)	13 (37.1%)	
History of previous shunting, n	2 (5.7%)	1 (2.9%)	0.169
NYHA Functional Class, n			0.454
I	2 (6.3%)	1 (3.1%)	
II	5 (15.6%)	12 (37.5%)	
III	4 (12.5%)	8 (25%)	
Echocardiographic Findings			
RV size, n			0.264
Moderate enlargement	1 (2.9%)	1 (2.9%)	
Moderate-to-severe enlargement	1 (2.9%)	0	
Severe enlargement	9 (25.7%)	23 (65.7%)	
RV Function, n			0.780
Moderate dysfunction	6 (17.1%)	15 (42.9%)	
Moderate-to-severe dysfunction	4 (11.4%)	6 (17.1%)	
Severe dysfunction	1 (2.9%)	3 (8.6%)	
RV diameter, cm	5.07 ± 0.75	5.05 ± 0.83	0.824
TV annulus, cm	4.57 ± 0.91	4.31 ± 0.59	0.488
Systolic PAP, mm Hg	32.09 ± 7.75	29.75 ± 8.55	0.445
Ejection fraction, %	41.59 ± 7.35	41.09 ± 6.06	0.834
Intraoperative Features			
PVR Type, n			0.675
Bioprosthetic	3 (8.6%)	5 (14.3%)	
Mechanical	8 (22.9%)	19 (54.3%)	
Cardiopulmonary bypass time, min	146.63 ± 74.15	150.75 ± 70.5	0.876
Concomitant operations, n	6 (17.1%)	10 (28.6%)	0.478

Data are presented as the mean ± the SD, the median (interquartile range), or numbers (%).
NYHA, Functional capacity; PAP, Pulmonary artery pressure; PS, Pulmonary stenosis; PVR, Pulmonary valve replacement; RV, Right ventricle; TOF, Tetralogy of Fallot; TR, Tricuspid regurgitation; TV, Tricuspid valve; TV repair, Tricuspid valve repair

Table 2: In-hospital outcomes of the studied patients in the groups by type of surgery

	Isolated PVR (n = 11)	PVR With TV Repair (n = 24)	*P* value
In-hospital mortality	0	0	1
ICU stay, d	3 (3, 4)	3 (3, 5)	0.734
ICU inotrope use, n	7 (20.6%)	13 (38.2%)	0.693
Postoperative arrhythmia, n	2 (5.9%)	4 (11.8%)	0.210
Follow-up Echocardiographic Findings			
TR Severity, n			<0.001
Less than moderate	0	15 (48.4%)	
Moderate	1 (3.2%)	5 (16.1%)	
More than moderate	8 (25.8%)	2 (6.5%)	
RV Size, n			0.927
Mild-to-moderate enlargement	0	1 (3.2%)	
Moderate enlargement	1 (3.2%)	2 (6.5%)	

Moderate-to-severe enlargement	1 (3.2%)	2 (6.5%)	
Severe enlargement	7 (22.6%)	17 (54.8%)	
RV Function, n			0.752
Mild-to-moderate dysfunction	0	1 (3.2%)	
Moderate dysfunction	1 (3.2%)	5 (16.1%)	
Moderate-to-severe dysfunction	6 (19.4%)	13 (41.9%)	
Severe dysfunction	2 (6.5%)	3 (9.7%)	
Systolic PAP, mm Hg	28.28 ± 5.31	19.88 ± 6.79	0.018
Ejection fraction, %	40.270 ± 5.06	39.88 ± 8.1	0.895

Data are presented as the mean ± the SD, the median (interquartile range), or numbers (%).
ICU, Intensive care unit; PAP, Pulmonary artery pressure; PVR, Pulmonary valve replacement; RV, Right ventricle; TR, Tricuspid regurgitation; TV, Tricuspid valve; TV repair, tricuspid valve repair

Table 3: Follow-up of the studied patients in the groups by type of surgery

	Isolated PVR (n = 11)	PVR With TV Repair (n = 24)	*P* value
Event time (mon)	75.12 ± 56.55	77.24 ± 45.38	0.900
Follow-up time (mon)	81.51 ± 55.7	77.24 ± 45.38	0.811
Mortality, n	3 (8.6%)	1 (2.9%)	0.046
Long-Term Follow-up NYHA Functional Class, n			0.009
I	2 (6.1%)	16 (48.5%)	
II	6 (18.2%)	6 (18.2%)	
III	1 (3%)	0	
IV	2 (6.1%)	0	
Follow-up reoperation, n	1 (2.9%)	1 (2.9%)	0.582
Follow-up arrhythmia, n	6 (17.6%)	7 (20.6%)	0.397
Follow-up Echocardiographic Findings			
Short-term (6 mon–1 y)			
TR severity, n			0.009
Less than moderate	0	9 (32.1%)	
Moderate	0	5 (17.9%)	
More than moderate	7 (25%)	7 (25%)	
RV Size, n			0.825
Mild enlargement	0	1 (3.6%)	
Mild-to-moderate enlargement	0	2 (7.1%)	
Moderate enlargement	1 (3.6%)	4 (14.3%)	
Moderate-to-severe enlargement	2 (7.1%)	6 (21.4%)	
Severe enlargement	4 (14.3%)	8 (28.6%)	
RV Function, n			0.707
Mild-to-moderate dysfunction	0	2 (7.1%)	
Moderate dysfunction	2 (7.1%)	7 (25%)	
Moderate-to-severe dysfunction	4 (14.3%)	11 (39.3%)	
Severe dysfunction	1 (3.6%)	1 (3.6%)	
Systolic PAP, mm Hg	21.83 ± 6.99	28.35 ± 9.76	0.158
Ejection fraction, %	43.57 ± 4	43.45 ± 5.72	0.960
Mid-term (1–3)			
TR Severity, n			0.035
Less than moderate	0	9 (34.6%)	
Moderate	1 (3.8%)	4 (15.4%)	
More than moderate	6 (23.1%)	6 (23.1%)	
RV Size, n			0.426
Mild enlargement	1 (3.8%)	1 (3.8%)	
Mild-to-moderate enlargement	0	4 (15.4%)	
Moderate enlargement	1 (3.8%)	6 (23.1%)	
Moderate-to-severe enlargement	2 (7.7%)	2 (7.7%)	
Severe enlargement	3 (11.5%)	6 (23.1%)	
RV Function, n			0.156

Mild dysfunction	1 (3.8%)	0	
Mild-to-moderate dysfunction	0	3 (11.5%)	
Moderate dysfunction	3 (11.5%)	10 (38.5%)	
Moderate-to-severe dysfunction	2 (7.7%)	6 (23.1%)	
Severe dysfunction	1 (3.8%)	0	
Systolic PAP, mm Hg	25.8 ± 4.26	23.4 ± 8.46	0.55
Ejection fraction, %	43.33 ± 2	41.58 ± 4.87	0.4

Data are presented as the mean ± the SD, the median (interquartile range), or numbers (%).
NYHA, Functional capacity; PAP, Pulmonary artery pressure; PVR, Pulmonary valve replacement; RV, Right ventricle; TR, Tricuspid regurgitation; TV, Tricuspid valve; TV repair, tricuspid valve repair

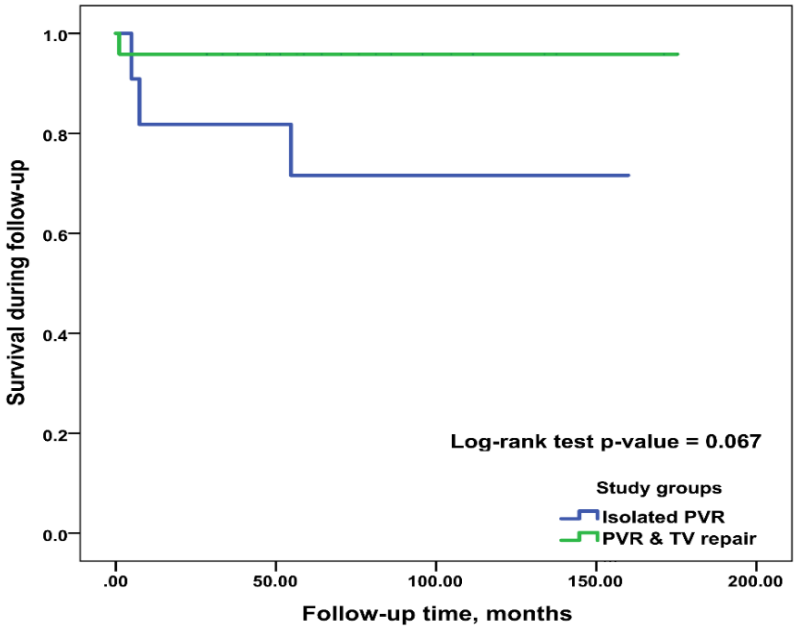

Figure 1: The image depicts the Kaplan-Meier analysis for the assessment of mortality freedom.
PVR, Pulmonary valve replacement; TV repair, Tricuspid valve repair

DISCUSSION

It has been indicated that severe TR is a predictor of adverse events.[5,6] In this regard, practical guidelines recommend that tricuspid valve repair in the setting of left-sided valve surgery should be performed when TR is severe, or tricuspid valve annular diameter is ≥40 mm or >21 mm/m^2 with lower grades of TR severity.[8] Right-sided valve pathologies involving the pulmonary valve are mostly congenital. Considering the improved survival of these patients, it is crucial to clarify how to approach severe TR in the candidates of PVR.[2] Some studies have proposed that by the elimination of the volume overload, the tricuspid valve annulus would be restored. Therefore, it is not required to manipulate the tricuspid valve.[10] On the other hand, reoperation in the case of the isolated tricuspid valve carries significant risks, while simultaneous tricuspid valve annuloplasty does not significantly extend the cardiopulmonary bypass time.[11]

This study was designed to determine the best approach to apply for patients with severe functional TR in the case of the pure volume overload state (severe pulmonary

insufficiency). We observed improved functional capacity in patients who underwent concomitant tricuspid valve repair along with PVR. Although greater mortality occurred in the isolated PVR group, it was not confirmed as significant by the Kaplan–Meier analysis. TR severity significantly improved in the tricuspid valve repair group in the early postoperative period and persisted into the mid-term follow-up. No surgical or in-hospital adverse events were noticed in the tricuspid valve repair group. These findings are consistent with the SCOTIA-PVR study,[12] which reported that concomitant tricuspid valve repair diminished TR severity by at least 1 grade with a 2.3-fold greater odds compared with PVR alone. Similarly, ring annuloplasty was the dominant type of tricuspid valve repair. It should be mentioned that in contrast to our study, pace lead-induced TR etiology was included in their survey. Roubertie et al[13] depicted the same results in a 1-year follow-up. Similarly, they did not detect any significant differences in RV size and RV function. This similarity with our study can explain the reason for the residual TR in the isolated PVR group. Bokma et al[6] stated the same results in the long-term follow-up.

Controversially, Kogon et al[2] contradicted the safety of the concomitant tricuspid valve repair at the time of PVR. It should be emphasized that the most frequent tricuspid valve repair technique in this study was suture annuloplasty, besides the inclusion of moderate TR severity. Kurkluoglu et al[10] followed up 43 patients after isolated PVR and recorded tricuspid valve annulus regression without any tricuspid valve interventions. The most important aspect was that none of the included patients in this study exhibited severe TR.

Considering all the findings, we strongly suggest concomitant tricuspid valve repair in severe functional TR subjected to PVR because of severe pulmonary insufficiency in adult congenital patients.

Study Limitations

This study was designed in a retrospective manner; as a result, the patients were not randomized in either surgical group. Albeit our hospital is a referral center, it would be better to perform this study in collaboration with other centers.

CONCLUSIONS

Our study has introduced the concomitant tricuspid valve repair as a safe approach in patients with severe functional TR at the time of PVR. It can efficiently reduce TR severity in mid-term follow-up and improve long-term functional capacity. However, there were no significant effects on mortality during the follow-up period.

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Conflict of Interest

There are none to declare.

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