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Letters

RESEARCH CORRESPONDENCE

Transcatheter Closure of Perimembranous Ventricular Septal Defects With Amplatzer Duct Occluders

Perimembranous-type ventricular septal defect (PmVSD) is the most common subtype of ventricular septal defect (VSD) (1). Surgical repair of these defects has achieved tremendous progress over the past 50 years (1). More recently, the similar morphologies of PmVSD and patent ductus arteriosus have attracted the attention of cardiac interventionists (1,2), and several studies have shown feasible short-term outcomes of the transcatheter closure of PmVSD with various patent ductus arteriosus occluders (Online Table 1). However, the mid-term results of such interventions in PmVSD remain unclear. Therefore, by using the data of a tertiary medical center between 2010 and 2016, we investigated the mid-term follow-up results of the transcatheter closure of PmVSD performed using Amplatzer Duct Occluders (ADOs).

This study was approved by Institutional Review Board of National Taiwan University Hospital. Demographics of patients, enrollment criteria, and follow-up protocol of echocardiography are provided in the Online Appendix. Catheterization procedures are also described in the Online Appendix. Briefly, a complete hemodynamic assessment was conducted to calculate the magnitude of a VSD shunt by applying Fick's principle. Standard ascending aortography and left ventricular angiography were performed in all patients to determine the defect location, its relationship with the aortic valve, and the defect diameter (Online Figure 1). Devices that were approximately 1.5 mm larger than the measured VSD diameters were selected.

We established an arteriovenous circuit as in previous studies (2). An adequately sized ADO was selected and introduced over the delivery sheath. We usually used first-generation ADOs for conical VSDs and second-generation ADOs for tubular VSDs. We deployed the devices under real-time transesophageal echocardiographic and fluoroscopic monitoring (Online Figure 2). A left ventriculogram and an ascending aortogram were obtained again to evaluate the adequacy of the occluder position, residual shunt, and aortic regurgitation (AR). After discharge, patients received platelet antiaggregation therapy (oral aspirin 3 to 5 mg/kg/day) for 6 months, and vigorous physical activity was not allowed for the first month. Echocardiographic follow-up was arranged at 1, 3, and 6 months after discharge and every 6 months thereafter.

Between 2011 and 2016, 105 patients with PmVSDs (53 men, median age 19.5 years, median body weight 49.9 kg) underwent transcatheter closure with ADOs. All patients were followed up until the end of 2016 with transthoracic echocardiography and electrocardiography. The median procedure and fluoroscopy

TABLE 1 Demographic and Procedural Data

	Perimembranous Trabecular-Type VSD (n = 87)	Perimembranous Outlet-Type VSD (n = 18)
Demographics		
Male/female	40/47	13/5
Age (yrs)	19.9 (10-28.5)	7.7 (6.3-22.5)
Body weight (kg)	52.0 (32.5-62.8)	38.1 (20.9-77.3)
Catheterization data		
No of failure	4	1
VSD diameter (mm)	4.2 (3.8-5.0)	4.6 (3.23-5.05)
Defect - Device (mm)	1.55 (0.97-2.35)	1.0 (0.40-1.75)
Qp/Qs	1.40 (1.22-1.68)	1.24 (1.12-1.35)
Mean PAP (mm Hg)	15 (13-18)	16 (15-17)
Mild or greater AR	21	6
Cusp prolapse		
No	30	3
Teardrop	52	12
Moderate	5	3
Procedure time (min)	112 (94-143)	105 (88-139)
Fluoroscopy time (min)	20.5 (8.7-25.9)	18.9 (9.6-25.1)
Device size (mm)		
ADO I	58	9
4	9	3
6	31	4
8	15	2
10	3	0
ADO II	26	8
4	8	4
5	8	3
6	10	2

Values are n or median (interquartile range).

ADO = Amplatzer Duct Occluder; AR = aortic regurgitation; PAP = pulmonary arterial pressure; VSD = ventricular septal defect.

time were 108.0 and 19.2 min, respectively. The median diameter of the PmVSDs was 4.24 mm (interquartile range: 3.31 to 5.0 mm). Only 2 patients (1.9%) in the PmVSD cohort had mean pulmonary arterial pressures >25 mm Hg. Clinical characteristics, hemodynamic status, and procedural data are summarized in **Table 1**, on the basis of the subtypes of PmVSD. No mortality was noted. Of the 105 attempts, 5 (4.8%; 4 with perimembranous trabecular-type VSDs) were abandoned after diagnostic catheterization for various reasons (details not shown here). The shape of the VSD was conical in 49 patients (perimembranous trabecular type, 42 patients) and tubular in 51 patients. The median ratio of pulmonary to systemic blood flow and device size implanted were 1.36 and 6 mm, respectively. The median aortic rim was 1.2 mm. Before closure, 72 patients had prolapsed aortic cusp, and 27 had mild or mild to moderate degrees of AR. None of them experienced new-onset AR, except for 1 18-year-old female patient who had a history of infective endocarditis before her VSD closure (Online Figure 3). None of patients had worsening tricuspid regurgitation after VSD closure. The 1-month, 6-month, 1-year, and 2-year probabilities of a persistent small residual VSD shunts were 8.7%, 7.2%, 5.9%, and 4.5%, respectively. No mortality or atrioventricular block was reported. One major adverse event was observed in a 15-year-old girl who had an episode of arteriovenous malformation-associated left frontal lobe intracranial hemorrhage 5 months after her transcatheter closure.

To the best of our knowledge, the present study is the first to enroll a large number of patients with PmVSDs and prolapsed aortic valves (72%) or mild AR (27%). Our results included a 100% success rate, no noted atrioventricular blocks, and the development of new-onset mild AR in only 1% of patients. These excellent results might be attributable to the use of a softer device and the conservative size of the device (Online Figures 3 and 4).

Traditionally, aortic cusp prolapse has been considered a contraindication to the device closure of PmVSDs because of concerns regarding the worsening of AR (2). In our present cohort, mild and moderate aortic prolapse was noted in 64 and 8 patients, respectively. Although none of them experienced new-onset AR or AR progression during the average 2-year follow-up period, the long-term feasibility of transcatheter closure with duct occluders for the subgroup of patients with PmVSD should be further validated in the future.

The results of surgical VSD repair have been consistently excellent for many years, with percentages of 1-year post-operative residual VSD leakage approaching 1% at many medical centers (1,2). In this study, we used ADOs, which have less polyester material and may have resulted in slightly delayed complete VSD closure (1-month residual shunt rate 7.2%). How to reduce the risk for residual VSD jets after transcatheter closure remains an important issue.

We demonstrated feasible mid-term results of transcatheter VSD closure in selected patient populations. With a conservative approach, the transcatheter closure of VSDs with ADOs may provide an alternative to open heart surgery.

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APPENDIX For supplemental figures and their legends and a table, please see the online version of this article.

RESEARCH CORRESPONDENCE

Transcatheter Patent Foramen Ovale Closure After Cryptogenic Stroke

An Updated Meta-Analysis of Randomized Trials

Paradoxical embolism from a patent foramen ovale (PFO) mediated right-to-left shunt is a well-described mechanism of ischemic stroke (1). In a patient level