



# Outcomes of Tricuspid Valve Detachment for Isolated Ventricular Septal Defect Closure

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## Abstract

Partial detachment of the septal and anterior leaflets of the tricuspid valve (TV) is a technique to visualize a perimembranous ventricular septal defect (VSD) for surgical closure in cases where the VSD is obscured by TV tissue. However, TV incision bears the risk of causing relevant postoperative TV regurgitation and higher degree atrioventricular (AV) block. A total of 40 patients were identified retrospectively in our institution who underwent isolated VSD closure between January 2013 and August 2015. Visualization of the VSD was achieved in 20 patients without and in 20 patients with additional partial detachment of the TV. The mean age of patients with partial tricuspid valve detachment (TVD) was  $0.7 \pm 0.1$  years compared with  $1 \pm 0.3$  years ( $p = 0.22$ ) of patients without TVD. There was no difference in cardiopulmonary bypass time between patients of both groups ( $123 \pm 11$  vs.  $103 \pm 5$  minutes,  $p = 0.1$ ). Cross-clamp time was longer if the TV was detached ( $69 \pm 5$  vs.  $54 \pm 4$  minutes,  $p = 0.023$ ). There was no perioperative mortality. Echocardiography at discharge and after 2.5 years (2 months–6 years) of follow-up showed neither a postoperative increase of tricuspid regurgitation nor any relevant residual shunt. Postoperative electrocardiograms were normal without any sign of higher degree AV block. TVD offers enhanced exposure and safe treatment of VSDs. It did not result in higher rates of TV regurgitation or relevant AV block compared with the control group.

## Keywords

- ▶ pediatric
- ▶ congenital heart disease
- ▶ outcomes

## Introduction

Along with bicuspid aortic valves, the isolated ventricular septal defect (VSD) is the most common lesion in congenital heart disease with a prevalence of 2.62 per 1,000 births.<sup>1</sup> In

fetal life, an interventricular communication is part of normal circulation. Failure to close the opening between the ventricles leads to perimembranous defects, the most common morphology of VSD. Some VSDs close spontaneously within the first year of life, though large defects always require surgical intervention.<sup>2</sup> In 1952, Muller and Dammann introduced palliation of the defect by placement of a

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pulmonary artery band,<sup>3</sup> thus preventing pulmonary overcirculation, heart failure, or hypertensive pulmonary vascular disease. Surgical closure was first performed in 1955 by Lillehei et al using cross circulation.<sup>4</sup> Since then, there have been significant changes in surgical strategy and in the current era, excellent short- and long-term results are reported. Nevertheless, the entire exposure of the VSD may be obscured by chordal attachments of the tricuspid valve (TV). For better visualization and thus to avoid residual VSD, Hudspeth et al described a temporary detachment of the septal leaflet of the TV.<sup>5</sup> Russell et al published their long-term experience of radial incision as a method to expose the defect.<sup>6</sup> Due to the advantages of good exposure on one side and the concerns regarding TV function and possible damage to the conduction system on the other side, this technique is still a matter of debate. In this comparative study, we retrospectively evaluated the tricuspid valve detachment (TVD) technique versus the regular exposure without detachment of the septal leaflet.

## Patients and Methods

Between January 2013 and September 2015, 40 consecutive patients with isolated VSD were operated on in our institution. For the study, the authors obeyed to the Declaration of Helsinki. Medical records were analyzed retrospectively and anonymously. The local ethics committee waived approval of the study (WF-063/20). Most recent findings were obtained by the outpatient department or by the referring pediatric cardiologist. Patients with concomitant procedures except for patent ductus arteriosus ligation, repair of atrial septal defect, or patent foramen ovale closure were excluded. Twenty patients (50%) had TVD. Operative records were analyzed to identify the technique and length of operation time. Two-dimensional color Doppler echocardiographic data were reviewed from the medical record. All patients received a preoperative and a discharge echocardiogram and electrocardiogram at our hospital. Follow-up echocardiograms and electrocardiograms were also obtained from the referring cardiologists. Characterization of the degree of TV insufficiency, the degree of residual VSD and the ventricular function as demonstrated on the echocardiograms, was

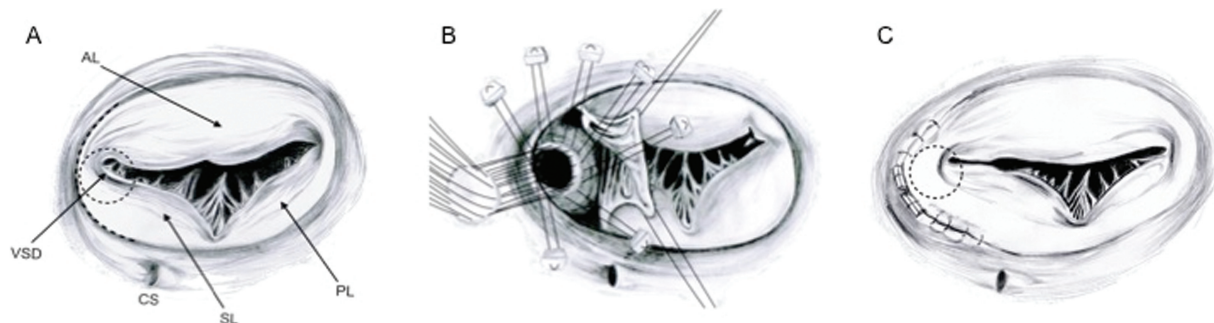
based on the judgment of the interpreting cardiologist as well as on the recommended criteria of the American Society of Echocardiography.<sup>7</sup> The degree of tricuspid regurgitation (TR) was subdivided into: 0 = none or trivial; 1 = mild; and 2 = moderate. None of the patients had severe regurgitation.

## Operative Technique

Surgical VSD closure was performed by either of two surgeons. In our facility, isolated VSDs were approached through a median sternotomy followed by initiation of cardiopulmonary bypass (CPB) using aortic and bicaval cannulation with moderate hypothermia (28–32°C). For myocardial preservation, cold crystalloid cardioplegia was used (Bretschneider cardioplegic solution 30 mL/kg body weight). After incision of the right atrium, the septal leaflet of the TV was retracted (►Fig. 1A). If the defect was exposed clearly, a standard repair was chosen. In case of an obscured VSD, TVD was the procedure of choice. The septal leaflet was detached from the annulus without injuring the aortic valve or the atrioventricular (AV) node (►Fig. 1B). In 34 patients (85%), a double velour patch (Bard, Tempe, Arizona, United States) was used for VSD closure. The patches were sewn in place using 6–0 nylon (Premio, Péters, Bobigny, France) interrupted mattress or running sutures. In the remaining six patients, the defect was closed directly with 5–0 nylon mattress sutures (Prolene, Ethicon, Norderstedt, Germany). The TV incision was closed by either continuous or interrupted 6–0 nylon (Prolene, Ethicon, Norderstedt, Germany) sutures (►Fig. 1C). The competence of the valve was controlled by filling the right ventricle with cold saline and by quantifying the residual regurgitation. In case of significant regurgitation ( $n = 4$ : 3 no TVD and 1 TVD), a single suture stitch was performed approximating the anterior and septal leaflets.

## Statistics

Statistical analysis was done with SPSS Version 22 (SPSS Inc., Chicago, Illinois, United States). Central tendency is expressed by mean and dispersion by standard deviation. Normal distribution was ruled out by the Kolmogorov–Smirnov’s test for most parameters. Consequently, differences among groups were assessed using two-tailed



**Fig. 1 Anteroseptal tricuspid valve detachment and technique of VSD closure.** (A) The tricuspid valve is depicted with a VSD (dashed circle) obscured by tricuspid valve tissue and chordal attachments. The dashed line indicates the location of leaflet incision. (B) After annular incision and placement of retraction sutures, the VSD is exposed for closure. Interrupted pledgeted 6–0 mattress sutures are placed around the defect and a Dacron patch is tied into place. (C) The septal incision is closed with running 6–0 nylon sutures. AL, anterior leaflet; CS, coronary sinus; PL, posterior leaflet; SL, septal leaflet; VSD, ventricular septal defect.

**Table 1** Patient characteristics and perioperative data

| Characteristics                  | TVD<br>Mean ± SD | No TVD<br>Mean ± SD | p-Value |
|----------------------------------|------------------|---------------------|---------|
| Age (y)                          | 1.1 ± 1.4        | 0.7 ± 0.5           | 0.33    |
| Weight (kg)                      | 7.4 ± 4.0        | 6.2 ± 2.2           | 0.39    |
| Height (cm)                      | 70.9 ± 15.2      | 65.0 ± 9.9          | 0.30    |
| Gender (M/F)                     | 16/4             | 10/10               | 0.10    |
| CPB time (min)                   | 123 ± 48         | 103 ± 20            | 0.10    |
| Cross-clamp time (min)           | 69 ± 23          | 54 ± 16             | 0.02    |
| Length of postoperative stay (d) | 10 ± 4           | 11 ± 7              | 0.93    |
| Length of ICU stay (d)           | 3 ± 1            | 4 ± 4               | 0.79    |

Abbreviations: CPB, cardiopulmonary bypass; ICU, intensive care unit; SD, standard deviation; TVD, tricuspid valve detachment.

chi-square and Mann–Whitney's *U* tests. Intraindividual differences were assessed by Wilcoxon's test.

## Results

Operative mortality was zero. There was no relevant operative or postoperative morbidity such as hemodynamically relevant residual shunt or permanent third-degree AV block.

### Patient Characteristics and Perioperative Data

Demographic data are displayed in ▶Table 1. The pathoanatomy of the VSDs was perimembranous in 29 (78%), inlet in 9 (17%), and 2 (5%) patients had muscular defects.

In the TVD group, 16 VSDs were perimembranous, and the remaining 4 were inlet VSDs. The two muscular defects were seen in the non-TVD group. In preoperative echocardiography, the most common findings besides the type of VSD were left atrial enlargement in 27 patients (44%); left ventricular

(LV) enlargement in 17 (28%); large, nonrestrictive VSD in 8 (13%); aortic insufficiency in 5 (8%); right ventricular enlargement in 3 (5%); and endocarditis in 1 (2%) patient.

The indication for surgery was congestive heart failure in 13 (26%) patients, failure to thrive in 12 (24%), volume overload with relative pulmonary stenosis in 18 (36%), aortic insufficiency in 6 (12%), and endocarditis in 1 (2%) patient. In terms of demographic data and hospital/intensive care unit stay, both groups were comparable. The only exception was cross-clamp time (69 ± 5 minutes for TVD and 54 ± 4 minutes for no TVD,  $p = 0.023$ ).

### Echocardiography

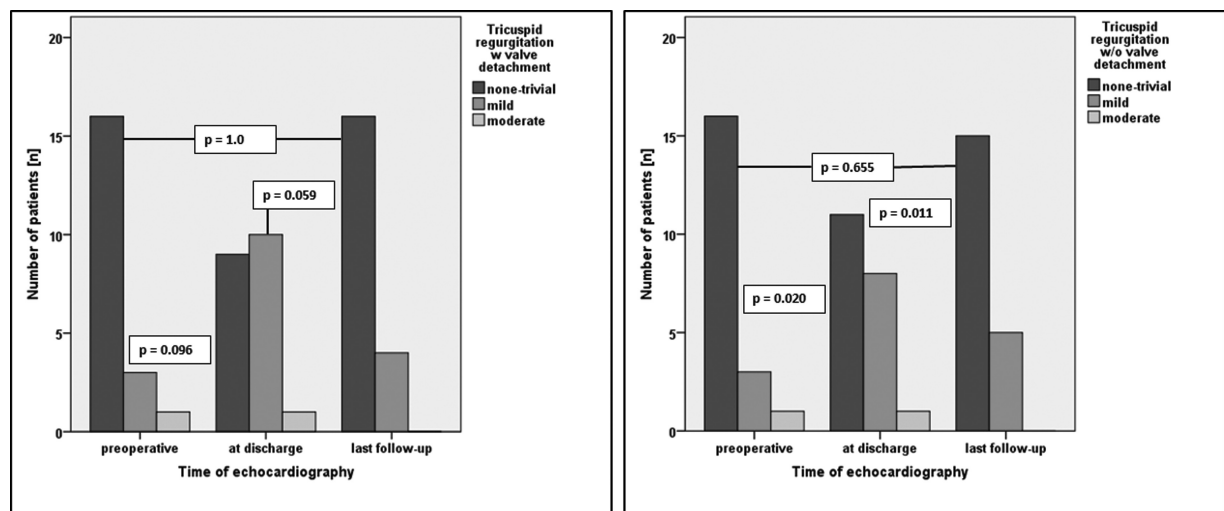
The risk of TV regurgitation and AV block are the key issues of this technique. ▶Fig. 2 displays the degree of TR. Intraindividual comparison of the TVD and non-TVD cohort did not reveal a significant change in TR from preoperative to last follow-up ( $p = 0.655$  and  $p = 1.000$ , respectively). However, the comparison between preoperative and discharge data reveals that there is an obvious influence of the operation on TR. Nevertheless, this finding is outgrown over time. Preoperative systolic LV function was normal in 95% and mildly impaired in 5% each in both groups. At discharge, in the non-TVD group, it was normal in 90% and mildly impaired in 10%; in the TVD group, it was normal in 80%, mildly impaired in 5%, and moderately impaired in 15% (intraindividual comparison to preoperative function:  $p = 0.567$  and  $p = 0.098$ , respectively). At follow-up, it was normal in all patients in both groups (intraindividual comparison to preoperative function:  $p = 0.317$ , both).

### Cardiac Biomarkers

Cardiac biomarkers drawn 1 day postoperatively are shown in ▶Table 2. There were no significant differences between groups.

### Electrocardiogram

Preoperatively, in the non-TVD group, there were six incomplete right bundle-branch blocks (RBBBs) (30%) versus eight



**Fig. 2** Intraindividual comparison of tricuspid regurgitation preoperative, at discharge, and at latest follow-up.

**Table 2** Cardiac biomarkers on the first postoperative day

| Cardiac marker     | No TVD<br>Mean ± SD | TVD<br>Mean ± SD | p-Value |
|--------------------|---------------------|------------------|---------|
| Troponin T (pg/mL) | 1,464 ± 690         | 1,833 ± 965      | 0.18    |
| CK (U/L)           | 740 ± 284           | 856 ± 350        | 0.25    |
| CK-MB (U/L)        | 75 ± 38             | 76 ± 26          | 0.92    |
| MB (%)             | 12 ± 9              | 9 ± 3            | 0.19    |

Abbreviations: CK, creatine kinase; MB, muscle-brain type; SD, standard deviation.

(40%) in the TVD group ( $p = 0.741$ ). At follow-up, all patients were in sinus rhythm. There were no left bundle branch blocks. In the non-TVD group, there were 7 (35%) complete RBBB and 5 (25%) incomplete RBBB versus 3 (15%) complete RBBB and 10 (50%) incomplete RBBB in the TVD group ( $p = 0.191$  [incomplete RBBB];  $p = 0.273$  [complete RBBB]). The TVD group included one patient who previously had a first-degree AV block and postoperatively developed a temporary third-degree AV block again followed by a permanent first-degree AV block.

## Discussion

In surgical VSD closure, as in all procedures, exposure is the key to success. Particularly in VSDs, exposure can be cumbersome. This is mostly due to tricuspid chordal tissue or additional connective tissue in the area of the VSD. To avoid residual shunts after repair, some surgeons prefer to expose

the VSD by partially detaching the septal leaflet of the TV. In addition to simply incising the septal and anterior leaflets parallel and close to the annulus, radial incision of the TV or detachment of the chordae from the septum is alternatives of exposing the VSDs.<sup>6,8,9</sup> TVD primarily in the anterior leaflet could be advantageous in terms of AV block rate and is preferred by some surgeons whenever the situation allows. However, these methods are not univocally accepted as they may cause TR, alter the AV node, or prolong the whole procedure. An overview of the literature to this work is presented in **Table 3**.

Comparison of cross-clamp and CPB times shows contradictory results. Russell et al reported that the radial incision approach adds only little complexity to the procedure. Thus, cross-clamp and CPB times did not differ significantly.<sup>6</sup> Other groups reported a significant longer cross-clamp time in the TVD group, but recommend to use it for better visualization whenever needed.<sup>21,22</sup> Most groups investigating sequelae of the circumferential incision approach did not find a significant impact on AV block and TR and considered the technique as safe. In line with these results, our study shows that even partial annular detachment of the septal and anterior leaflets does not increase the risk of TR or conduction disorders in our cohort. Nevertheless, it is common knowledge that complete AV blocks after VSD closure occur. A sizeable multi-institutional study estimated the risk at roughly 1% for patients with an isolated perimembranous VSD.<sup>23</sup> Furthermore, we found significantly more TR in both groups at discharge, which disappeared over time. Most likely, there is some structural rearrangement over time. Having this observation in mind, a much longer follow-up in the future is certainly of

**Table 3** Summary of literature of patients undergoing tricuspid valve incision or detachment to expose anatomy for VSD closure (latest follow-up)

| First author              | Enrollment period | Patients no. | TVD (%) | Heart block | Residual VSD | TR ≥ moderate | Detached leaflet | Age (y), mean    |
|---------------------------|-------------------|--------------|---------|-------------|--------------|---------------|------------------|------------------|
| Frenckner <sup>10</sup>   | 1966–1979         | 27           | 18      | 0           | 0            | 0             | SL               | 5 <sup>a</sup>   |
| Pridjian <sup>11</sup>    | 1982–1993         | 40           | 100     | 0           | 0            | 0             | SL               | 1.5 <sup>a</sup> |
| Tatebe <sup>12</sup>      | 1981–1994         | 13           | 8       | 0           | 0            | 2             | SL/AL            | 2.9 <sup>a</sup> |
| Gaynor <sup>13</sup>      | 1996–1999         | 36           | 21      | 0           | 0            | 0             | SL               | 0.5 <sup>a</sup> |
| Bol-Raap <sup>14</sup>    | 1985–1992         | 39           | 26      | 0           | 0            | 0             | SL/AL            | 1.3              |
| Zhao <sup>15</sup>        | 1991–2001         | 122          | 20      | 0           | 0            | 0             | SL               | 4.6              |
| Lin <sup>16</sup>         | 1997–2004         | 86           | 51      | 0           | 5            | 2             | SL               | 6.7              |
| Sasson <sup>17</sup>      | 2000–2004         | 41           | 23      | 0           | 0            | 0             | SL               | 3.4              |
| Scully <sup>18</sup>      | 2000–2006         | 52           | 24      | 0           | 0            | 0             | X                | 0.8              |
| Weymann <sup>19</sup>     | 2004–2011         | 20           | 57      | 0           | 0            | 0             | SL               | 0.5 <sup>a</sup> |
| Fraser <sup>20</sup>      | 1997–2013         | 83           | 34      | 0           | 0            | 1             | SL               | 0.6 <sup>a</sup> |
| Bang <sup>21</sup>        | 2004–2013         | 49           | 17      | 0           | 1            | 1             | SL/AL            | 0.2 <sup>a</sup> |
| Current study             | 2012–2015         | 20           | 50      | 0           | 0            | 0             | SL               | 1.1              |
| Pourmoghadam <sup>9</sup> | 2005–2016         | 26           | 23      | 0           | 0            | 0             | SL               | 0.6 <sup>a</sup> |
| Giordano <sup>22</sup>    | 2008–2017         | 11           | 7       | 0           | 0            | 1             | SL               | 0.5              |

Abbreviations: AL, anterior leaflet; SL, septal leaflet; TR, tricuspid regurgitation; TVD, tricuspid valve detachment; X, no data.

<sup>a</sup>Median age.

interest. CPB and aortic cross-clamping were longer in the TVD group because of the additional time needed to reattach the leaflets after VSD closure. However, for CPB, it did not reach a level of statistical significance and it is likely that the patients with TVD had principally the more difficult anatomies. Consequently, to facilitate better exposure and adequate visualization of the VSD and to thus guarantee a more sufficient closure, the cost of a prolonged operation time should be accepted. This study is limited by a somewhat small sample size and its retrospective nature. In addition, the fact that only two surgeons performed the operations by choice with or without TVD could further limit the interpretability of our study. It is likely that all VSDs could have been closed without TVD as well. However, experience and preference of the surgeon may play an important role. Based on our data, we recommend TVD as a valuable technique to visualize the entire (perimembranous and inlet) defect in selected cases.

#### Note

The study is part of the doctoral thesis of John Schittek at the University of Hamburg.

#### Conflict of Interest

None declared.

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