

The Fate of the Tricuspid Valve After the Transatrial Closure of the Ventricular Septal Defect



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Background. The transatrial repair of the ventricular septal defect (VSD) requires an adequate exposure of its rim. We retrospectively evaluated the effect of using the tricuspid valve incision (TVI) technique, with detachment or radial incision, on the postoperative outcome of children undergoing surgical VSD repair.

Methods. From January 2008 to September 2017, we retrospectively enrolled 141 patients, divided into two groups: 97 patients (68.8%) underwent TVI and 44 patients (31.2%) did not undergo TVI. All patients received an echocardiogram upon discharge from the hospital and after 1 month, 3 months, 6 months, and 1 year from the treatment.

Results. No perioperative or late deaths occurred. TVI was associated with a slightly longer cardiopulmonary bypass and cross-clamp time, but there were no differences in the surgical outcome between the two groups. Moreover, no differences occurred concerning residual

VSD, atrioventricular block, or tricuspid regurgitation at discharge. Echocardiograms at follow-up were available for 134 patients (95%) with a median of 5.3 years (range, 0.5 to 9.3 years), and the degree of tricuspid regurgitation did not differ between groups. No patient required reoperation for tricuspid regurgitation or residual inter-ventricular shunt. Finally, no difference was found when the two TVI subgroups were compared.

Conclusions. TVI should be used whenever intraoperative exposure of VSD is compromised to avoid a residual shunt and atrioventricular block. Here we show that this procedure does not significantly compromise tricuspid function, although a large, multicenter, randomized controlled trial is advised to validate this hypothesis.

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The closure of the ventricular septal defect (VSD), performed through a right atriotomy, is the technique most commonly used nowadays to correct cardiac defects. This approach, however, can be related to an inadequate exposure, and subsequently, to a nonoptimal repair of the defect itself [1–3]. In fact, the exposure of the VSD may be inadequate in 10% to 30% of patients [1, 3], resulting in a further correction of the cardiac defect by way of a residual interventricular shunt. To more efficiently achieve the closure of the VSD, some surgeons resort to temporary tricuspid valve detachment (TVD) [4] or to tricuspid radial incision (TRI) according to the different techniques that have been developed over time [5, 6].

Numerous reports have shown the advantages of these techniques [5–8]. However, only a handful of studies [9, 10], with conflicting results, have actually given preoperative or intraoperative systematic surgical indications regarding tricuspid valve incision (TVI). In this study, we retrospectively evaluated the effect of using the TVI

technique (with detachment or radial incision) on the postoperative outcome of children undergoing surgical VSD repair.

Material and Methods

The local Hospital Ethics Committee approved the study protocol. Informed consent was obtained from the parents/guardians of all the patients included in the study.

The patients (n = 141) were retrospectively enrolled from January 2008 to September 2017 and divided in two groups: the TVI group (n = 97) and the non-TV I group (n = 44). Inclusion criteria were patients with VSD who underwent a surgical repair. Exclusion criteria were patients exposed to other concomitant heart surgical procedures or to other techniques used for tricuspid management.

Surgical Technique

During the study period, the VSD closure was always performed by the same 2 surgeons (G.P.), and all other parameters that could influence perioperative management, such as anesthesia and the course of

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cardiopulmonary bypass (CPB) in particular, were kept constant. The surgical approach was a median sternotomy in all cases. Standard CPB with bicaval cannulation and a left ventricular vent, placed in the right superior pulmonary vein, was performed. Once mild hypothermia (32°C) was reached, antegrade cold-blood cardioplegic solution was administered in the aortic bulb to achieve diastolic cardiac arrest. The right atrium was opened and the VSD exposed by opening the tricuspid valve.

A radial incision of the septal or anterior leaflets of the tricuspid valve was performed when exposure of the defect was compromised due to the limited possibility to retract the tricuspid valve because of the presence of a large septal leaflet, or for tight chordal structures, or even excess of tricuspid tissue. In all other cases, a TVD was performed through an incision along the annulus, as others have previously described [1, 4]. The surgical technique used was subjectively chosen according to the location and extension of the VSD to be repaired but, in any case, by using a Dacron (DuPont, Wilmington, DE) patch fixed by a continuous 6-0 Prolene suture (Ethicon, Somerville, NJ).

If transection of the chordae tendineae was necessary due to the difficult visualization of the VSD, these were replaced in the same position by performing an interrupted 7-0 Prolene suture to prevent any new post-operative valvular regurgitation. The tricuspid valve was then repaired along the line of incision using an interrupted 6-0 Prolene suture for radial incisions or by applying a continuous locked 7-0 Prolene suture for detachments. The competence of the tricuspid valve was checked with a hydraulic test by filling the right ventricle with cold saline solution.

Echocardiography Follow-Up

All patients were assessed with an echocardiogram upon discharge from the hospital and after 1 month, 3 months, 6 months, and 1 year from the treatment. Transthoracic echocardiography was performed by the same 2 pediatric cardiologists, who were blind to the repair technique used during the operation, according to standardized protocols [11, 12]. The severity of tricuspid regurgitation was assessed according to international recommendations by applying the qualitative and semiquantitative variables that are commonly used in adults [13].

Qualitative variables included the size of the jet area flow (small, moderate, or large), the convergence of the jet area flow (transient, intermediate, and large), and the density of the jet area flow (partial/dense, parabolic, or triangular). Semiquantitative variables included the state of the vena contracta (mild, <0.3 cm; moderate, 0.3 to 0.69 cm; or severe, >0.7 cm), the proximal isovelocity surface area of the proximal isovelocity surface area radius (mild, <0.5 cm; moderate, 0.6 to 0.9 cm; or severe, >0.9 cm), and hepatic vein flow (systolic dominance, systolic blunting, or systolic flow reversal). Quantitative variables were not included because their use in pediatrics is very limited [12]. All clinical data were collected by an investigator who was blind to the type of operative technique used.

Statistical Analysis

Continuous variables are presented as mean \pm SD. The clinical variables between the two groups were compared by the nonparametric Mann-Whitney *U* test for continuous variables or the χ^2 and Fisher exact tests for categorical variables. A *p* value of less than 0.05 was considered statistically significant. Data were analyzed using Statistica 6.0 software (StatSoft, Inc, Tulsa, OK).

Results

For the scope of this study, we retrospectively enrolled at our institute 141 patients who underwent surgical closure of the isolated VSD. The VSD types diagnosed were perimembranous in 121 patients (85.8%) or muscular in 20 patients (14.2%). To repair the VSD, we performed a TVI in 97 patients (68.8%) by way of a radial incision in 86 (61%) or through a detachment in 11 (7.8%).

The operative characteristics were similar between the TVI and non-TVI groups (Table 1), except for the mean CBP time (*p* = 0.015) and the mean aortic cross-clamp time (*p* = 0.0001). No operative or late deaths occurred in our sample population.

The mean intensive care unit and hospitalization lengths of stay were 2.1 ± 1.1 and 8.1 ± 2.2 days, respectively, for the TVI group and 2.2 ± 1.3 and 8.0 ± 2.0 days, respectively, for the non-TVI group, with no significant differences between groups (*p* = 0.63 and *p* = 0.79, respectively). Seventy-four patients (53%), 51 in the TVI group and 23 in the non-TVI group (*p* = 0.33), received inotropic support for the first 48 to 72 hours after treatment due to transitory left ventricular dysfunction or hemodynamic instability. Residual, small, and hemodynamically nonsignificant VSDs occurred in 8 patients (5.7%), 5 in the TVI group and 3 in the non-TVI group (*p* = 0.48). A temporary atrioventricular block developed in 10 patients (7.1%), 7 in the TVI group and 3 in the non-TVI group (*p* = 0.61), which resolved in less than 14 days.

Echocardiograms assessing the degree of tricuspid valve regurgitation were available for all the patients in the study upon discharge from the hospital (Table 2), and

Table 1. Operative Data and Ventricular Septal Defect Type Between Groups With and Without Tricuspid Valve Incision

Variable ^a	TVI (n = 97)	Non-TVI (n = 44)	<i>p</i> Value
Age, months	6.3 \pm 1.4	6.5 \pm 1.5	0.44
Weight, kg	6.5 \pm 1.2	6.6 \pm 1.4	0.66
CPB time, minutes	92 \pm 14	86 \pm 12	0.015
Cross-clamp time, minutes	63 \pm 9	57 \pm 7	0.0001
VSD type			
Perimembranous	85 (87.6)	36 (81.8)	0.51
Muscular	12 (12.4)	8 (18.2)	0.51

^a Continuous data are presented as the mean \pm SD and categorical data as number (%).

CPB = cardiopulmonary bypass; TVI = tricuspid valve incision; VSD = ventricular septal defect.

Table 2. Degree of Tricuspid Valve Regurgitation at Discharge From the Hospital Between the Groups With and Without Tricuspid Valve Incision

Degree	TVI (n = 97) No. (%)	No-TVI (n = 44) No. (%)	p Value
None or trivial	58 (59.8)	26 (59)	0.91
Mild	35 (36.1)	17 (38.7)	0.91
Moderate	4 (4.1)	1 (2.3)	0.50
Severe	0	0	1

TVI = tricuspid valve incision.

follow-up echocardiograms were available for 134 patients (95%), with a median of 5.3 years (range, 0.5 to 9.3 years; TVI group, median 5.6 years; non-TVI group, median 5.1 years; Table 3). No significant differences emerged in the degree of tricuspid regurgitation between the two groups at discharge (Table 2) or at follow-up (Table 3).

No patient required reoperation for tricuspid regurgitation or residual interventricular shunt. A severe degree of tricuspid valve regurgitation developed at follow-up in 1 boy in the TVI group, but he was asymptomatic and receiving treatment with diuretics waiting to become older to perform corrective surgical repair. Before the operation, this patient had a moderate TV regurgitation due to a dysplastic tricuspid valve.

No statistically significant differences were found when the degree of tricuspid regurgitation within the TVI group at discharge was compared with follow-up (Fig 1). Moreover, no significant differences were found concerning operative data and echocardiographic results at follow-up between the two TRI and TVD subgroups (Table 4).

Comment

To avoid residual shunt, the transatrial repair of the VSD requires an adequate exposure of the margins, which can be obtained by using different techniques [1, 2].

TVI was described for the first time in 1962 by Hudspeth and colleagues [4], who performed the technique in

Table 3. Degree of Tricuspid Valve Regurgitation at Follow-Up Between the Groups With and Without Tricuspid Valve Incision

Variable ^a	TVI (n = 92)	Non-TVI (n = 42)	p Value
Follow-up, years	5.6 ± 2.5	5.1 ± 2.9	0.31
Degree			
None or trivial	48 (52.2)	22 (52.4)	0.87
Mild	40 (43.5)	18 (42.8)	0.90
Moderate	3 (3.3)	2 (4.8)	0.50
Severe	1 (1)	0	0.68

^a Continuous data are presented as the mean ± SD and categoric data as number (%).

TVI = tricuspid valve incision.

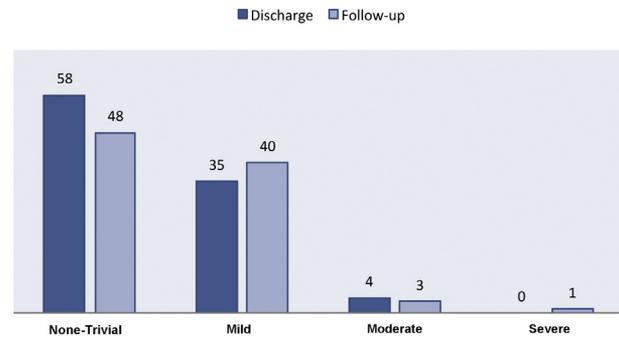


Fig 1. Tricuspid regurgitation in the tricuspid valve incision group comparing echocardiograms at discharge and at follow-up.

8 patients. Over time, other authors have described their experience with the same technique and obtaining similar results, with no increase in heart block, in the incidence of residual VSD, or in tricuspid regurgitation. This is crucial because a postoperative residual shunt can cause several complications, such as endocarditis, cardiac and pulmonary overload, and increased tricuspid insufficiency.

To improve the exposure of the VSD, we have been performing a radial incision or detachment of the tricuspid valve leaflets in our center for more than 20 years. When needed, we usually cut the chordae tendineae, which are then reimplemented in the same place, to improve the spreading of the tricuspid leaflets. We thus conducted this retrospective study after having analyzed the results of several research groups, as reported in the literature, to increase our knowledge of the topic and technique used.

In 1994 Bol-Raap and colleagues [9] performed TVD in 39 patients. They observed a slightly longer cross-clamp time, although tricuspid valve function was not compromised after the operation. Furthermore, they found a slightly higher incidence of trivial residual VSDs in the

Table 4. Operative Data and Degree of Tricuspid Regurgitation at Follow-Up Between the Tricuspid Radial Incision and Tricuspid Valve Detachment Subgroups

Variable ^a	TRI (n = 86)	TVD (n = 11)	p Value
CPB time, minutes	91 ± 13	94 ± 11	0.46
Cross-clamp time, minutes	60 ± 9	65 ± 8	0.08
Follow-up, years	5.7 ± 2.6	5.1 ± 2.3	0.47
Degree of TR at last follow-up	(n = 81)	(n = 11)	
None or trivial	43 (53.1)	5 (45.5)	0.88
Mild	35 (43.2)	5 (45.5)	0.85
Moderate	2 (2.5)	1 (9)	0.32
Severe	1 (1.2)	0	0.88

^a Continuous data are presented as the mean ± SD and categoric data as number (%).

CPB = cardiopulmonary bypass; TR = tricuspid regurgitation; TRI = tricuspid radial incision; TVD = tricuspid valve detachment.

patients where the valve was not detached. Subsequently, in 2001 Gaynor and colleagues [1] used a similar technique to that described by Bol-Raap and coworkers [9] in 36 patients and reported no increase in heart block, in the incidence of residual VSD, or in tricuspid insufficiency after detachment. However, in contrast to the previous study, no differences in CPB time, cross-clamp time, or postoperative stay were observed.

In our retrospective study, we obtained similar results to those described above. In fact, when analyzing our sample population, we observed that the TVI group presented a slightly longer CPB and cross-clamp time than the non-TVI group but that this had no clinical repercussions or resulted in any differences in the surgical outcome between the two groups. Furthermore, when the two TVI subgroups were compared, we did not find any differences between TRI and TVD in operative data and echocardiographic results at follow-up. Although surgeons did not give indications of the criteria used for TVI and the technique used was a subjective choice, in our experience, we found that TVI was effective in the closure of difficult VSDs. No reoperations for residual shunts or permanent atrioventricular blocks and no reoperations for the tricuspid valve occurred in our sample population.

In 2006 in a prospective study, Sasson and colleagues [10] evaluated three predefined echocardiographic and intraoperative criteria as an indication of TVD in 179 patients scheduled for VSD closure: (1) multiple tricuspid valve chordal arrangement obscuring the margins of the defect, (2) tricuspid valve aneurysm precluding easy access to the defect, and (3) the high position of the defect with outlet extension, requiring excessive traction on the tricuspid valve leaflet for exposure. This study showed that among 95 patients with a preoperative indication of TVD, only 41 were actually exposed to it during the operation. The authors observed that patients with a preoperative indication of TVD and in whom the detachment was actually performed during VSD closure had fewer postoperative surgical complications than those patients who fulfilled the criteria but did not undergo the detachment.

Russell and colleagues [6] recently described the outcome of TRI for VSD closure in 230 (63%) of 366 patients. No differences were observed between the TRI vs non-TRI groups in CBP and cross-clamp time. Echocardiograms at the average follow-up of 3.5 years showed a tricuspid regurgitation for the TRI group that was none or trivial in 65% of patients, mild in 30%, and moderate in 5%. The degree of tricuspid regurgitation was similar between patients whose tricuspid valve was or was not incised.

The most recent study in 2016 by Lucchese and colleagues [5] described TVD in 68 children who were prospectively enrolled. With an average follow-up of 5.9 years, they observed a trivial to mild regurgitation in 91% of the patients. They further reported that tricuspid dysplasia with severe regurgitation by a univariate analysis was the only risk factor for postoperative moderate insufficiency. The other risk factors tested and excluded

were low weight at operation, younger age, female sex, presence of systemic pulmonary artery pressure, VSD type, and need of associated operative procedures. They found no demonstrable correlation between the degree of postoperative tricuspid regurgitation and the extension of the TVD [5].

The analysis of the literature has thus shown that several surgeons use TVI in a high percentage of cases, up to 50% [6]. We have observed an even greater percentage (68.8%) in our experience. This technique, which is not particularly difficult to perform, is to be preferred for certain types of VSD and appears to be associated with a good outcome, as our data series has confirmed.

Our study presents some limitations, however, which should be underlined, including the retrospective design, the small number of patients enrolled, and the mid-term follow-up. Furthermore, we cannot exclude a possible bias in results due to the variability of the surgeons who chose the surgical technique subjectively, the variability of cardiologists for the echocardiogram examination at follow-up, and the lack of recommendations for the echocardiogram evaluation of the severity of the tricuspid valve regurgitation in pediatric age.

We agree with the concept expressed by Russell and colleagues [6], according to which patients who underwent TVI probably had a more difficult surgical anatomy, and therefore, the two groups were not completely identical. However, given the equivalent clinical results, this assumption reinforces our results in promoting the use of TVI for VSD closure.

In conclusion, the results of our study, despite the limitations just described, are promising and confirm the use of TVI whenever intraoperative exposure of the VSD is compromised to avoid residual shunt and atrioventricular block. The procedure does not significantly compromise tricuspid function, although a large, multicenter, randomized controlled trial should be promoted to validate this concept.

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