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Research Article

Impact of the Tricuspid Valve Detachment Technique on Hard-to-Expose Ventricular Septal Defect Closure

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Ventricular septal defect (VSD) closure is a common procedure in congenital heart surgery. The exposure of VSDs can be challenging, especially in cases involving the tricuspid septal or anterior leaflets, chordae, or subvalvular apparatus. Although tricuspid valve detachment has been suggested to improve surgical visibility, its long-term effects remain unclear. Herein, we investigated the outcomes of VSD closure with or without tricuspid valve detachment and assessed the impact of this technique on postoperative tricuspid valve function and atrioventricular conduction. In total, 175 patients who underwent isolated VSD closure through the right atrium were retrospectively enrolled and divided into 2 groups: the tricuspid valve detachment group ($n = 17$, 9.7%) and the nontricuspid valve detachment group ($n = 158$, 90.3%). Patient characteristics were comparable between the two groups, and medical records and echocardiography reports were reviewed for each patient. The primary outcomes were mortality and reoperation, whereas the secondary outcomes included residual VSD, tricuspid valve regurgitation, advanced atrioventricular block, and aortic valve regurgitation. Clinical variables were compared between the two groups. Overall, tricuspid valve detachment did not increase perioperative complications or affect long-term tricuspid valve function. There were no cases of mortality or reoperation in either group. Although the tricuspid valve detachment group had longer bypass and cross-clamp times, this did not significantly affect ventilation or intensive care unit stay duration. Follow-up echocardiography revealed no significant intergroup differences in tricuspid regurgitation, residual shunt, or aortic valve regurgitation. In conclusion, tricuspid valve detachment is a safe and reliable technique for the complete closure of hard-to-expose VSDs without compromising tricuspid valve function. Moreover, it does not increase the risk of adverse events, and its outcomes remain favorable during short- and long-term follow-ups.

1. Introduction

Ventricular septal defect (VSD) closure is one of the most frequent procedures performed in congenital heart surgery [1]. However, the incidence of residual VSD, including small shunts, has been reported to reach a considerable rate of up to 51% [1, 2]. Although insignificant residual VSDs (<1 mm) tend to undergo spontaneous closure, significant residual VSD is recognized as a risk factor of postoperative major adverse events [3]. Achieving a successful outcome in VSD closure appears to hinge upon the complete closure of the entire rim surrounding the VSD.

Owing to the presence of the tricuspid septal or anterior leaflets, chordae, or subvalvular apparatus, the exposure of the VSD can be especially challenging in cases of transright atrial VSD closure. Recent studies have further suggested

that detaching the tricuspid valve (TV) can enhance the surgical view of the VSD [4–6]. However, the long-term implications of this technique remain uncertain, particularly in smaller patients who may be at risk of TV regurgitation (TR) and complete atrioventricular block (AVB).

This study presents the outcomes of VSD closure with and without TV detachment (TVD). We aimed to assess the influence of the TVD technique on TV function and atrioventricular conduction during short-term and long-term follow-ups.

2. Materials and Methods

2.1. Participants. This retrospective analysis was conducted on 175 patients who underwent isolated VSD closure through the right atrium between January 2007 and March 2022. The patients were categorized into two groups: the TVD group (Group A) and the non-TVD group (Group B). The inclusion criteria were as follows: (1) patient's age at the time of surgery <20 years, (2) diagnosis of VSD made by transthoracic echocardiogram before surgery, and (3) absence of complex cardiac anomalies. This study was conducted in accordance with the tenets of the Declaration of Helsinki. The study protocol was approved by the Institutional Review Board (MH2022-058), and informed consent was obtained in writing from the guardians of all patients at the time of the preoperative explanation of the surgery. For each patient, we retrospectively reviewed the medical records and echocardiography reports at hospital discharge and at the one- and five-year follow-up visits.

2.2. Surgical Technique. The surgical approach was full- or lower-half median sternotomy in all cases. Cardiopulmonary bypass was initiated through ascending aortic and bicaval cannulation, and a left ventricular vent was inserted via the right upper pulmonary vein. Upon the cross-clamping of the ascending aorta, antegrade cardioplegia was administered to induce diastolic cardiac arrest. A right atrial incision was made, followed by the retraction of the TV to expose the VSD. In most cases, we retracted the tricuspid septal leaflet with a silk suture near the posteroinferior rim, with a pledgeted 6-0 polypropylene suture near the posterosuperior rim to visualize the edge of the VSD. If exposure remained challenging because of the TV or subvalvular apparatus, we proceeded with the TVD technique.

Prior to TV incision, cardioplegia was administered to the ascending aorta to ensure the precise location of the aortic valve and prevent any inadvertent injury. Moreover, we confirmed the positioning of the posteroinferior rim of the VSD to avoid injuring atrioventricular conduction. Typically, we made an incision along the annulus of the tricuspid septal leaflet, preserved a 2 mm margin, and extended it in both the cephalad and caudal directions until the entire rim of the VSD became visible. For less accessible VSDs, particularly those addressed using the TVD technique, we predominantly employed an interrupted approach with an ePTFE patch to close the defect. Conversely, easy-to-expose VSD closure is typically performed continuously. After confirming the complete closure of the VSD without any residual leakage, we reattached the TV by using continuous 7-0 (early infancy) or 6-0 (late infancy or later) polypropylene thread sutures. The needle on the annulus side was applied as thinly as possible over the endocardium to prevent conduction disorders. In the case in which a VSD patch was located beyond the tricuspid annular plane, the septal leaflet was reattached by sandwiching the VSD patch between the annulus and leaflet. Additional TV repair was performed in cases wherein it was deemed necessary based on the results of the TV injection test (e.g., edge-to-edge repair of the anteroseptal commissure).

2.3. Outcomes. In this study, the primary outcomes assessed were the mortality and reoperation rates. Secondary outcomes included residual VSD, regardless of size; significant TV and aortic valve regurgitation (AR) defined as moderate or greater valve regurgitation observed on follow-up echocardiography; and advanced AVB.

2.4. Statistical Analysis. Continuous variables are presented as medians with interquartile ranges, whereas categorical variables are presented as frequencies or percentages, as appropriate. To compare clinical variables between the two groups, the nonparametric Mann–Whitney *U* test was used for continuous variables, whereas the chi-square and Fisher's exact tests were used for categorical variables. Statistical significance was set at $p < 0.05$. Data analysis was conducted using SPSS software (IBM Corp., Armonk, NY, USA).

3. Results

During the study period, 175 patients underwent VSD closure via the right atrium at our institution (Table 1). Of these, 158 patients underwent VSD closure without TVD (Group B), whereas 17 required TVD (Group A). The patient characteristics were comparable between the 2 groups, with no significant differences in age (10 [3–47] months for Group A vs. 4 [2–12] months for Group B) or body weight (7.1 [4.8–14.4] kg for Group A vs. 5.4 [4.2–7.3] kg for Group B). Preoperatively, 6 (35%) and 15 (9.4%) patients had TR of moderate or greater severity in Groups A and B, respectively ($p = 0.012$).

Intraoperative and postoperative characteristics are presented in Table 2. There were no cases of mortality or reoperation, including pacemaker implantation, in either group. The median bypass and cross-clamp times were 124 (101–150) and 86 (76–101) min in Group A, respectively, and 100 (83–120) and 64 (51–77) min in Group B, respectively; both of which were significantly longer in Group A ($p = 0.001$ and ≤ 0.001). However, no significant differences were observed in the duration of first ventilation (26 [7.5–70] h for Group A vs. 28 [13–72] h for Group B, $p = 0.393$) or length of intensive care unit (ICU) stay (4 [3–7] days for Group A vs. 4 [3–7] days for Group B, $p = 0.398$).

Table 1: Preoperative variables.

Variables	TVD group ($n = 17$)	Non-TVD group ($n = 158$)	p value
Age (months)	10 (3–47)	4 (2–12)	0.098
Weight (kg)	7.1 (4.8–14.4)	5.4 (4.2–7.3)	0.096
Sex			0.722
Male	8 (47)	81 (51)	
Female	9 (53)	77 (49)	
Qp/Qs	2.0 (1.6–2.6)	2.4 (1.8–3.4)	0.588
TR > mild	6 (35)	15 (9.4)	0.012

Continuous data are presented as medians (interquartile ranges), and categorical data are shown as numbers (%). Qp/Qs, ratio of pulmonary to systemic blood flow; TR, tricuspid valve regurgitation; TVD, tricuspid valve detachment.

Table 2: Intraoperative and postoperative variables.

Variables	TVD group ($n = 17$)	Non-TVD group ($n = 158$)	p value
CPB time (minutes)	124 (101–150)	100 (83–120)	0.001
Cross-clamp time (minutes)	86 (76–101)	64 (51–77)	≤0.001
Time to extubation (hours)	26 (7.5–70)	28 (13–72)	0.393
ICU stay (days)	4 (3–7)	4 (3–7)	0.398
Reoperation	0 (0)	0 (0)	—
Postoperative morbidity	0 (0)	0 (0)	—

Continuous data are presented as medians (interquartile ranges), and categorical data are shown as numbers (%). CPB, cardiopulmonary bypass; TVD, tricuspid valve detachment.

The median follow-up duration for this cohort was 85 (44–102) months in Group A and 70 (26–113) months in Group B, with no statistically significant difference.

Table 3 summarizes the echocardiographic findings during follow-up for all patients. TR of moderate or greater severity was observed in four patients (one in Group A and three in Group B), whereas residual shunt was observed in four patients (one in Group A and three in Group B), with no statistically significant difference. There was only one case of moderate or high AR in both groups at the five-year follow-up examination. No patients required reoperation during the follow-up period in either group.

4. Discussion

Visualizing VSDs in their entirety when using a transatrial approach for VSD closure can be challenging because of the anatomical location of the defect behind the TV tissue [7]. In such cases, TVD has been reported as a technique that can enhance visualization and enable complete closure of the defect [8]. However, the long-term outcomes of the TVD technique have not been extensively documented. Our study demonstrated that TVD did not increase perioperative complications and had no effect on long-term TV function.

Based on our experience, TVD was performed when the defect extended to the conus outlet, and visualization was hindered by the TV tissue. Furthermore, we used a traction thread to pull the septal chordae; if the edge of the VSD remained unclear, we opted for TVD. Fraser et al. [4] reported that they employed TVD in cases of severe defect malalignment, a large septal or anterior valve leaflet, basal valve chordae attached to the edge of the defect, or a VSD that impeded adequate exposure because of the major chordae. In such cases, the TV was detached through an incision along the septal annulus. Other methods, such as longitudinal incision of the valve leaflet and cutting of the chordae or papillary muscles, have also been described [6, 9]. The choice of method depends on the experience of the surgical facility, and several recent studies have reported favorable outcomes with these techniques during short-term follow-up [5]. In older children, where the pouch of the TV covers the VSD, a longitudinal incision is more likely to reveal the location of the VSD margins and allow for easier VSD closure. Conversely, in small infants, where excessive tricuspid attachments are present along the crest of the VSD, a longitudinal TV incision may not allow a firm view of the superior and inferior margins of the VSD, and circumferential incision may be useful [10]. It may allow us to prevent aortic valve deformation and damage because the positional relationship between the aortic valve and VSD can be clearly observed. Moreover, conduction system damage can be avoided because the view of the inferior-posterior corner can be obtained. In the current study, the TVD technique was associated with a longer duration of cardiopulmonary bypass and cross-clamp time; however, it did not increase perioperative mortality or risk of prolonged ICU stay. These results were consistent with those of a previous study [11].

Analysis of patients at the five-year follow-up period revealed that TVD did not increase the risk of complications, such as residual VSD, valve regurgitation, or heart block. Studies have reported that the incidence of residual VSD was 4.7%–51% [1–3]. The question of whether age or weight at the time of the operation is a risk factor for residual VSD remains controversial [1, 12, 13]; however, significant residual VSD has been identified as a predictor of complications [3]. In cases of small patients, achieving adequate exposure is particularly crucial, and Bang et al. [14] reported that TVD is a safe and reproducible method in infants aged

Table 3: Echocardiographic findings at discharge and follow-up.

Variables	TVD group ($n = 17$)	Non-TVD group ($n = 158$)	p value
TTE at discharge			
Residual VSD regardless of the size	4 (23.5)	40 (25.3)	0.490
TR > mild	1 (5.9)	5 (3.2)	0.508
AR > mild	0 (0)	1 (0.6)	0.890
Advanced AVB	0 (0)	1 (0.6)	0.893
TTE at 1-year follow-up			
Residual VSD regardless of the size	0 (0)	5 (3.2)	0.641
TR > mild	0 (0)	4 (2.5)	0.702
AR > mild	0 (0)	2 (1.3)	0.839
Advanced AVB	0 (0)	0 (0)	—
TTE at 5-year follow-up			
Residual VSD regardless of the size	1 (5.9)	3 (1.9)	0.316
TR > mild	1 (5.9)	3 (1.9)	0.373
AR > mild	0 (0)	1 (0.6)	0.911
Advanced AVB	0 (0)	0 (0)	—

Categorical data are shown as numbers (%). AR, aortic valve regurgitation; AVB, atrioventricular block; TR, tricuspid valve regurgitation; TTE, transthoracic echocardiography; TVD, tricuspid valve detachment; VSD, ventricular septal defect.

<3 months. In our study, we included two patients aged <3 months in the TVD group, who experienced no complications, including residual VSD, during the long-term follow-up period. As Bilen et al. [15] reported, the TVD technique can reduce residual VSD and provide benefits even for younger infants.

Herein, we provide evidence that the long-term outcomes of the TVD technique for VSD closure are favorable. Our results indicate that TV function is not affected by valve detachment during VSD closure. Furthermore, this technique does not affect the aortic valve or atrioventricular node function. None of the patients required subsequent valve interventions or permanent pacemaker implantation during the follow-up period. Collectively, these results show that TVD is a method that enhances the visualization of VSD without impairing valve function.

Our study had several limitations. It was a retrospective single-center investigation, and the decision to perform TVD was left to the surgeon's discretion. There were few cases in which it was difficult to obtain a visual field with VSD surgery. Therefore, TVD was performed only in a small cohort of patients, thus making the comparison of variables difficult. Further studies with longer follow-up periods are necessary to examine the outcomes of TVD in larger patient cohorts.

5. Conclusion

In our study, TVD during transatrial VSD closure did not result in adverse effects on TV function, aortic valve function, or atrioventricular conduction during the short- and long-term follow-ups. Further studies are warranted to validate these findings in larger patient populations with longer follow-up periods.

Data Availability

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Conflicts of Interest

The authors declare that they have no conflicts of interest regarding the publication of this paper.

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