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Predictors Of Residual VSD After Surgical Versus Transcatheter Closure

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ORIGINAL STUDY

Predictors of residual ventricular septal defect after surgical versus transcatheter closure

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Abstract

Background: **Ventricular septal defect (VSD) repair is a frequently performed cardiac procedure in children, and it is associated with an extremely low likelihood of experiencing post-operative complications.**

Aim: **To identify the incidence of residual shunt across interventricular septum after surgical repair or device closure of isolated VSD or associated with another congenital anomaly.**

Methods: **This is a retrospective study included 60 patients undergoing closure of VSD between January 2021 and January 2023 in the National Heart Institute. They were divided into two groups: group I underwent surgical closure (30 patients) and group II underwent transcatheter closure (30 patients). Trans-esophageal echocardiogram (TEE) was done directly post-operative. Patients with residual shunt were called, to be re-evaluated with TEE.**

Results: **Group I had 16 (53.3%) female patients. The mean age was 2.47 ± 2.14 years, the mean weight was 11.38 ± 4.17 Kg, the mean height was 81.68 ± 15.76 cm and the mean body surface area was 0.48 ± 0.10 M^2. The types of VSD were outlet in 13 (43.3%) patients, perimembranous in 12 (40%) patients, inlet in three (10%) patients, and muscular in two (6.7%) patients. The mean size of VSD was 7.88 ± 2.01 cm. A residual shunt was diagnosed in 15 (50%) patients with the mean size of the residual shunt was 2.06 ± 0.97 mm. In follow-up TEE, residual shunt was diagnosed in nine (30%) patients with a mean size of the residual shunt was 1.43 ± 0.61 mm. Group II had 15 (50.0%) female patients. The mean age was 8.49 ± 4.99 years, the mean weight was 27.08 ± 14.69 Kg, the mean height was 121.63 ± 27.14 cm and the mean body surface area was 0.94 ± 0.35 M^2. The types of VSD were perimembranous in 19 (63.3%) patients and muscular in 11 (36.7%) patients. The mean size of VSD was 5.47 ± 1.36 cm. A residual shunt was diagnosed in nine (30%) patients with the mean size of residual shunt was 1.0 ± 0.0 mm. In follow-up TEE, the residual shunt was diagnosed in two (6.7%) patients with a mean size of the residual shunt was 1.0 ± 0.0 mm. Univariate and multivariate regression analyses regarding residual VSD shunt revealed that the size of VSD was a predictive factor in surgical or device closure of VSD.**

Conclusion: **Postoperative echocardiograms routinely show residual VSD following surgical or transcatheter closure. The size of the VSD was found to be an independent factor contributing to the presence of residual VSD in both surgical and transcatheter closure procedures.**

Keywords: Mortality, Residual ventricular septal defect, Tricuspid valve, Ventricular septal defect (VSD)

1. Introduction

The most common congenital cardiac anomaly in children and the second most frequent congenital abnormality in adults is a ventricular septal defect (VSD) [1]. Repair of VSDs is a frequently executed procedure in pediatric cardiac interventions, accompanied by an exceptionally low incidence of anticipated post-operative complications [2].

Surgical repair is the conventional method of treatment, initially performed by Lillehei in 1954 [3]. The surgical procedure is often regarded as the most reliable and effective method with minimal operative mortality, but it is associated with morbidity, post-operative pain, and surgical scarring. The

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development of percutaneous techniques has been encouraged to lessen the drawbacks of surgery. Using a transcatheter technique, Lock closed the first VSD [4]. The percutaneous closure of VSDs is still limited to muscular and perimembranous types with special requirements. However, the surgical closure provides accessibility to close all types of VSDs [5].

A residual shunt surrounding the repair's perimeter is frequently discovered as a result of resolution improvements and the regular use of intraoperative echocardiography after the procedure [5]. The presence of residual defects observed on echo Doppler is typically attributed to minor irregularities in the ventricular muscle, which, when combined with narrow gaps between sutures in the patch, create a passage for blood flow [6]. It is expected that these minor leaks will gradually cure over a period of weeks to months as the healing process covers the patch, causing the leak to become less visible. These leaks are different from intramural residual defects, which involve tissue channels around the edges of a VSD patch [6].

2. Methodology

This is a retrospective study that included 60 pediatric patients who were referred for VSD closure in National Heart Institute, between January 2021 and January 2023. All of the patients were below 18 years of age. They were divided into two groups (surgical and device closure groups). The surgical group included 30 patients and the device closure group included 30 patients.

(1) Inclusion criteria: all patients referred for VSD closure (whether surgical or device closure) were below 18 years of age.
(2) Exclusion criteria: 1. Patients with acquired VSD. 2. Redo VSD closure. 3. Patients who refuse to participate in the study.

All patients were subjected to the following:

(1) Preoperative; (demographic data, echocardiographic data, full labs [complete blood count, international normalized ratio (INR), alanine transaminase (ALT), aspartate transaminase (AST), Creatinine], chest radiography).
(2) Operative; Surgical group (surgical Approach, types of Patch material, Suture technique, concomitant cardiac defects, aortic cross-clamp time, total operative time, complications).

Device closure group [Maneuver, size of VSD by Transeophageal echocardiogram (TEE) and angiography, device, type of device, waist diameter, disc diameter and total fluoroscopic time].

(3) Postoperative; (Residual shunt across, intensive care units stay, duration of mechanical ventilation, total hospital stay, Morbidity and Mortality)

Transcatheter closure was indicated in patients with the following criteria:

(1) Perimembranous and muscular VSD.
(2) Sufficient rim to lodge the device.
(3) Not associated with other congenital anomalies.
(4) Not associated with other significant valve anomalies.

The VSD was surgically corrected by making midline sternotomy. This procedure involved employing cardiopulmonary bypass (CPB) and cooling the patients to a temperature of 32ºC–34 °C. The type of cardioplegia was either Custodial or cold blood cardioplegia. Surgical correction of the VSD was performed through a midline sternotomy, using CPB with patients cooled to 32°C-34 °C and the heart arrested with Custodial or cold blood cardioplegia. The VSD was surgically accessible either through an incision in the right atrium (80%) or through the transpulmonary artery (20%). In order to accomplish VSD exposure via the right atrium, the tricuspid valve was detached in three (10%) patients . The VSDs were sealed by pericardial patch (53.3%) or Gor Tex patch (46.7%).

The competence of the tricuspid valve was consistently assessed prior to the closure of the right atrium. Tricuspid valve repair was carried out in four patients, accounting for 13.3% of the total. All patients had post-operative TEE with two-dimensional and color doppler to evaluate for any residual shunting and to assess the competence of the tricuspid valve.

Transcatheter device closure was performed in a total of 30 cases. In 13 (43.33%) cases, the treatment involved complete left and right cardiac catheterization using only femoral arterial access with a retrograde approach. In the remaining 17 (56.66%) cases, both femoral artery and venous access were used for an antegrade approach. The whole procedures were done under general anesthesia. TEE was utilized in all patients and left ventricular angiography in four chamber view was utilized to investigate the VSD in depth. Different VSD closure device were used as reported in (Table 5).

Echocardiography defines residual VSD as flow across the ventricular septum. It was done immediately following surgery or at the initial outpatient clinic visit. The classification is based on the color jet width, which can be categorized as trivial (1 mm), small (1–2 mm), moderate (2–4 mm), or large (4 mm).

2.1. Statistics

The data were presented as a frequency or percentage for nominal variables, as the median (range) for categorical variables, and as the mean plus standard deviation or median (range) for continuous variables. Statistical computations were performed using JASP 0.16.

The following dependent outcome variable were analyzed: residual VSD shunt. The following variables were included in the analysis: Female gender, age, weight, height, body surface area, left ventricular end diastolic diameter (LVEDD), left ventricular end systolic diameter (LVESD), interventricular septum thickness, ejection fraction, left atrium diameter, right ventricle (RV) diameter, pulmonary artery pressure, size of VSD, cross clamp time, bypass time, tricuspid valve repair (yes/no), ventilation time, Waist diameter, disc diameter, ICU stay duration and total hospital stay.

Logistic regression analysis, the ×2 test, the Fisher test, and unpaired Student's *t*-test were utilized as appropriate for univariate analysis. Using multiple logistic regression analysis, a multivariable examination of risk factors for residual VSD was conducted. The multivariable model contained independent variables that had a *P* value of less than 0.2 in the univariate analysis. The multivariable model contained independent variables, for which odds ratios and their corresponding 95% confidence intervals were generated. A probability value below 0.05 was considered statistically significant.

3. Results

A total of 60 children met criteria and were included in the study. There were divided into two groups. Group I included 30 patients who underwent surgical closure of the VSD and group II included 30 patients who underwent Transcatheter closure of VSD. No mortality reported in both groups.

Regarding the demographic data, group I had 16 (53.3%) female patients. The mean age was 2.47 ± 2.14 years, the mean weight was 11.38 ± 4.17 Kg, the mean height was 81.68 ± 15.76 cm and the mean body surface area (BSA) was 0.48 ± 0.10 M^2. Isolated VSD was reported in 14 (46.7%) patients while concomitant pathology in 16 (53.3%) patients. While in group II, there was 15 (50.0%) female patients. The mean age was 8.49 ± 4.99 years, the mean weight was 27.08 ± 14.69 Kg, the mean height was 121.63 ± 27.14 cm and the mean BSA was 0.94 ± 0.35 M^2. All of the patients had isolated VSD. There were significant differences between both groups regarding the mean age, weight, height, BSA and associated pathologies ($P < 0.001$ in all). These differences are related mainly to the different ages in both groups and the early needing of surgery in patients with concomitant pathologies (as shown in Table 1).

Regarding the preoperative echocardiogram data: in group I, the mean LVEDD was 3.02 ± 0.68 cm, the mean LVESD was 1.80 ± 0.50 cm, the mean interventricular septum was 0.70 ± 0.20 cm, the mean EF was 69.90 ± 6.90%, the mean left atrium (LA) diameter was 2.0 ± 0.70 cm, the mean RV diameter was 1.40 ± 0.40 cm and the mean pulmonary artery systolic pressure (PASP) was 40.06 ± 14.56 mmHg. The types of VSD were outlet in 13 (43.3%) patients, perimembranous in 12 (40%) patients, inlet in three (10%) patients and muscular in two (6.7%) patients. The mean size of VSD was 7.88 ± 2.01 cm.

In group II, the mean LVEDD was 3.76 ± 0.72 cm, the mean LVESD was 2.22 ± 0.50 cm, the mean interventricular septum was 0.80 ± 0.20 cm, the mean EF was 68.70 ± 4.50%, the mean LA diameter was 2.50 ± 0.60 cm, the mean RV diameter was 1.60 ± 0.40 cm and the mean PASP was 48.30 ± 5.24 mmHg. The types of VSD were perimembranous in 19 (63.3%) patients and muscular in 11 (36.7%) patients. The mean size of VSD was 5.47 ± 1.36 cm. They were significant statistical differences between the groups regarding the mean LVEDD, LVESD, LA diameter, PASP, degree of

Table 1. Shows the demographic data of the group I and group II.

	Group I (no = 30)	Group II (no = 30)	*P* value
Age (y)	2.47 ± 2.14	8.49 ± 4.99	<0.001[a]
Female sex	16 (53.3%)	15 (50.0%)	0.795
Weight (kg)	11.38 ± 4.17	27.08 ± 14.69	<0.001[a]
Height (cm)	81.68 ± 15.76	121.63 ± 27.14	<0.001[a]
BSA (M^2)	0.48 ± 0.10	0.94 ± 0.35	<0.001
Down syndrome	8 (26.7%)	4 (13.33%)	0.196
Diagnosis			
VSD	14 (46.7%)	30 (100.0%)	<0.001[a]
TOF	10 (33.3%)	–	
CAVC	3 (10.0%)	–	
DORV	2 (6.7%)	–	
VSD + PS	1 (3.3%)	–	

BSA, body surface area; CAVC, complete atrioventricular canal defect; DORV, double outlet right ventricle; PS, pulmonary stenosis; TOF, tertalogy of Fallout; VSD, ventricular septal defect.

[a] Indicates statistically significant.

tricuspid regurgitation, the types of VSD and mean size of the VSD (P < 0.001, = 0,001, = 0.004, = 0.005, = 0.043, <0.001, <0.001, respectively) (as shown in Table 2).

Regarding the post-operative data: in group I, the mean ventilation time was 11.98 ± 16.01 h, the mean ICU stay was 79.54 ± 76.83 h and the mean total hospital stay was 15.64 ± 7.44 days. A residual shunt was diagnosed in 15 (50%) patients with the mean size of residual shunt was 2.06 ± 0.97 mm. In follow-up TEE, residual shunt was diagnosed in nine (30%) patients with mean size of residual shunt was 1.43 ± 0.61 mm.

In group II, the mean ventilation time was 0.95 ± 0.25 h, the mean ICU stay was 24.0 ± 0.0 h and the mean total hospital stay was 1.71 ± 0.65 days. A residual shunt was diagnosed in nine (30%) patients with the mean size of residual shunt was 1.0 ± 0.0 mm. In follow-up TEE, residual shunt was diagnosed in two (6.7%) patients with mean size of residual shunt was 1.0 ± 0.0 mm. There were significant statistical differences between the both groups regarding the ventilation time, ICU stay and total hospital stay (P < 0.001) (as shown in Table 3).

Table 2. Shows comparison between group I and group II regarding the preoperative echo data.

	Group I (no = 30)	Group II (no = 30)	P value
Preoperative Echo			
LVEDD (cm)	3.02 ± 0.68	3.76 ± 0.72	<0.001[a]
LVESD (cm)	1.80 ± 0.50	2.22 ± 0.50	0.001[a]
IVS (cm)	0.70 ± 0.20	0.80 ± 0.20	0.057
EF (%)	69.90 ± 6.90	68.70 ± 4.50	0.428
LA (cm)	2.0 ± 0.70	2.50 ± 0.60	0.004[a]
RV (cm)	1.40 ± 0.40	1.60 ± 0.40	0.057
PASP (mmHg)	40.06 ± 14.56	48.30 ± 5.24	0.005[a]
MR			
No	23 (76.7%)	26 (86.7%)	0.228
Mild	3 (10.0%)	4 (13.3%)	
Moderate	2 (6.7%)	–	
Severe	2 (6.7%)	–	
AR			
No	28 (93.4%)	30 (100.0%)	0.355
Mild	1 (3.3%)	–	
Moderate	1 (3.3%)	–	
TR			
No	14 (46.7%)	23 (76.7%)	0.043[a]
Mild	8 (26.7%)	6 (20.0%)	
Moderate	5 (16.7%)	1 (3.3%)	
Severe	3 (10.0%)	–	
Types of VSD			
Outlet	13 (43.3%)	–	<0.001[a]
Perimembranous	12 (40.0%)	19 (63.3%)	
Inlet	3 (10.0%)	–	
Muscular	2 (6.7%)	11 (36.7%)	
Size of VSD (mm)	7.88 ± 2.01	5.47 ± 1.36	<0.001[a]

AR, aortic regurge; EF, ejection fraction; IVS, interventricular septum; LA, left atrium; LVEDD, left ventricular end diastolic diameter; LVESD, left ventricular end systolic diameter; MR, mitral regurge; PASP, pulmonary artery systolic pressure; RV, right ventricle; TR, tricuspid regurge.

[a] Indicates statistically significant.

Each group was subdivided into nonresidual residual and nonresidual subgroups. Group I was divided into residual group I (no = 15) and group I (no = 15). Group II was divided into residual group I (no = 9) and nonresidual group I (no = 21). In group I, there were significant statistical differences between subgroups regarding the associated pathologies, the types of VSD and the mean size of the VSD (P = 0.026, = 0.044, <0.001). In group II, there were significant statistical differences between subgroups regarding the mean size of the VSD (<0.001) (as shown in Tables 4 and 5).

Univariate logistic regression analysis for incidence of residual VSD in group I revealed that size of VSD (OR = 1.911, P value < 0.001), cross clamp time (OR = 1.024, P value = 0.014) and CPB time (OR = 1.022, P value = 0.024). Multivariate logistic regression analysis revealed that size of VSD (OR = 2.386, P value = 0.001) was predictive factor (as shown in Table 6).

Univariate logistic regression analysis for incidence of residual VSD in group II revealed that size of VSD (OR = 3.517, P value = 0.013). Multivariate logistic regression analysis revealed that size of VSD (OR = 3.408, P value = 0.019) was predictive factor (as shown in Table 7).

4. Discussion

4.1. Group I

The presence of residual VSD following surgical closure is frequently observed and necessitates regular outpatient follow-up. This condition may elevate the risk of infection, both in the early and late stages, and can potentially impact the

Table 3. Shows comparison between group I and group II regarding the post-operative data.

	Group I (no = 30)	Group II (no = 30)	P value
Ventilation time (hrs)	11.98 ± 16.01	0.95 ± 0.25	<0.001[a]
ICU stay (hrs)	79.54 ± 76.83	24.0 ± 0.0	<0.001[a]
Total hospital stay (days)	15.64 ± 7.44	1.71 ± 0.65	<0.001[a]
Residual shunt			
Before discharge	15 (50.0%)	9 (30.0%)	0.113
In follow-up	9 (30.0%)	2 (6.7%)	<0.001[a]
Size of residual shunt (mm)			
Before discharge	2.06 ± 0.97	1.0 ± 0.0	0.003[a]
In follow-up	1.43 ± 0.61	1.0 ± 0.0	0.363

ICU, Intensive care unit.

[a] Indicates statistically significant.

Table 4. Shows comparison between the residual shunt and nonresidual shunt subgroups in group I.

	Group I (no = 30)	Residual shunt group I (no = 15)	Nonresidual shunt group I (no = 15)	*P* value
Age (y)	2.47 ± 2.14	2.19 ± 1.95	2.75 ± 2.45	0.492
Female sex	16 (53.3%)	9 (60.0%)	7 (46.7%)	0.536
Weight (kg)	11.38 ± 4.17	10.90 ± 3.74	11.86 ± 4.87	0.549
Height (cm)	81.68 ± 15.76	79.49 ± 14.27	83.88 ± 18.12	0.467
BSA (M^2)	0.48 ± 0.10	0.47 ± 0.13	0.50 ± 0.16	0.577
Diagnosis				
VSD	14 (46.7%)	3 (20.0%)	11 (73.3%)	0.026[a]
TOF	10 (33.3%)	6 (40.0%)	4 (26.7%)	
CAVC	3 (10.0%)	3 (20.0%)	0	
DORV	2 (6.7%)	2 (13.3%)	0	
VSD + PS	1 (3.3%)	1 (6.7%)	0	
Type of VSD				
Outlet	13 (43.3%)	7 (46.7%)	6 (40.0%)	0.044[a]
Perimembranous	12 (40.0%)	3 (20.0%)	9 (60.0%)	
Inlet	3 (10.0%)	3 (20.0%)	0	
Muscular	2 (6.7%)	2 (13.3%)	0	
Size of VSD (mm)	7.88 ± 2.01	9.20 ± 2.07	6.51 ± 1.79	<0.001[a]
BP time (min)	116.37 ± 27.54	124.26 ± 25.39	108.48 ± 28.85	0.011[a]
CC time (min)	86.22 ± 28.61	95.20 ± 26.58	77.24 ± 29.01	0.005[a]
Surgical approach				
Rt atriotomy	24 (80.0%)	11 (73.3%)	13 (86.7%)	0.361
Trans-pulmonary	6 (20.0%)	4 (26.7%)	2 (13.3%)	
Patch material				
Pericardial	16 (53.3%)	9 (60.0%)	7 (46.7%)	0.464
Gortex	14 (46.7%)	6 (40.0%)	8 (53.3%)	
Suture technique				
Interrupted	15 (50.0%)	8 (53.3%)	7 (46.7%)	0.715
Continuous	15 (50.0%)	7 (46.7%)	8 (53.3%)	
RVOT muscle resection	13 (43.3%)	7 (46.7%)	6 (40.0%)	0.712
Tricuspid valve detachment	3 (10.0%)	2 (13.3%)	1 (6.7%)	0.543
Ventilation time (h)	11.98 ± 16.01	15.57 ± 19.17	8.40 ± 5.21	0.173
ICU stay (h)	79.54 ± 76.83	90.13 ± 85.29	68.96 ± 57.71	0.432
Total hospital stay (days)	15.64 ± 7.44	9.20 ± 8.95	6.44 ± 2.70	0.262

BP time, bypass time; BSA, body surface area; CAVC, complete atrioventricular canal defect; CC time, cross clamp time; DORV, double outlet right ventricle; ICU, Intensive care unit; PS, pulmonary stenosis; Rt atriotomy, right atriotomy; RVOT, right ventricle outflow tract; TOF, tertalogy of Fallout; VSD, ventricular septal defect.
[a] Indicates statistically significant.

functioning of adjacent valves or maintain abnormal physiology through an ongoing shunt. Hence, it is crucial to consistently reassess and prioritize the examination of the medical records pertaining to the surgical correction of VSD.

The incidence of residual VSD in our study was 50% . In the literature, in Yang *et al*. was 41% [5], Raap *et al*. was 39% [7], Oses *et al*. was 47% [8] and Sayadpour-Zanjani *et al*. was 56% [9].

The choice of patch closure material remains diverse among different centers, indicating either the absence of an ideal material or little variations among the options available. These reports indicate that there is no apparent correlation between the rate of residual defect and the type of patch material utilized. No statistically significant difference was observed among the materials utilized in relation to the presence of post-operative residual VSD in our study.

Bibevski S and colleagues observed that the residual VSD was predominantly concentrated in the cranial region of the septal leaflet. This region corresponds to the boundary between the aortic valve annulus and the tricuspid valve leaflet annulus, which could account for the presence of minor remaining openings [6].

However, it is crucial to differentiate between a peri-patch residual defect, as discussed in this context, and residual intramural flaws. The latter abnormalities arise due to an alternative route for blood to pass through the septum, which is located outside the area where the VSD patch has been stitched (known as a separate but adjacent VSD). These defects seem to be related with increased mortality, morbidity, and longer length of stay compared to peri-patch defects [10,11].

Our study revelaed that more than 40% of the residual VSDs sealed spontaneously within a period

Table 5. Shows comparison between the residual shunt and nonresidual shunt subgroups in group II.

	Group II (no = 30)	Residual shunt group II (no = 9)	Nonresidual shunt group II (no = 21)	*P* value
Age (y)	8.47 ± 4.99	10.50 ± 3.66	7.60 ± 4.76	0.114
Female sex	15 (50.0%)	4 (44.4%)	11 (52.4%)	0.690
Weight (kg)	26.37 ± 14.69	29.0 ± 12.76	25.25 ± 12.75	0.466
Height (cm)	10 ± 27.14	132.25 ± 17.11	117.75 ± 26.83	0.147
BSA (M^2)	0.93 ± 0.35	1.01 ± 0.26	0.90 ± 0.32	0.371
Type of VSD				
Perimembranous	19 (63.3%)	6 (66.7%)	13 (61.9%)	0.803
Muscular	11 (36.7%)	3 (33.3%)	8 (38.1%)	
Size of VSD (mm)	5.47 ± 1.36	6.75 ± 1.16	4.93 ± 1.14	<0.001[a]
Size of VSD by TEE (mm)	5.70 ± 1.30	6.81 ± 1.36	5.23 ± 1.06	0.001[a]
Size of VSD by angiography (mm)	5.71 ± 1.31	6.88 ± 1.33	5.21 ± 1.05	0.001[a]
Type of Device				
Amplatzer™	18 (60.0%)	5 (55.6%)	13 (61.9%)	0.872
Cera™	8 (26.7%)	3 (33.3%)	5 (23.8%)	
KONAR-MF™	3 (10.0%)	1 (11.1%)	2 (9.5%)	
Hyperion™	1 (3.3%)	0 (0.0%)	1 (4.8%)	
Model of Device				
ADO I	3 (10.0%)	2 (22.2%)	1 (4.8%)	0.664
ADO II	14 (46.6%)	3 (33.3%)	11 (52.4%)	
VSD-MU	2 (6.7%)	1 (11.1%)	1 (4.8%)	
VSD-MUSC	2 (6.7%)	1 (11.1%)	1 (4.8%)	
VSD-SYM	4 (13.3%)	1 (11.1%)	3 (14.3%)	
MFO	3 (10.0%)	1 (11.1%)	2 (9.5%)	
LT-PDA	2 (6.7%)	0	2 (9.5%)	
Waist diameter (mm)	6.07 ± 2.42	6.12 ± 1.35	6.05 ± 2.56	0.939
Disc diameter (mm)	10.08 ± 2.39	10.62 ± 2.97	9.85 ± 2.30	0.447
Total fluoroscopic time (min)	12.88 ± 10.57	7.25 ± 1.38	15.30 ± 12.23	0.060
Ventilation time (h)	0.95 ± 0.25	0.97 ± 0.13	0.93 ± 0.29	0.696
ICU stay (h)	24.0 ± 0.0	24.0 ± 0.0	24.0 ± 0.0	1.000
Total hospital stay (days)	1.71 ± 0.65	1.64 ± 0.23	1.78 ± 0.78	0.604

BSA, body surface area; ICU, Intensive care unit; TEE, Trans-esophageal echocardiography; VSD, ventricular septal defect.
[a] Indicates statistically significant.

Table 6. Shows univariate and multivariate logistic regression analysis for independent risk factors for incidence of residual ventricular septal defect in group I.

	Odds ratio	*P* value	95% Confidence of interval	
PASP	1.029	0.124	−0.008	0.065
Size of VSD	1.911	<0.001*	0.327	0.968
Cross clamp time	1.024	0.014*	0.005	0.042
Bypass time	1.022	0.024*	0.003	0.041
Ventilation duration	1.068	0.158	−0.026	0.157
Total hospital stay	1.141	0.131	−0.039	0.303
Multivariate				
Size of VSD	2.386	0.001**	0.341	1.399

Table 7. Shows univariate and multivariate logistic regression analysis for independent risk factors for incidence of residual ventricular septal defect in group II.

	Odds ratio	*P* value	95% Confidence of interval	
Age	1.012	0.141	−0.004	0.028
Height	1.027	0.173	−0.012	0.065
LA	5.047	0.113	−0.381	3.619
Size of VSD	3.517	0.013*	0.267	2.248
Multivariate				
Size of VSD	3.408	0.019**	0.202	2.250

of 6 months. It was shown by Raap that, by the median period of 3.9 years, 51% of their residual VSDs were closed [7].

We found that about fifth of the residual VSD closed spontaneously within 6 months. Raap demonstrated that 51% of their residual VSDs had closed by median time of 3.9 years [7]. Long-term follow-up will be required to assess if these residual shunts are still present after the five and ten years.

Our study found no correlation between age, weight, and the presence of a residual VSD. This conclusion is consistent with the findings of other studies. Cross clamp time and CPB time were statistically significant between the two subgroups. It may be related to long procedures in concomitant pathologies rather. Concomitant pathology with VSD, type of VSD and size of VSD were contributing factor for residual VSD. In our study, the size of residual defect was around 2 mm.

There was no significant statistically difference between both subgroups regarding tricuspid valve detachment. This study illustrates that tricuspid valve detachment is a safe method to enhance the exposure of a VSD.

4.2. Group II

The success rate was very high as closure was successfully achieved all of the patients. (Failure of procedure occurred in two patients and referred for surgery, they were excluded from the study). This coincides with the data reported in the literature where the success rate ranges between 87 and 100% of the cases [12]. In our study, there was no early mortality.

Residual VSD shunt diagnosed in 26.6% of the patients. The mean size of residual VSD was 1 mm. In the literature, residual shunt rate of 3–29% has been reported [12–16]. The incidence of a residual VSD in our study was not influenced by age or weight. Also, type of device and total fluoroscopic time were insignificant statistically between both subgroups.

Tricuspid regurgitation and aortic regurgitation were the most frequent valve lesions during transcatheter device closure in the literature. Possible causes include the occlude device impinged against the valve leaflets, migration of the occlude, the shape memory of nitinol wires, or the rupture of chordae tendineae [17]. Our study included a single patient who experienced severe tricuspid regurgitation following implantation.

The advantages of transcatheter device closure include eliminating the need for cardiopulmonary bypass, minimizing psychological impact, shorter hospital stay, less use of intensive care resources, and faster recovery time for routine activities. However, It is effective only in certain types of VSD with certain criteria. Surgery still a gold standard for complicated VSD. Unfortunately, it is difficult to establish direct comparisons between the 2 modalities given that current time frames and indications differ for them.

4.3. Conclusion

Residual VSD after surgical repair or transcatheter closure is diagnosed frequently by post-operative echocardiogram. It is usually smaller than 2 mm in surgical closure and 1 mm in Transcatheter closure. They tend to be closed spontaneously over time without significant complications. The only predictive factor for residual VSD is the size of the VSD.

Transcatheter closure of VSD is a beneficial alternative to surgery for specific forms of VSDs, particularly in well-established centers and in the present period.

Authorship

First and second authors are responsible for data collection and writing the manuscript.

Conflicts of interest

Please consider checking the following:

All authors have participated in (a) conceptualization and designing, or analyzing and drawing conclusions of the data; (b) modification and revision of the article for necessary intellectual content; and (c) approving on the final version.

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