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Assessment of Tricuspid Valve Detachment Efficiency for Ventricular Septal Defect Closure: A Retrospective Comparative Study

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Background: The aim of this study was to investigate the efficiency of tricuspid valve detachment (TVD) during the surgical treatment of perimembranous ventricular septal defects (VSDs) and to compare the early and mid-term results to patients without TVD in terms of tricuspid insufficiency.

Methods: A total of 170 patients who had undergone surgical closure of perimembranous VSDs between November 2012 and January 2019 were included in this study, of whom 50 had an additional TVD procedure during the surgery. All patients were examined by transthoracic echocardiography before and after the operation with regular intervals, and the tricuspid valve function was then evaluated.

Results: There was no significant difference between subgroups with an unchanging degree of TVR, however, the result was also similar among those who had a decreased degree of TVR at any level ($p = 0.271$, $p = 0.451$). At the end of the study, all patients were in New York Heart Association class I.

Conclusion: We suggest that, in appropriate patients, VSD closure can be safely performed with an additional TVD application through an incision of the septal leaflet of the tricuspid valve without impairing the valve function or reducing the growth potential of the valve at midterm follow-up.

Key Words: Tricuspid valve detachment • Tricuspid valve function • Ventricular septal defect

INTRODUCTION

Ventricular septal defect (VSD) is the most common congenital heart anomaly.[1,2] In most cases the size of the defect is restricted, and therefore patients often remain asymptomatic for years. However, in a significant number of cases, the VSDs close spontaneously.[3] If the VSDs do not spontaneously close, in advanced years, patients may manifest with complications such as aortic valve insufficiency, endocarditis and pulmonary hypertension that warrant surgery.

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In surgical treatment, the transatrial approach is frequently chosen because it involves less right bundle block and ventricular scarring risk compared to the right ventricular approach. VSDs may be occasionally located beneath the tricuspid valve, and such cases remain a challenge because it is hard to achieve complete visualization of the circumferential VSD margins. This situation makes it difficult for surgeons to establish suture lines. Achieving a complete repair is crucial in these patients; in case of residual defects, serious complications affecting morbidity and mortality such as low cardiac output, post-operative arrhythmia, and pulmonary hypertensive crisis may develop.[4]

The procedure of separating the septal leaflet of the tricuspid valve from the annulus to better facilitate repair of the VSD margins was initially described by Hudspeth et al. in 1962.[5] In the past, it has been thought that the tricuspid detachment procedure would cause tricuspid

valve regurgitation, longer operation time, and increase the risk of heart block. However, recent studies have shown that if it is performed in appropriate patients then it can provide better results.[6] However, long-term outcomes of this technique are unclear.

In this study, we evaluated the results of patients who had undergone tricuspid valve detachment (TVD) and compared the results to those who did not undergo TVD, particularly in terms of tricuspid valve regurgitation (TVR).

PATIENTS AND METHODS

This study included 170 patients who underwent surgical closure with the diagnosis of perimembranous VSD between 07/11/2012 and 01/01/2019. These patients were divided into two groups according to whether or not TVD was required during the procedure. In total, 50 patients underwent additional TVD. The most frequent surgical indications were; newly emerged aortic regurgitation, Qp/Qs > 2, left ventricular dysfunction, and pulmonary arterial hypertension (Table 1). All patients were evaluated preoperatively via transthoracic echocardiography (TTE) and then in the event of increased pulmonary arterial hypertension. Conventional angiography was performed in 16 (10.4%) patients. When the VSDs were located beneath the tricuspid valve and the edges of the VSD were unclear and hard to reach, the TVD procedure was used.

Operative technique

Mediastinal access was achieved through a median sternotomy. Following heparinization and aorta-bicaval cannulation in a standard manner, cardiopulmonary bypass (CPB) was established. Diastolic arrest was then achieved by administering topical cold and antegrade blood cardioplegia. Right atriotomy was opened parallel to the atrial groove, and the VSD was exposed after pulling the septal leaflet towards the right atrium. The tricuspid valve was incised from a distance of approximately 1 mm away from the line where the septal leaflet was connected to the annulus. The procedure continued by first detaching the septal leaflet towards the anteroseptal commissure, and then the incision was extended gradually counterclockwise toward the posteroseptal commissure. If possible, we preferred to avoid performing papillary detachment and reattachment or chordae tendineae resection and we only applied chordae tendineae detachment and reattachment in a few cases. Marking stitches were placed to aid in determining the accurate position of the leaflet at a later time. Afterwards, the VSD was closed with running sutures by using a patch starting from the middle of the anterior margin. In addition, during this process, the chordae tendineae were excised and then repositioned on to the VSD patch when they were attached to the margin of the defect. When the suture line reached the two ends of the tricuspid valve, the patch was sutured between the annulus and leaflet (Figure 1). Afterwards, the leakage test with saline infusion (hydrostatic test) was applied to test the valve's competence. The right atriotomy was then closed and the decannulation process was carried out. After bleeding control, the operation was terminated as usual.

Follow-up

The tricuspid valve was evaluated by TTE before the operation, 1 week postoperatively before discharge, and then 1 and 3 months postoperatively during follow-up. Subsequently, all of the patients received regular TTE examinations at yearly intervals. In these measurements, the TVR levels were classified as; 0, absent or negligible; 1, mild; 2, moderate and 3, severe. In addition, repeated TTE examinations did not detect any residual VSD in the patients.

Statistical analysis

All data were presented as mean ± standard deviation, median and interval data. Statistical analysis was

Table 1. Indications for surgery

Indications	TVD group (n)	Non-TVD group (n)
Aortic regurgitation	12	40
Left ventricular dilation	15	42
Pulmonary hypertension	9	7
Endocarditis	6	18
Left ventricular dysfunction	6	15
Coronary cusp prolapse	4	10
Mitral regurgitation	3	10
Subaortic stenosis	1	2

Overall n value is more than 100% because many patients had multiple indications. TVD, tricuspid valve detachment.

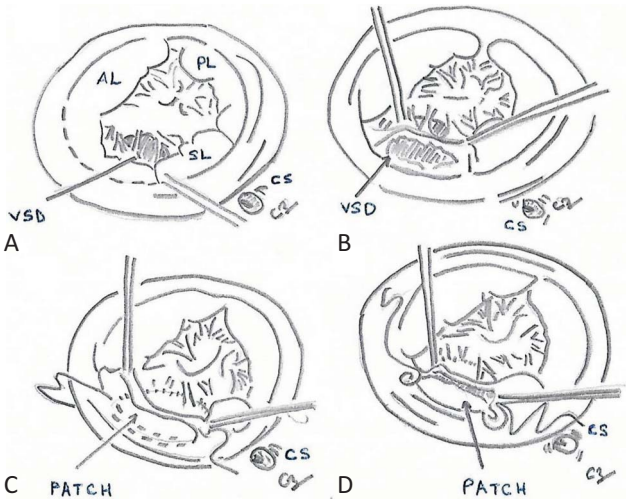

Figure 1. *Drawing of the ventricular septal defect (VSD) procedure. (A) Detachment of the septal leaflet begins from the anteroseptal commissure towards the posteroseptal commissure, with an approximate 1 mm distance away from the annulus. (B) An adequate visualization of the VSD beneath the septal leaflet is achieved in most cases, occasionally if an extension is needed, the incision is renewed toward the anterior or posterior leaflet. (C) The VSD is covered by using a pericardial patch with running suture technique. (D) The leaflets are reattached to the annulus with use of a continuous locked 7-0 Prolene suture.*

performed using SPSS version 17.0. Variables with normal distribution were assessed using the Student's T-test, otherwise, the Mann Whitney-U test was used for comparisons. A p value ≤ 0.05 was considered to be significant.

RESULTS

The mean age was 23.26 ± 22.66 months in the TVD group and 24.80 ± 23.48 months in the non-TVD group. The number of female patients was 29 and 55 in the TVD and non-TVD groups, respectively. Prior to VSD closure in the TVD group, PDA ligation was concomitantly performed on three patients, while aortic coarctation and aortic interruption repairs were performed on one patient each. In the non-TVD group, PDA ligation was performed on nine patients, aortic coarctation repair was performed on one patient, and aortic interruption repair was performed on two patients.

We preferred to perform pulmonary artery banding (PAB) primarily as the definitive surgery in the presence of large or multiple defects. Eighteen (10.5%) patients had multiple lesions. After PAB, in most cases, the muscular defects spontaneously closed. Only a few cases (n = 3) required surgical closure, however, we were able to close these residual defects through right atriotomy. We also considered PAB to be an option in young infants to achieve growth. In our cohort, prior PAB was performed on eight patients in the TVD group and 14 patients in the non-TVD group (Table 2).

In all operations, the VSDs were closed using a Gore-Tex patch. The mean duration of cardiopulmonary bypass was 66.92 ± 17.21 minutes in the TVD group, compared to 59.60 ± 12.63 minutes in the non-TVD group, and this difference was statistically significant (p = 0.02). In between-group comparisons, the durations of x-clamp were 53.80 ± 14.45 minutes and 47.35 ± 9.91 minutes in the TVD and non-TVD groups, respectively. Consequently, the TVD group had a significantly longer duration of x-clamp (p = 0.002) (Table 2).

In addition to the VSD closure procedure, 10 patients underwent ASD closure, one patient underwent patent ductus arteriosus (PDA) ligation and one patient underwent subaortic membrane resection in the TVD group. Moreover, pulmonary artery enlargement was performed on eight patients. In the non-TVD group, pulmonary artery enlargement was performed on 14 patients, while 12 patients underwent ASD closure. Nonetheless, two patients underwent PDA ligation and two patients underwent subaortic membrane resection in the non-TVD group. The concomitant surgical approaches are presented in Table 2.

No statistically significant differences were observed between groups in terms of intubation time and duration of intensive care. There was only one case of in-hospital mortality caused by a pulmonary hypertensive crisis in the non-TVD group. The mortality rate did not differ between groups (p = 0.517). Permanent pacemakers had to be implanted in one patient in the TVD group and two patients in the non-TVD group (p = 0.880) (Table 2).

TTE examinations were performed before the operation then repeated after the operation at regular intervals. The patients were followed up for 36.38 ± 13.96 months in the TVD group and 35.35 ± 14.54 months in the non-TVD group after discharge. In the follow-up period, while 44 patients had no TVR, first-degree TVR was found in only six patients in the TVD group. In addition, in the non-TVD group, 10 patients had first-degree TVR

Table 2. Demographic and perioperative findings

	TVD group	Non-TVD group	p value
Demographics			
Age (month)	23.26 ± 22.66 (min 4 max 96)	24.80 ± 23.48 (min 4 max 99)	0.631
Weight (kg)	10.03 ± 4.36	10.20 ± 5.70	0.881
Gender			0.647
Male	21 (42%)	55 (45.8%)	
Female	29 (58%)	65 (54.2%)	
NYHA functional class			0.208
I	40 (80%)	105 (87.5%)	
II	10 (20%)	15 (12.5%)	
Previous operations			
Patent ductus arteriosus ligation	3 (6%)	9 (7.5%)	0.728
Pulmonary artery banding	8 (16%)	14 (11.6%)	0.443
Aortic arch enlargement	1 (2%)	2 (1.6%)	0.880
Aortic coarctectomy	1 (2%)	1 (0.8%)	0.520
Intraoperative data			
Cardiopulmonary bypass time (min)	66.92 ± 17.21	59.60 ± 12.63	0.02*
Aortic cross-clamp time (min)	53.80 ± 14.45	47.35 ± 9.91	0.002*
Additional surgical procedures			
Atrial septal defect closure	10 (20%)	12 (10%)	0.077
Patent ductus arteriosus ligation	1 (2%)	2 (1.6%)	0.880
Pulmonary artery enlargement	8 (16%)	14 (11.6%)	0.443
Subaortic membrane resection	1 (2%)	2 (1.6%)	0.880
Postoperative data			
Intensive care unit stay (h)	17.64 ± 3.85	17.81 ± 4.06	0.948
Intubation time (h)	5.06 ± 3.59	5.07 ± 3.56	0.912
Need for permanent pacemaker	1	2	0.880
Mortality	0	1	0.517
Follow-up (month)	36.38 ± 13.96	35.35 ± 14.54	0.599

NYHA, New York Heart Association.
No patient had postoperative tricuspid stenosis. All patients were in New York Heart Association functional class I at the time of follow-up evaluation.
Data are presented as number and percentage. $p < 0.05$ was considered statistically significant. TVD, tricuspid valve detachment.

while the other patients were uneventful. The grades of TVR are presented in Table 3. Furthermore, the groups were evaluated in terms of alterations in the level of TVR. There were no significant differences in subgroups with an unchanging degree of TVR. However, the results were also similar among those who had a decreased degree of TVR at any level ($p = 0.271$, $p = 0.451$) (Table 4). At the end of the study, all patients were in New York Heart Association class I.

DISCUSSION

We evaluated the results of TVD and compared them to patients who did not undergo TVD, especially in terms of TVR development. There were no significant differences in the findings between groups, and hence the use of TVD seems to be acceptable.

VSD is the most common congenital heart disease, and therefore surgical techniques have been well developed and standardized.[7] Adequate exposure of the VSD is crucial to avoid complications such as residual VSDs, TVR and complete heart block. However, in some patients, chordal connections may cause difficulties in the complete visualization of the VSD margins. Therefore, several TVD techniques have been introduced to improve visualization and to achieve an optimal repair of hard-to-expose VSDs, in an attempt to diminish the oc-

Table 3. Grades of preoperative and postoperative TVR

Preoperative Grade of tricuspid regurgitation		
TR Grade	TVD (n = 50)	Non-TVD (n = 120)
0	40 (80%)	101 (87.2%)
1	8 (16%)	16 (18.3%)
2	2 (4%)	3 (8.3%)
3	0	0
Postoperative Grade of tricuspid regurgitation at first week		
0	36 (72%)	98 (81.6%)
1	13 (26%)	19 (15.8%)
2	1 (2%)	3 (2.5%)
3	0 (0%)	0 (0%)
Postoperative Grade of tricuspid regurgitation at last follow-up		
0	44 (88%)	110 (91.7%)
1	6 (12%)	10 (8.3%)
2	0	0
3	0	0

TVD, tricuspid valve detachment; TVR, tricuspid valve regurgitation.

currence of postoperative morbidities and improve outcomes. Temporary TVD provides a clear view of the edge between the conal septum, the aortic annulus and the ventriculo-infundibular fold, thus minimizing the incidence of residual defects.[8] Further variants of TVD involving septal leaflet detachment have also been described in the literature as the patients age.[9-11] Moreover, circumferential detachment of the septal or anterior leaflets, longitudinal incision of the septal leaflet, subvalvular tricuspid apparatus detachment (chordae papillary muscle or both) from the septum have all been reported in prior reports accompanying tricuspid valve examination results in short-term follow-up.[12] However, a consensus concerning the indications for TVD has yet to be agreed. Therefore, the choice to use TVD mostly depends on clinical experience and visual evaluation during surgery. However, preoperative echocardiography findings may aid in selecting appropriate patients for TVD. For instance, compatible with our observation, Sasson et al.[6] suggested that patients with large defects with outlet extension or tricuspid pouch tend to undergo TVD.

Although its use has been considered to be controversial in past decades, as a consequence of reports from numerous centers worldwide, the use of TVD has become more common and has been reported to be a

Table 4. Tricuspid valve regurgitation changes in the groups

TVR change	TVD (n = 50)	Non-TVD (n = 120)
-3	0	0
-2	1	2
-1	6	10
0	41	106
1	2	2
2	0	0
3	0	0

TVD, tricuspid valve detachment; TVR, tricuspid valve regurgitation.
Data are presented as number and percentage. $p < 0.05$ was considered statistically significant.

feasible and safe method even in infants younger than 3 months.[13] In addition, the first use of TVD in an adult patient was reported by Roughneen et al.[14]

Weymann et al.[15] compiled the outcomes of 14 previous studies and presented their results. Larger series did not identify any residual VSD, whereas a higher incidence of significant residual VSD was observed in control groups consisting of patients who had undergone VSD closure without the use of TVD.[12,16] Nonetheless, we did not observe any residual defects either, hence our results corroborate those in the literature.

CPB time is also a controversial issue. Temporary TVD may shorten the operation time by easing the placing and suturing processes of the patch. Nevertheless, the technique necessitates additional time during the repair of the septal (or anterior) leaflet of the tricuspid valve. Recent studies have reported different results. Fraser et al.[12] and Pourmoghadam et al.[16] demonstrated significant increases in both CPB time and X-clamp time. On the other hand, Gaynor et al.[10] and Russell et al.[11] reported no differences between TVD and non-TVD groups. Although we found significantly higher CPB and X-clamp times in the TVD group, we think that these differences will decrease as the experience increases.

There have been concerns regarding the function of the tricuspid valve after TVD. Beyond TVR, growth impairment after the plasty that produces tricuspid stenosis is also under debate. Similar to most studies on this issue, our follow-up TTE results did not reveal more than mild regurgitation. In long-term follow-up results (mean 2343 days) of 164 patients, Fraser et al.[12] determined that TVD did not affect long-term valve durability and did not cause increased morbidity. In a study with a

smaller sample size of 68 patients with a mean 5.9 years follow-up, Lucchese et al.[18] confirmed the aforementioned outcomes and verified usual tricuspid valve growth without developing any tricuspid valve stenosis. Therefore, they assumed that tricuspid valve growth was unimpaired following TVD.

Complete heart block is considered to be a rare but important complication in patients undergoing TVD during the closure of perimembranous or inlet VSDs. Andersen et al.[19] conducted a study with a large cohort of > 2000 patients and reported an incidence of third-degree atrioventricular block of below < 1%. Unfortunately, the rate of permanent pacemaker implication was higher in our series. When the characteristics and preoperative findings were assessed, known risk factors were present in these cases. For example, they may have been due to Down syndrome in two cases, inlet extension in two cases, failure to thrive in two cases, and tricuspid valve endocarditis in one case.[20,21] Nonetheless, when considered that only one of three patients were in the TVD group, this result may be interpreted in favor of the reliability of TVD. Beyond that, several authors have reported that both from their own experience and a review of the literature that the incidence of complete AV block development does not depend on how the surgeon performs detachment of the septal leaflet of the tricuspid valve. Moreover, Aeba et al. reported that even the liberal use of TVD did not result in heart block.[22]

There are inherent limitations to this study due to its retrospective design. Furthermore, the sample sizes varied between groups. Although all procedures were performed by the same surgical team, there was no randomization. Moreover, the cardiologists were not blinded in the TTE examinations either. Therefore, further prospective, multi-centered studies with larger series are needed to confirm our results.

CONCLUSION

Several studies with a large number of patients have examined the use of TVD utilization from different point of views. These results support the use of TVD with a reduced residual shunt rate and similar CPB and X-clamping times without increasing the occurrence of AV block and development of TVR in long-term follow-up. Accordingly, we suggest that the application of TVD through an incision of the septal leaflet of the tricuspid valve is a reliable method that provides satisfactory results in the closure of perimembranous VSDs.

DECLARATION OF CONFLICTING INTERESTS

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