Outcome of Percutaneous Transcatheter Device Closure of Ventricular Septal Defect in Children Weighing Less than 10 Kilograms

[1] Elissa Dyann Soriano MD[1], Jean Antonio Villareal MD[2]

[2] Philppine Heart Center, Division of Pediatric Invasive Cardiology
[3] Training Officer, Philppine Heart Center, Division of Pediatric Invasive Cardiology

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Abstract

Introduction: Ventricular Septat Defect is the most common congenital heart disease in children. Infants weighing less than 10 kilograms with hemodynamically significant shunts may benefit from early transcather closure of VSD.

Methods: Patients who underwent percutaneous transcather closure of VSD from December 1, 2019 to April 30, 2020 were included in this study. All charts and records of the study group including demographic data, echocardiographic studies, angiographic data and procedural details were reviewed and analyzed.

Results: All patients in the study group underwent successful percutaneous transcatheter VSD device closure. Mean age of the subjects is 16.7±8.56 months with mean weight of 7.38±1.87 kilograms. Angiography reve aled mean VSD size of 0.43±0.09 cm and all were occluded using the Lifetech Konar Multifunctional Occluder with device size ranging from 6/4 to 10/8 and mean delivery sheath size of 5.2±0.91. There was significant improvement on follow -up after 1 month in terms of weight gain (mean weight gain of 1.22 kilograms), decrease in left ventricular end diastolic dimension (7.37% decrease from baseline) and pulmonary arterial pressure (33.16% decrease from baseline) with t-value of 0.008 9, 0.0202 and 0.0455 respectively. Minor complications noted were blood loss requiring transfusion in 60% of subjects and the presence of residual shunt in 10% of the subjects with mean hospital stay of 3.6 ± 0.69 days.

Conclusion: Early percutaneous transcatheter closure of hemodynamically significant ventricular septal defect in patients weighing less than 10 kilograms using the low profile Lifetech Konar Multifunctional Occluder is feasible and effective.

Keywords: *transcatheter device closure, ventricular septal defect, multifunctional occluder.*

INTRODUCTION

Ventricular septal defect (VSD) is the most common congenital heart disease identified in children[1]. Surgical and transcatheter closure of VSD are both well established modes of treatment. Both procedures carry some risks but are generally well tolerated. Percutaneous closure of VSD in patients less than 10 kilograms is rarely done and the usual practice is to wait for the natural closure of small shunts in children. However, patients with hemodynamically significant large shunts may benefit from early closure.

In the Philippine Heart Center, percutaneous transcatheter closure of shunts in pediatric patients have been done successfully. PDA and ASD device closure procedures were started in the early 2000 and percutaneous closure of VSD followed after a few years. Several studies have been done on early transcatheter closure of patent ductus arteriosus and atrial septal defects but there are limited literature available on percutaneous VSD device closure in children weighing less than 10 kilograms, or even in children less than 2 years of age. Reports on device closure in small infants are done via perventricular access and complications of this approach includes wire perforation of cardiac chambers, esophageal perforation, pericardial effusion and mediastinitis[2].

Thakkar et al reported a single center experience of muscular VSD device closure in infants in India. The study was done between 2008 to 2010 and it included 24 infants 2-12 months of age and weighing 2.7-4.9 kilograms. The perventricular access is used to accommodate the 6Fr -8Fr device loaders. They included symptomatic children with hemodynamically left to right shunt. The device was deployed under the guidance of transesophageal echocardiography using 6Fr to 8Fr delivery sheaths and the procedure was successful in 21 out of the 24 infants. The remaining three infants who underwent perventricular device closure had immediate surgery for the following reasons: perforation of the left ventricle, difficult access of the VSD and a large residual shunt after release of device. There were 4 major complications reported - death in 2 infants due aspiration and severe pneumonia, 1 infant with esophageal tear, and 1 infant with complete heart block and left ventricular outflow obstruction[2].

In the study by Thakkar et al, perventricular apporoach to device closure of VSD in small infants is preferred to percutaneous access due to the large delivery sheaths needed to deploy the device. However, with the availability of the newer Lifetech Konar Multifunctional Occluder (MFO),

with the availability of the newer Lifetech Konar Multifunctional Occluder (MFO), which can close shunt susing 4Fr to 7Fr delivery sheath, percutaneous transcatheter VSD closure in smaller infants is possible. This study aims to determine the outcome of percutaneous transcatheter device closure of hemodynamically significant VSD in children weighing less than 10 kilograms.

OBJECTIVES

A. General Objective

To describe the outcomes of transcatheter device closure of a hemodynamically significant ventricular septal defect in children less than 10 kilograms.

B. Specific Objectives

1. To determine the prevalence of percutaneous transcatheter VSD closure in children with hemodynamically significant VSD weighing less than 10 kilograms.

2. To describe the demographic profile and characteristics of children weighing less than 10 kilograms undergoing transcatheter VSD device closure
   - Age
   - Sex
   - Actual weight
   - Z value of weight for age
   - Comorbidities
   - Associated cardiac lesions

3. To describe the pre-procedural echocardiographic parameters and indications for transcatheter VSD device closure of children less than 10 kilograms
   a. Type of ventricular septal defect
   b. Size of the defect (cm)
   c. Qp:Qs ratio
   d. Left ventricular end-diastolic dimension and corresponding z-value
   e. Pulmonary artery pressure

4. To describe the intraprocedural characteristics of VSD transcatheter device closure on patients less than 10 kilograms
   a. Type of occluder used
   b. Size of occluder used
   c. Size of the VSD on angiogram
   d. Size of delivery sheath used
   e. Flouroscopy dose (Cumulative Air Kerma in mGy)

5. To describe the outcomes of transcatheter VSD device closure on patients less than 10 kilograms
   a. Procedural success or failure
      i. Device implanted and released
      ii. Device implanted but not released
      iii. Device embolization
      iv. Procedure aborted
   b. Presence of complications
      i. None
      ii. Minor complications
         1. Device embolization requiring percutaneous removal
         2. Hematoma
         3. Blood loss requiring transfusion
         4. Residual shunt
         5. New onset or increased regurgitation
         6. Arrhythmia other than complete heart block
         7. Prolonged hospital stay
         8. Hospital acquired infection
      iii. Major complications
         1. Thromboembolism
         2. Device embolization requiring surgical removal
         3. Complete heart block
         4. New onset or increased regurgitation requiring surgery
      iv. Death

6. To describe the post-procedural echocardiographic parameters 1 month after transcatheter VSD device closure in children less than 10 kilograms
   a. Presence of residual shunts
   b. Left ventricular end-diastolic dimension and corresponding z-value
   c. Pulmonary artery pressure

7. To compare the pre-procedural to post-procedural parameters as to the following:
   a. Weight on follow up (after 1 month)
   b. Left ventricular end-diastolic dimension
   c. Pulmonary artery pressure

METHODOLOGY

A. Design
- Cross-sectional descriptive study

B. Population

Inclusion Criteria
- All pediatric patients ages 0 to 5 years old weighing less than 10 kilograms who underwent transcatheter VSD device closure from December 1, 2019 to April 30, 2020.

Exclusion Criteria
- Subjects with complex congenital heart disease or cardiac lesions other than an atrial septal defect or a patent ductus arteriosus
- Subjects with other interventional procedure done other than hemodynamic studies and transcatheter device closure
- Subjects with no informed consent granted by their parents or legal guardians.

C. Operational Definitions

1. Hemodynamically significant VSD
- The presence of a ventricular septal defect in a patient with signs and symptoms of heart failure secondary to the shunt anomaly, has a QP:QS ratio of 1.5:1 or greater, LV enlargement on chest x-ray and echocardiography.

2. VSD device closure
- Patients who were qualified for VSD device closure are those with hemodynamically significant VSD and underwent percutaneous closure of the defect. The patients were screened at least a week before the procedure with routine pre-catheterization work-up done such as chest x-ray, electrocardiogram, creatinine, complete blood count, prothrombin time and partial thromboplastin time. The qualified patients were admitted a day prior to the procedure and are reevaluated and referred to anesthesia department for sedation. Patients less than 10 kilograms, were intubated and were given general anesthesia for the procedure.

3. Weight for age
- The patient's weight was plotted in the WHO growth charts to get the z-score for the weight for age. The Z-scores were reported as follows:
  i. Z-score of less than -2: underweight
  ii. Z-score of -2 to +2: normal weight for age
  iii. Z-score above +2: overweight

4. Echocardiographic Studies

a. All echocardiographic studies were done within 1 month before and a month after the transcatheter device closure. The echocardiogram was done by a non-invasive clinical research fellow and was counterchecked by a level III pediatric echocardiographer. All echocardiographic studies were reviewed by the interventionalist prior to the procedure. The result of the echocardiogram was relayed to the attending physician. The following echocardiographic findings were described and reported in the study as follows:

i. Type of VSD
- The VSD was described according to the location as seen in at least 2 echocardiographic views (parasternal long axis, parasternal short axis, 5chamber view and subcostal view):
  a. Perimembranous
  b. Subaortic
  c. Subpulmonic
  d. Doubly committed
  e. Muscular

ii. Size of the defect
  a. The VSD measurement was taken in at least 2 echocardiographic views (parasternal long axis, parasternal short axis, 5-chamber view and subcostal view)

iii. QP:QS
  a. The QP:QS ratio was measured echocardiographically using the formula:

$$\frac{\textbf{\textit{RVOT diameter x Pulmonic Valve VTI}}}{\textbf{\textit{LVOT diameter x Aortic Valve VTI}}}$$

iv. Left ventricular end-diastolic dimension (LVEDd)
- The LVEDd was measured in the m-mode of the short axis view. Normal values are based on LVEDd z-score for weight and are used to describe the LVEDd dimension as follows:
  1. Less than the normal for weight (z-score less than -2): Small LV cavity
  2. Within the normal limits for weight (z-score less than -2): Normal LV dimensions for age
  3. Above the normal limits for weight (z-score above +2): LV dilatation

v. Pulmonary artery pressure (PAP)
- The pulmonary artery pressure measurements were derived from the following:
  1. Pulmonary acceleration time – measured in the color doppler pulse wave of the pulmonic valve
  2. VSD gradient – measured in at least 2 views. The pulmonary artery pressure was measured by subtracting the systemic blood pressure of the patient from the measured VSD gradient in mmHg.

STUDY MANEUVER

All patients ages 0 to 5 years old and weighing less than 10 kilograms who underwent VSD device closure from December 1, 2019 to April 30, 2020 were included in the study. Consent were obtained from the parents. The following data were also obtained:

1. Demographic profile and characteristics
   a. Age
   b. Sex
   c. Actual weight
   d. Z value of weight for age and corresponding z-value
   e. Comorbidities and associated cardiac lesions

2. Pre-procedural echocardiographic parameters and indications for transcatheter VSD device closure
   a. Type of ventricular septal defect
   b. Size of the defect (cm)
   c. Qp:Qs ratio
   d. Left ventricular end-diastolic dimension and corresponding z-value
   e. Pulmonary artery pressure

3. Intraprocedural characteristics
   a. Occluder used as to:
      i. Type of occluder
      ii. Size of occluder
   b. Size of delivery sheath
   c. Size of the VSD on angiogram
      - The VSD measurement will be taken by the interventionalist on either the left anterior or true lateral view or both
   d. Fluoroscopy dose as cumulative air in kerma in milligray (mGy)

4. Procedure Outcomes
   a. Procedural success or failure
      i. Device implanted and released – The device is successfully deployed and released. Cineangiographic imaging post deployment shows proper placement of the device with no heart block upon deployment of device.
      ii. Device implanted but not released – The device is implanted but cineangiographic imaging post-depoloyment shows device placement that is not amenable for release (ex: the presence of a significant leak, the presence of a significant aortic regurgitation secondary to the device, etc) or note of complete heart block upon deployment of device
      iii. Device embolization – The device was deployed and released but embolized after release.
      iv. Procedure aborted – The procedure is aborted prior to deployment of the device for whatever reason.

   b. Complications will be described as either having no complications, minor complications and major complications.
      i. None
      ii. Minor complications
         a. Device embolization requiring percutaneous removal
         b. Hematoma in the groin or puncture site
         c. Blood loss requiring transfusion - Patients with significant blood loss during the procedure that would require blood transfusion during or after the procedure (within the same hospitalization).
         d. Residual shunt – leak or residual shunt after the transcatheter closure seen on post-procedure angiogram and follow up echocardiogram
         e. New onset or increased regurgitation
         f. Arrythmia other than complete heart block not requiring pacemaker insertion
         g. Prolonged hospital stay - Patients less that 10 kilograms who underwent VSD device closure were expected to be admitted for 5 days or less. Patients who were admitted for more than 5 days were considered as having prolonged hospital stay.

h. Hospital acquired infection - Patients who developed fever and clinical sepsis were referred to the pediatric infectious disease specialist for evaluation. Work-up for infection was done such as CRP, procalcitonin, CBC and blood culture. Those patients who were require additional antiobiotics for hospital acquired infection as assessed by the pediatric infectious disease specialist were described as having hospital acquired infection as a complication.

iii. Major complications

a. Thromboembolism - Patients with signs and symptoms of arterial or vascular thrombosis (Table 1) after the procedure was referred to vascular service for assessment and underwent doppler studies for documentation.

Table 1. Clinical presentation of venous thrombosis and arterial thrombosis based on symptomatology

Venous thrombosis	Arterial thrombosis
Bluish discoloration Engorgement of the veins Warmth Edema	Pallor Mottling Cold and clammy extremity Decrease in the pulse

b. Device embolization requiring surgical removal

c. Complete heart block - Patients who had successful transcatheter VSD device closure but developed complete heart block after release requiring pacemaker insertion.

d. New onset or increased regurgitation requiring surgery

e. Death occurring within 1 month from the procedure regardless of cause

5. Post-procedural echocardiographic parameters

- The echocardiogram was done 1 month after the procedure. The following parameters were described:
  - i. Presence of residual shunts including the size and gradient across the residual shunt if present
  - ii. Qp:Qs if a residual shunt is present
  - iii. Left ventricular end-diastolic dimension and corresponding zvalue
  - iv. Pulmonary artery pressure

Ethical Considerations

The study was conducted in compliance with the ethical principles set forth in the Declaration of Helsinki and the National Ethical Guidelines for Health and Health-Related Research of 2017 (NEGHHR 2017). Prior to study initiation, review and approval of the study protocol and informed consent and subsequent amendments was obtained from the Philippine Heart Center Institutional Ethics Review Board (PHC IERB).

There was a direct benefit for the subjects joining this study. The result of the echocardiographic study to be done after 1 month from the procedure was relayed to the attending physician. This echocardiogram was free of charge. The results of the study helped in the care of patients with similar condition in the future. This was a minimal risk study. The risk may be due to discomfort from the echocardiographic study as well as possible breach of data confidentiality.

The subject was considered vulnerable because of their age. In accordance with NEGHHR 2017, consent was obtained through the subject's legally authorized representative (LAR), which may be the child's parent/s or legal guardian.

Before a subject's participation, a written informed consent was obtained by the investigator after adequate explanation of the aims, methods, anticipated benefits and potential risks of the study. The informed consent was signed and personally dated by the subject's LAR and the person conducted the informed consent discussion prior to retrieval of the subject's medical records. One copy of the signed informed consent was given to the subject's LAR.

The investigator preserved the confidentiality of all subjects taking part in the study. The investigator ensured that the subject's anonymity was maintained. The risk to the subject's privacy was minimal and no sensitive information was obtained. The investigator ensured that the subject's anonymity was maintained. All data were encoded using a password-protected Excel spreadsheet. A code number was assigned for each patient. To maintain anonymity, a separate password protected spreadsheet that links the study code to the patient's name was made. Only the principal investigator had access to this file. After encoding, all data collection forms were kept in a secured cabinet. Once the researcher has been given clearance by the IERB and CTRD, the file that contains the link of the study code with the subjects' identifier was deleted. The data collection form were shredded and disposed. The researchers intend to adhere fully to the provisions of the Data Privacy Act of 2012.

Statistical analysis

Data were tabulated for organization and was analyzed using statistical tool STATA 13.1. Descriptive statistics was used to summarize the demographic and clinical characteristics of the patients. Frequency and proportion was used for categorical variables, median and inter quartile range for non-normally distributed continuous variables, and mean for normally distributed continuous variables. Ttest was used to compare the echocardiographic parameters before and after transcatheter VSD closure.

RESULT

The study included 10 subjects (n=10) weighing less than 10 kilograms who underwent transcatheter closure of VSD from December 1, 2019 to April 30, 2020. All medical records underwent a thorough medical chart review. Demographic data pre-procedural and post-procedural echocardiographic parameters, and intraprocedural characterstics and outcomes were recorded and analysed.

Table 2 shows the demographic profile of the studied group. The results indicate that majority of the subjects were aged 13-23 months (60%) while the minority were 24-36 months old comprising 10% of the total population. In terms of gender, it shows that majority were female which is 60% of the population. For the actual weight in kilograms, 70% weigh more than 6 kilograms with weight range of 4.9 to 10 kg in all patients in this study group. Majority of them were classified as severely underweight (50%) in terms of weight-for-age with a z-value of less than -3. No other comorbidities were reported among the patients. However, 3 out of 10 patients had other shunt lesions reported as follows – patent foramen ovale, patent ductus arteriosus and atrial septal defect.

Table 2. Demographic Profile

Parameters	Total (n=10)	Frequency (%)	Mean
Age in months			16.7±8.56
0 – 12 months	3	30%	
13 – 23 months	6	60%	
24 – 36 months	1	10%	
Sex			
Male	4	40%	
Female	6	60%	
Actual Weight (kg)			7.38±1.87
<3 kg	0	0%	
3 – 6 kg	3	30%	
>6 kg	7	70%	
Weight-for-age Z-value			
Overweight (>2)	0	0%	
Normal (0 to 2)	2	20%	
Underweight (-2 to 0)	3	30%	
Severely underweight (< - 3)	5	50	
Comorbidities			
With Comorbidities	0	0%	
Without Comorbidities	10	100%	
Other Cardiac Lesions			
PFO	1	10%	
PDA	1	10%	
ASD	1	10%	

PFO – patent foramen ovale, PDA -patent ductus arteriosus, ASD – arterial septal defect

Table 3. Pre-procedural echocardiographic parameters

Parameters	Total (n=10)	Frequency (%)	Mean
Type of Ventricular Septal Defect	10	100%	
Perimembranous	-	-	
Subaortic	-	-	
Subpulmonic	-	- -	
Muscular	-		
Mixed			
Size of VSD Defect (cm)			0.47± 0.10
Qp:Qs ratio			2.33± 1.33
Left ventricular end-diastolic dimension (cm)			3.16± 0.55
Left ventricular end-diastolic dimension (z-value)			2.1± 1.91
Pulmonary artery pressure			
Normal	3	30%	
Mild (25-40)	3	30%	
Moderate (40-60)	2	20%	
Severe (>60)	2	20%	

Pre-procedural echocardiographic parameters of the studied group are presented in Table 3. Based on the results, all patients (n=10) had perimembranous type of VSD. Mean size of VSD defect in centimeters was 0.47 cm (range 0.3-0.7), mean Qp:Qs was 2.33 (range 1.5-6.0), left ventricular end diastolic dimension was 3.16 cm (range 2.4-3.5) and the mean left ventricular enddiastolic dimension based on z-value was 2.1 (range 0-5). In terms of pulmonary artery pressure, 30% had normal PAP, 30% had mild pulmonary arterial hypertension, 20% had moderate pulmonary arterial hypertension and 20% had severe pulmonary arterial hypertension.

Table 4 shows the intra-procedural characteristics of the studied group based on the angiographic findings, type of occluder and delivery sheath used, technique used as well as the total fluoroscopy dose. Based on the results, majority of patients had a perimembranous (90%) type of VSD. However, one patient had a subpulmonic type of VSD on angiogram. For all the patients in this study, a Lifetech Multi-functional Occluder was used (100%) and the device size used were 6/4 to 10/8, using delivery sheaths ranging from 4Fr to 7Fr. The frequently used technique for the procedure was retrograde (70%) versus antegrade approach (30%). The mean size of VSD defect seen on angiogram was 0.43 cm (range 0.33 to 0.6cm). The mean fluoroscopy dose expressed as cumulative Air Kerma in mGy was 218.94 (range 88.3 – 320.69).

Table 5 shows the clinical outcome of transcatheter VSD device closure among the studied group. Results show 100% procedural success with no reported cases of embolized device or aborted procedure . Conversely, 60% of the total population reported intraprocedural blood loss requiring transfusion of blood components particularly packed red blood cell. Patients had a mean hospital stay of 3.6 days (range 3-5 days).

Post-procedural echocardiographic parameters are seen in Table 6. From the above results, it shows that one month post-procedure, 90% of the studied patients had no residual shunts or leaks noted. On the other hand, one of the patients who was seen to have a large perimembranous VSD had residual shunt measuring 0.3 cm. New onset valvular regurgitation was also noted in one patient wherein the echocardiogram on follow-up reported trivial tricuspid regurgitation. Furthermore, the left ventricular end-diastolic diameter shows improvement with a mean of 2.93 cm (range 2.6 – 3.5) from its initial mean of 3.16 cm (range 2.4-3.5). Likewise, the pulmonary artery pressure also improved wherein 7 out of 10 patients have normal (70%) pulmonary pressure, 2 patients (20%) have mild PAH and 1 patient (10%) has moderate PAH.

Table 4. Intra-procedural characteristics

Parameters	Total (n=10)	Frequency (%)	Mean
Type of Ventricular Septal Defect based on angiogram			
Perimembranous	9	90%	
Subaortic	-	-	
Subpulmonic	1	10%	
Muscular	-	-	
Type of occluder used			
Multi-functional Occluder (MFO)	10	100%	
Muscular VSD Occluder	0	0	
Membranous VSD Occluder	0	0	
Size of occluder used			
6/4	2	20%	
7/5	3	30%	
8/6	2	20%	
9/7	1	10%	
10/8	2	20%	
Size of delivery sheath used			5.2 ± 0.91 (range 4Fr-7Fr)
Technique			
Retrograde	7	70%	
Antegrade	3	30%	
Size of VSD Defect (cm)			0.43±0.09
Flouroscopy dose (cumulative Air Kerma in mGy)			218.94±81.23

Table 5. Outcome of VSD Transcatheter device closure

Parameters	Total (n=10)	Frequency(%)
Procedural success		
Device implanted and released	10	100%
Device implanted but not released	-	-
Device embolization	-	-
Procedure aborted	-	-
Complications noted during hospitalization		
Vascular thrombosis	-	-
Bleeding requiring transfusion	6	60%
Prolonged hospital stay	-	-
Hospital acquired infection	-	-
Death	-	-
None	-	-
Hospital stay (days)		3.6±0.69

Table 6. Post-procedural echocardiographic parameters

Parameters	Total (n=10)	Frequency (%)	Mean
Presence of residual shunts			
Yes	1	10%	
No	9	90%	
New valvular regurgitation / obstruction			
None	9	90%	
Trivial	1	10%	
Mild	-	-	
Moderate	-	-	
Severe	-	-	
Left Ventricular end-diastolic dimension (cm)			2.93±0.34
Left Ventricular end-diastolic dimension (z-value)			1.39±0.8
Pulmonary artery pressure			
Normal	7	70%	
Mild (25-40 mmHg)	2	20%	
Moderate (40-60 mmHg)	1	10%	
Severe (>60 mmHg)	0	0%	

Table 7 shows the comparison of the three parameters before and after transcatheter closure of the VSD. Paired T-test was done to test and determine if the mean difference between two groups is statistically significant. It was observed that weight, pulmonary artery pressure measured by echocardiogram, and left ventricular end diastolic dimension showed significant difference from the prepocedural to post-procedural results with t-value of 0.0089, 0.0202 and 0.0455, respectively. This table also shows that there was a 16.53% increase in the weight of the patients after 1 month and 33.16% and 7.37% decrease in the pulmonary artery pressure and LVEDd respectively on their follow-up echocardiogram.

Table 7. Comparison of weight, pulmonary artery pressure and left ventricular end diastolic dimension before and after transcatheter device closure

Parameters	Pre-Procedure	Post-Procedure	Percent change	Paired t-test p-value
Weight (kg)	7.38 ± 0.59	8.60 ± 0.86	**16.53% increase**	**p=0.0089**
Pulmonary Artery Pressure (mmHg)	38.60 ± 6.11	25.80 ± 3.03	**33.16% decrease**	**p=0.0202**
Left Ventricular End Diastolic Dimension (cm)	3.16 ± 0.17	2.93 ± 0.11	**7.37% decrease**	**p=0.0455**

Table 8. Minor and major adverse events after transcatheter VSD closure

Complications	Total	Frequency (%)
Minor		
• Device embolization requiring percutaneous removal	-	-
• Hematoma in the groin or puncture site	-	-
• Blood loss requiring transfusion	6	60%
• Residual shunt on follow up echocardiogram	1	10%
• New onset or increased regurgitation	1	10%
	-	-
• Arrhythmia other than complete heart block not requiring pacemaker insertion	-	-
• Prolonged hospital stay	-	-
• Hospital acquired infection		
Major		
• Device embolization requiring surgical removal	-	-
• Complete heart block	-	-
• New onset or increased regurgitation requiring surgery	-	-
• Death	-	-

All adverse events after transcatheter VSD closure seen in this study group are listed in table 8. Similar to the study of Yang et al, the complications are categorized as minor or major adverse events. No major events were noted in all patients and minor event noted were blood loss requiring transfusion, presence of a residual shunt on follow up echocardiogram and new onset regurgitation.

Listed in table 9 is the summary of the pre-, intra- and post-catheterization parameters as to the subjects' weight, left ventricular end diastolic dimension, QP:QS ratio, VSD size by angiography, associated cardiac lesion, occluder and delivery sheath size, technique used by the operator, length of hospital stay and the complications noted during the entire hospital course up to the follow-up at 1 month post-procedure.

Table 9. Summary of pre-, intra- and post-catheterization parameters

Patient #	Age (mo)	Weight (kg)		LVED (cm)		QP:QS ratio	VSD size (cm)	VSD type	Associated lesion	Device size	Delivery sheath (Fr)	Approach	Hospital stay (days)	Remarks
		Pre-	Post-	Pre-	Post-									
1	11	6.5	7	2.5	2.6	2.6	0.33	SP	none	8/6	5	retrograde	4	Blood transfusion
2	14	4.9	5	2.4	2.8	6	0.45	SP	PDA	8/6	5	retrograde	5	Blood transfusion (+)residual shunt
3	13	5.9	6	3.2	2.7	2	0.5	PM	PFO	9/7	7	antegrade	4	Blood transfusion
4	36	10	14	3	2.9	1.5	0.4	PM	none	6/4	4	retrograde	3	None
5	13	9	10	3.3	2.7	1.6	0.6	PM	none	10/8	6	antegrade	3	Blood transfusion (+)TR trivial
6	22	8	9.5	3.4	3	2	0.4	PM	none	7/5	5	retrograde	3	None
7	17	7	8	4	3.5	2.1	0.5	PM	none	7/5	5	retrograde	3	None
8	24	10	11.5	3.5	3.2	1.5	0.33	PM	ASD	7/5	5	retrograde	4	None
9	10	7.5	8	2.53	2.5	2	0.3	PM	none	6/4	4	retrograde	3	Blood transfusion
10	7	5	7	3.8	3.4	2	0.5	PM	none	10/8	6	retrograde	4	Blood transfusion

LVED- left ventricular end diastolic dimension, SP – subpulmonic VSD, TR-tricuspid regurgitation

DISCUSSION

Percutaneous transcatheter VSD closure is already a well-accepted treatment for patients with VSD. From the time it was first performed in the 1980s[4], numerous device occluders, delivery systems, deployment techniques and approaches have been developed. Nevertheless, transcatheter device closure procedures in small infants are not yet prevalent due to the possible risks and complications that the procedure may incur. Device closure of VSD was initially done via the perventricular approach which eliminates the risk of having acute limb ischemia but otherwise still carries major risks such as ventricular perforation and ventricular pseudoaneurysm[2]. Percutaneous closure of VSD in small infants have been done by many centers but are described to be more challenging compared to transcatheter procedures in older and bigger patients because of the more difficult catheter manipulation as well as the limited available calibers of the delivery systems suitable for small patients. According to Xing et al, a number of published studies even suggested that small infants weighing less that 10 kilograms are not suitable for percutaneous transcatheter VSD closure[5].

In this study, 10 patients with mean weight of 7.38 ± 1.87 kilograms and mean age of 16.7 ± 8.56 months underwent successful transcatheter VSD closure. This result is similar to the study of Xing et al who reported successful transcatheter VSD closure of infants with mean weight of 6.8 ± 2.8 kilograms but with a younger study group whose mean age is 7.2 ± 4.7 months. The older age group of our patients may be attributed to the later timing of intervention in our setting. Fifty percent of the patients in this study are malnourished with z-value of their weightfor-age noted to be less than -3. On follow up, all patients were noted to have increase in their weight with average weight gain of 1.22 kg and mean weight of 8.6 ± 2.7 kg for all patients after a month from discharge.

All patients in this study underwent transthoracic echocardiogram prior to the procedure and all patients included had a perimembranous type of VSD with mean VSD size 0.47 ± 0.10 cm. Angiographic findings were different in 20% of the patients wherein 1 patient had a subpulmonic type of VSD on angiogram while another patient had a mixed type of VSD with a perimembranous and subpulmonic component. These findings were also confirmed in the intra-procedural as well as the post-procedural transthoracic echocardiogram done. A subpulmonic and a subaortic VSD is more challenging to close percutaneously the distance of the defect from the semilunar valves will help the operator decide if device closure can be done. In both patients with the subpulmonic defect, the occluder was successfully implanted and completely occluded the subpulmonic defect. For the patient with both perimembranous and subpulmonic defects, the subpulmonic VSD was successfully occluded but there was still egress of contrast material noted through the perimembranous exit on angiogram.

Comparing other echocardiographic parameters before and after VSD closure showed significant improvement as well. The mean left ventricular end diastolic dimension of the study group is 3.16 ± 0.55. On follow up, the mean LVEDd of the study group is 2.93 ± 0.34. Using the Z-value for LVEDd, the difference of the pre-procedure mean Z-value of 2.1 to the post-procedure mean Z-value of 1.3 is significantly lower. Considering that the follow-up echocardiogram of the patients in this study was done a month after the procedure, this is comparable to the report of Yang et al in 2014 wherein they reported improvement in the LVEDd Z-value from 1.7 to 0.7 after 2 years. Pulmonary arterial pressure measurement pre- and post-procedure show that all patients with moderate to severe pulmonary arterial hypertension had significant decrease in the PA pressure. Two patients from the study group had severe pulmonary arterial hypertension prior to the device closure and both of them had more than 30% fall in the PA pressure decreasing their PA pressures to 39 mmHg and 45 mmHg from the baseline of 66mmHg and 68 mmHg respectively.

In all patients in this study group, Lifetech Konar Multi-Functional Occluders (MFO) were used with occluder sizes ranging from 6/4mm to 10/8 mm. The MFO is made from nitinol mesh with 144 wires of nitinol cables[6]. It is designed as a combination of two discs wherein 1 disc serves as a high-pressure disc (left disc) attached to a truncated cone and the other serves as a low-pressure disc (right disc) and is attached to the waist arm[7].

The high-pressure disc is usually placed in the left ventricular (LV) side and the low-pressure is placed in the right ventricular (RV) side. Conversely, the delivery system can be attached to either disc can be deployed either from the arterial access (retrograde technique) or from the venous access (antegrade technique). In one of the patients with a subpulmonic defect, the technique used was retrograde technique but the LV disc was placed in the right ventricle and the RV disc was placed in the left ventricle.

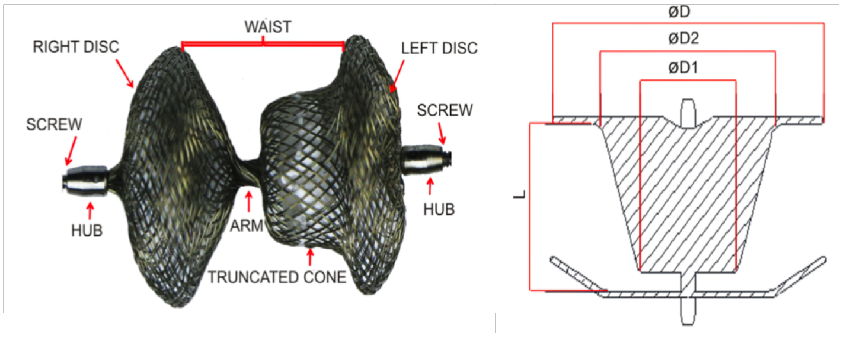

Figure 1. The Lifetech Konar Multi -functional Occluder has two discs that are connected by a cone-shaped waist. Both ends can be screwed to the delivery system and can be deployed from either disc. *Adapted from "Endovascular VSD Closure with Lifetech KONAR-Multifunctional Occluder – Novel Device" by Barbosa et al, Journal of Structural Heart Disease, December 2019, Volume 5, Issue 6:237-247.*

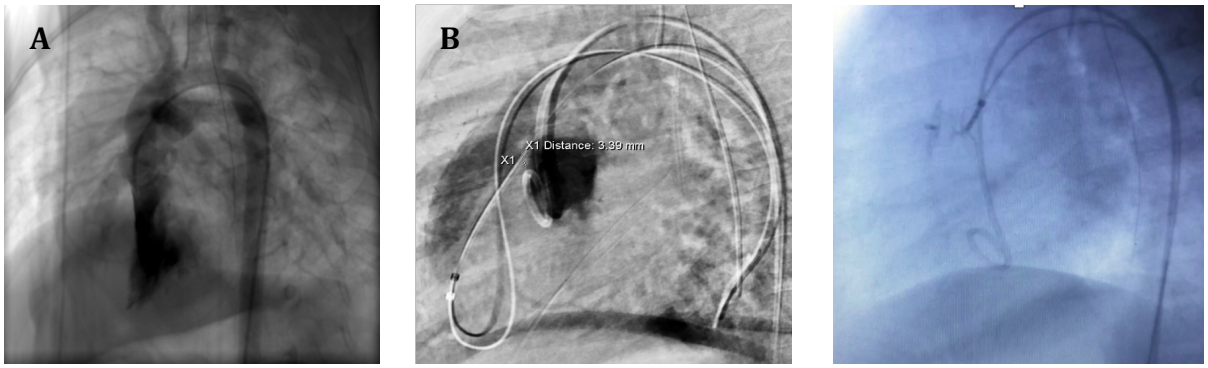

Figure 2. Patient P A, 11 months old weighing 6.5 kilograms with a subpulmonic VSD. **A**: LV angiogram taken at left anterior oblique view showing the defect. **B:** The defect was measured at 0.33 cm, **C:** a Lifetech Konar-MFO device deployed from the arterial access (ret rograde technique) but with the MFO device inverted (LV disc placed in the RV and the RV disc placed in the LV).

There was a mild obstruction to the right ventricular outflow tract (RVOT), immediately post occlussion but no gradient was noted on the follow-up echocardiogram.

The Konar MFO device is suitable for small infants because of the smaller caliber delivery sheaths available. The delivery system is low profile with a 3Fr delivery cable and 4Fr to 7Fr delivery sheath[7]. Majority of the patients in this study group with a VSD size of 0.3 – 0.4 cm used a 4Fr to 5Fr delivery sheath while the patients with VSD size of 0.5 to 0.6 cm and used device size of 9/7 to 10/8 used a 6Fr to 7Fr delivery sheath.

Two patients in this study had other significant shunt anomalies. One patient had a Patent Ductus Arteriosus (PDA) and was occluded using also a Konar-MFO 7/5 device and the other patient had a secundum Atrial Septal Defect (ASD) which was closed using a 10mm Ceraflex ASD device.

There were no reported major complications in all the patients in this study group with a mean hospital stay of 3.6 ± 0.69 days (range of 3-5 days). This is comparable to the study done by Yang et al in 2010 where they reported a mean hospital stay of 3.3 days[8]. In our institution, all patients less than 10 kilograms undergoing catheterization procedure are intubated and are weaned and extubated in the intensive care unit. All patients in this study were discharged in 35 days and were only reported to have minor complications. Yang reported that major adverse events in patients undergoing transcatheter VSD closure are thromboembolism, heart block requiring pacemaker insertion, device embolization and new-onset regurgitation requiring surgery while minor adverse events are hematoma, blood transfusion due to blood loss, embolization with transcatheter removal, hemolysis, arrhythmia, new or increased valvular regurgitation and fever[8].

Catalog Number		D Disc Diameter (mm)	D2 Waist Diameter LV Side (mm)	D1 Waist Diameter RV Side (mm)	L Waist Length (mm)	Recommended Delivery Sheath (Fr)
	LT-MFO-5-3	10	5	3	4	4F-5F
	LT-MFO-6-4	10	6	4	4	
	LT-MFO-7-5	12	7	5	4	
	LT-MFO-8-6	12	8	6	4	
 with membrane	LT-MFO-9-7	14	9	7	4	6F
	LT-MFO-10-8	14	10	8	4	
	LT-MFO-12-10	16	12	10	4	7F
	LT-MFO-14-12	18	14	12	4	

Figure 4. Different sizes of MFO and their corresponding recommended delivery sheaths. Sizes 5/3 to 8/6 have no membrane and uses a 4Fr to 5Fr delivery sheath while 9/7 to 14/12 devices have a PTFE membrane within the disc and uses 6Fr to 7Fr delivery sheath. *Adapted from "Endovascular VSD Closure with Lifetech KONAR-Multifunctional Occluder– Novel Device" by Barbosa et al, Journal of Structural Heart Disease, December 2019, Volume 5, Issue 6:237-247.*

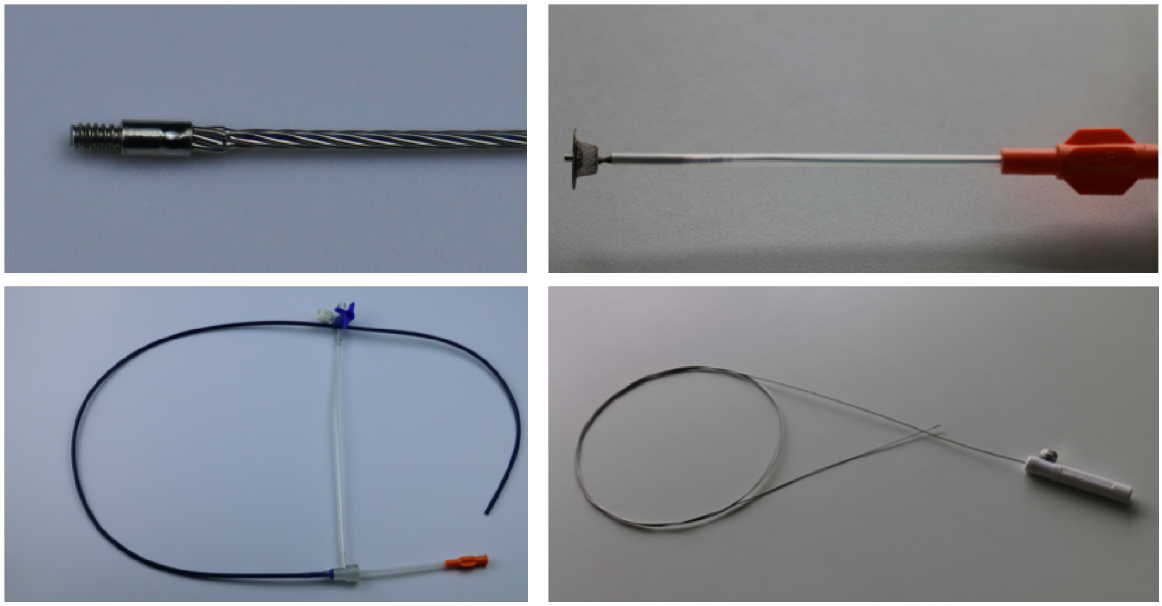

Figure 5. The Konar-MFO delivery system is low profile which makes it easier to manipulate. **A:** Screw at the end of the delivery cable which can attach to either disc of the device. **B:** The loader with the delivery cable and device through it. **C:** The delivery sheath. **D:** The delivery cable with a screw for the device on one end and a handle on the other. *Adapted from "Endovascular VSD Closure with Lifetech KONAR-Multifunctional Occluder– Novel Device" by Barbosa et al, Journal of Structural Heart Disease, December 2019, Volume 5, Issue 6:237-247.*

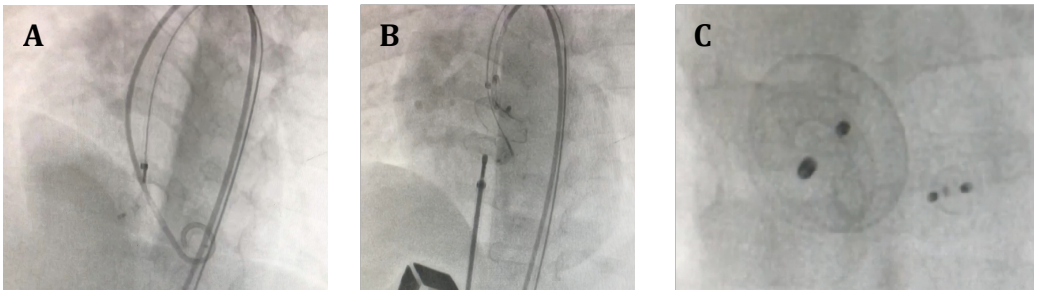

Figure 6. Patient VP, a 2 year old patient with an 0.8 cm secundum ASD and a 0.3 cm perimembranous VSD. **A:** Retrograde technique of VSD device closure using a Konar MFO 7/5. **B:** ASD device and MFO device at the VSD in place attached to their respective delivery cables. **C:** ASD device and MFO device released.

Minor complications noted in the patients post-procedure in this study are blood loss requiring transfusion in 60% of the patients, presence of residual shunt in one patient and trivial tricuspid regurgitation in one patient seen on follow up echocardiogram.

CONCLUSION

Transcatheter closure of ventricular septal defect was done successfully in 10 patients weighing less than 10 kilograms using the Lifetech Konar Multifunctional Occluder. Minor complications noted were blood loss requiring transfusion and the presence of residual shunt. On follow-up after 1 month, there was noted clinical improvement in terms of weight gain and decrease in the pulmonary arterial pressure and left ventricular end diastolic dimension.

RECOMMENDATION

We recommend a larger, multicenter, and prospective controlled to further evaluate the feasibility and long-term results of percutaneous transcatheter closure of ventricula septal defects in infants. A continuous follow-up among subjects is also necessary to evaluate the long-term complications.

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Contact details of corresponding authors:

- **Elissa Dyann Soriano, MD** sorianodyann@gmail.com +639178198346
- **Jean Antonio G. Villareal, MD** jagv7671@gmail.com +639999913479

Editorial Review

"Transcatheter closure of perimembranous ventricular septal defect (Pm VSD) is not new. The eccentric device was introduced in 2006 had changed the scenario in the world (1). But soon after the early results, the device was withdrawn due to unacceptably high incidence of complete heart block. The novel KONAR-MF TM device is unique in nature by several folds and appears promising for Pm VSD closure (2). The device has low-pressure disc and high-pressure disc with a major hemodynamic advantage due to incremental diameters of the central connecting cone shaped structure. This advantage allows the operator to position the device easily in the defect. The medium profile design can be easily negotiated through 5-6fr delivery sheaths. The clamping force and shear stress by the device is negligible due to its profile and design. The added advantage of retention screws on either side is useful to deploy from either side of the device.

"The authors of the study "Outcome of percutaneous transcatheter device closure of ventricular septal defect in children weighing less than 10 kilograms" are very much appreciated for producing good clinical outcome. All the patients of the study were under 10 kilograms and underwent successful closure of Pm VSD using KONAR-MF. There were no major complications. The delivery sheath was < 6fr. This study clearly shows the device can be effectively used in the young. All patients in the study were having shunt >2:1. The men left ventricular end diastolic dimension was > 3.16 ± 55 suggests that all patients were having hemodynamically significant Pm VSD. There were 7 children had mild to severe pulmonary hypertension in the study group became normal after the device closure. The operators chose to deploy the device using retrograde method in 70% of cases (3). This is possible with KONAR-MF due to retention n screws on either side. The high-pressure disc is positioned in the arterial side in case of retrograde deployment. Authors chose this method probably due to the device can be easily deployed using smaller size sheath even in the young patients.

The follow-up echocardiographic results are very much encouraging in the present study. The left ventricular end diastolic dimension ('z') decreased significantly to 1.39±0.8. All patients gained the weight during followup by 16.5% (p=0.008). Overall the results of the study is very much encouraging. The study power is somewhat less due to a smaller number of patients. This is due to smaller number of patients suitable for the device closure. The case suitability and indications for the device closure are usually less in this subset of population. Therefore, the present study shows that usage of KONAR-MF in young children under 10 kilograms is feasible with negligible complications. Retrograde method is useful even in smaller children to close the Pm VSD effectively."

NAGESWARA RAO KONETI, MD
DM
Chief Pediatric Cardiologist
Rainbow Children's Heart Institute
Hyderabad, India

Disclosure:

Dr. Nageswara Rao Koneti receives royalty from Lifetech Scientific for KONAR-MF.

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