

ORIGINAL ARTICLE

Percutaneous Closure of Perimembranous Outlet Ventricular Septal Defect with Partial Right Coronary Cusp Prolapse: A Single-Center Experience.

Syed Asif Akbar Shah, Zaland Ahmed Yousafzai & Qazi Kamran Amin

Department of Pediatric Cardiology, Lady Reading Hospital, MTI, Peshawar, Pakistan.

Copyright © The Author(s). 2026 This is an open-access article distributed under the terms of the Creative Commons Attribution 4.0 International License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.



Citation:

Shah SAA, Yousafzai ZA, Amin QK. Percutaneous Closure of Perimembranous Outlet Ventricular Septal Defect with Partial Right Coronary Cusp Prolapse: A Single-Center Experience. *PJCVI*. 2026; 6(2): XX-XX

Corresponding Author Email:

zaland.yousafzai@gmail.com

DOI: 10.58889/PJCVI.6.2.XX.XX

Funding:

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Conflicts of Interests:

The authors declare no conflict of interest related to this publication.

Received 17/01/2026

Accepted 22/03/2026

First Published 08/10/2026

Abstract

Background: Perimembranous ventricular septal defects (PmVSD) with outlet extension and partial right coronary cusp (RCC) prolapse are a difficult category for transcatheter closure due to their closeness to the aortic valve. This study describes our single-center experience with percutaneous device closure in a high-risk group.

Methodology: A retrospective analysis was conducted on all patients who underwent attempted transcatheter closure of perimembranous outlet VSD with partial RCC prolapse at Lady Reading Hospital MTI Peshawar between January 2022 and June 2025. Demographic, procedural, and follow-up data were reviewed.

Results: A total of 34 patients (mean age 8.5 years, range 2-22 years; 52.9% male) had attempted device closure. The median left ventricular defect size was 6.2 mm (range 4-10 mm). The KONAR-MF multipurpose occluder was employed in 82.4% of instances, with the remaining using the Amplatzer duct occluder II. The procedure was successful in 91.2% (31/34) of the patients. Three procedures were halted due to device-related aortic regurgitation. Complete closure was observed in 77.4% of cases at discharge, which increased to 93.5% at 6-month follow-up. Of the 31 successful procedures, eight patients (25.8%) had pre-existing mild AR that remained stable throughout follow-up; two additional patients (6.5%) developed new-onset mild aortic regurgitation post-procedure. No patient developed moderate or severe AR. There were no occurrences of total heart block, device embolization, or significant vascular problems.

Conclusion: In conclusion, percutaneous closure of perimembranous outlet VSD with partial RCC prolapse is feasible and safe in selected patients, with high procedural success and acceptable complication rates. Careful patient selection, suitable device selection, and cautious technique are required for best results in this difficult population.

Keywords

Ventricular Septal Defect, Perimembranous Outlet, Right Coronary Cusp Prolapse, Transcatheter Closure, KONAR-MF Occluder, Aortic Regurgitation

Introduction

Ventricular septal defect (VSD) is the most prevalent congenital heart condition, accounting for roughly 40% of all cardiac malformations¹. Perimembranous VSD (PmVSD) is the most common anatomical subtype, accounting for 70–80% of all VSDs². The natural history of PmVSD is varied, with spontaneous closure occurring in 30–50% of small defects during childhood¹. However, moderate to large abnormalities frequently necessitate intervention due to hemodynamic implications, the danger of infective endocarditis, or progressive aortic valve complications.

Perimembranous outlet VSD with partial right coronary cusp (RCC) prolapse is an especially challenging subset. The outlet extension of these defects takes them near to the aortic valve, and the Venturi effect caused by the high-velocity left-to-right shunt can cause the RCC to prolapse into the defect³. This anatomical configuration raises the risk of progressive aortic regurgitation (AR), hence early closure is recommended⁴. Historically, such abnormalities were regarded as contraindications for transcatheter closure due to concerns regarding device interference with aortic valve function⁵.

The introduction of newer generation devices, particularly the KONAR-MF (multifunctional occluder), has broadened the indications for transcatheter VSD closure⁶. The KONAR-MF device's distinct design incorporates a soft, thin, low-profile nitinol mesh that conforms to the dynamic motion of the aortic valve leaflets with minimal interference⁷. This feature has enabled closure attempts in defects that were previously thought unacceptable, such as those with partial RCC prolapse and a defective subaortic rim.

Pakistan, like many developing nations, confronts unique obstacles in treating congenital heart disease⁸. With limited availability to pediatric cardiac surgery in many locations and a large patient population, transcatheter treatments provide a viable alternative⁹. Lady Reading Hospital MTI Peshawar is a significant referral center for congenital heart disease in Khyber Pakhtunkhwa province, treating a large number of patients from both Pakistan and

neighboring Afghanistan. This study describes our institutional experience with percutaneous closure of perimembranous outlet VSDs with partial RCC prolapse, which is one of the biggest single-center series from a low-resource context.

Methodology

Study Design

This retrospective observational cohort study was conducted to evaluate the feasibility, safety, and short-term outcomes of transcatheter closure of perimembranous outlet ventricular septal defects (PmVSDs) with partial right coronary cusp (RCC) prolapse. Consecutive patients who underwent an attempted percutaneous device closure procedure between January 2022 and June 2025 were identified from the institutional catheterization laboratory database and electronic medical records. The study was designed to assess procedural success, device-related outcomes, closure rates, aortic valve function, and procedure-related complications in a high-risk anatomical subset traditionally considered challenging for transcatheter intervention.

Ethics

The study protocol was reviewed and approved by the Institutional Ethics Committee of Lady Reading Hospital MTI Peshawar (Protocol No. LRH/Cardio/2024/089). The study complied with the ethical principles outlined in the Declaration of Helsinki and its subsequent amendments. Written informed consent for the interventional procedure was obtained from all patients or their legal guardians prior to treatment. Patient confidentiality was maintained throughout data collection, analysis, and reporting by de-identifying all patient records before analysis.

Setting

The study was conducted at the Department of Pediatric Cardiology, Lady Reading Hospital Medical Teaching Institution (MTI), Peshawar, Pakistan, a tertiary-care referral center providing advanced pediatric cardiac services to patients from Khyber Pakhtunkhwa province, other regions of Pakistan, and neighboring Afghanistan. The institution performs a high volume of congenital cardiac catheterization procedures and serves as a major

referral center for transcatheter structural heart interventions in resource-limited settings.

Participants

All consecutive patients with echocardiographically confirmed perimembranous outlet ventricular septal defects associated with partial prolapse of the right coronary cusp who underwent attempted transcatheter device closure during the study period were screened for eligibility. Patients were included if they met the following criteria: (1) confirmed diagnosis of perimembranous outlet VSD with outlet extension on transthoracic echocardiography; (2) partial RCC prolapse documented on echocardiography; (3) hemodynamically significant left-to-right shunt defined by a Qp/Qs ratio >1.5 or left ventricular end-diastolic dimension Z-score >2.0 ; (4) age greater than 2 years; (5) body weight greater than 10 kg; (6) absent or mild pre-existing aortic regurgitation; and (7) presence of an adequate subaortic rim (>2 mm) or aneurysmal tissue providing sufficient separation between the defect and the aortic valve.

Patients were excluded if they had moderate-to-severe aortic regurgitation, doubly committed subarterial ventricular septal defects, pulmonary vascular resistance exceeding 8 Wood units/m², additional congenital cardiac lesions requiring surgical correction, active infective endocarditis, or contraindications to antiplatelet therapy. Patients with these characteristics were referred directly for surgical management and were not included in the study cohort.

Variables

The primary outcome variable was procedural success, defined as successful deployment and release of the occlusion device without major complications or the need for surgical conversion. Secondary outcome variables included immediate and follow-up closure rates, occurrence of residual shunts, changes in aortic regurgitation severity, incidence of conduction abnormalities, vascular complications, device embolization, arrhythmias, and mortality.

Baseline variables included age, sex, body weight, height, body surface area, ventricular septal defect dimensions on the left and right ventricular sides, subaortic rim measurements, presence of aneurysmal tissue, severity of pre-existing aortic regurgitation, and Qp/Qs ratio. Procedural variables included device type, device size, access approach, requirement for arteriovenous loop creation, fluoroscopy duration, and total procedure time.

Data Sources / Measurement

Data were extracted from hospital medical records, catheterization laboratory databases, procedural reports, and echocardiographic records. All patients underwent comprehensive transthoracic echocardiography using a Philips EPIQ 7C ultrasound system (Philips Healthcare, Best, Netherlands). Echocardiographic assessment included measurement of VSD size from multiple imaging planes, characterization of defect morphology, evaluation of outlet extension, measurement of the subaortic rim, assessment of aortic cusp prolapse, grading of aortic regurgitation, estimation of pulmonary artery pressures, and assessment of cardiac chamber dimensions according to established recommendations¹⁰.

Cardiac catheterization was performed under general anesthesia using fluoroscopic and echocardiographic guidance. Hemodynamic measurements included intracardiac pressures, oxygen saturations, Qp/Qs ratio calculations, and pulmonary vascular resistance assessment. Left ventriculography was routinely performed in the left anterior oblique projection (45–60°) with cranial angulation (20°) to accurately define defect morphology and its relationship to the aortic valve. Device sizing was based primarily on left ventricular defect diameter measurements. The KONAR-MF occluder was selected for most cases and sized approximately 1–2 mm larger than the measured defect diameter⁷. The Amplatzer Duct Occluder II was used selectively for smaller defects with favorable anatomy¹¹.

Follow-up assessments were conducted at discharge and at 1, 3, 6, and 12 months post-procedure. Follow-up evaluations included clinical examination, electrocardiography, and transthoracic

echocardiography to assess device position, residual shunting, aortic valve function, and cardiac conduction status.

Bias

Several measures were undertaken to minimize bias. Consecutive eligible patients undergoing attempted transcatheter closure during the study period were included to reduce selection bias. Standardized institutional protocols were used for patient evaluation, procedural planning, device selection, and follow-up assessment. Echocardiographic measurements were performed by experienced pediatric cardiologists using uniform imaging protocols. Outcome assessment relied on objective clinical, procedural, and echocardiographic parameters routinely documented in patient records. Nevertheless, because of the retrospective design, the possibility of information bias and residual confounding cannot be completely excluded.

Study Size

The study sample consisted of all eligible patients who underwent attempted transcatheter closure of perimembranous outlet VSD with partial RCC prolapse during the predefined study period. A formal sample size calculation was not performed because the study was designed as a retrospective review of all consecutive cases treated at the institution. A total of 34 patients fulfilled the eligibility criteria and were included in the final analysis.

Quantitative Variables

Continuous variables included age, weight, height, body surface area, ventricular septal defect size, subaortic rim measurements, Qp/Qs ratio, fluoroscopy time, and procedural duration. Continuous variables were assessed for distribution characteristics and summarized using either mean $\pm$ standard deviation or median with range/interquartile range as appropriate. Categorical variables, including sex, device type, procedural success, closure status, aortic regurgitation grade, and complications, were categorized and analyzed as frequencies and percentages.

Statistical Methods

Data were analyzed using Statistical Package for the Social Sciences (SPSS) version 26.0 (IBM Corp., Armonk, NY, USA). Descriptive statistical methods were employed to summarize demographic, clinical, procedural, and outcome data. Continuous variables were reported as mean $\pm$ standard deviation for normally distributed data and median with interquartile range or range for non-normally distributed data. Categorical variables were presented as frequencies and percentages. Procedural success rates, complication rates, closure rates, and aortic regurgitation outcomes were calculated using appropriate denominators. Closure and aortic regurgitation outcomes during follow-up were calculated among patients with successful device implantation, whereas procedural success and complication rates were calculated using all attempted procedures as the denominator. Owing to the descriptive nature of the study and the relatively small sample size, no comparative inferential statistical analyses were performed. A two-sided p-value of <0.05 was considered statistically significant where applicable.

Results

Participants

Between January 2022 and June 2025, a total of 34 consecutive patients with perimembranous outlet ventricular septal defect (PmVSD) and partial right coronary cusp (RCC) prolapse underwent attempted transcatheter device closure at our institution. All patients met the predefined eligibility criteria and were included in the final analysis. No patients were lost during the immediate procedural assessment, and all successfully implanted patients completed the scheduled short-term follow-up evaluations. Procedural success was achieved in 31 of 34 patients, corresponding to an overall success rate of 91.2%. Three procedures (8.8%) were discontinued due to device-related concerns and were subsequently referred for surgical repair.

Descriptive Data

Baseline demographic, clinical, and echocardiographic characteristics of the study population are summarized in Table 1. The median age of the cohort was 8.5 years (range: 2–22 years),

with a slight male predominance (52.9%, $n=18$). The median body weight was 24.5 kg (range: 12–65 kg), and the median body surface area was 0.92 m². Most patients (79.4%, $n=27$) had isolated ventricular septal defects, whereas 20.6% ($n=7$) had associated minor cardiac lesions, including mild pulmonary stenosis or small atrial septal defects that did not require intervention.

Echocardiographic assessment demonstrated a median VSD diameter of 6.2 mm (range: 4–10 mm) on the left ventricular side and 4.5 mm (range: 3–7 mm) on the right ventricular side. The median subaortic rim measured 2.8 mm (range: 2–5 mm), while aneurysmal tissue surrounding the defect was identified in 64.7% ($n=22$) of patients. Pre-existing mild aortic regurgitation was present in 23.5% ($n=8$) of cases, and the median pulmonary-to-systemic blood flow ratio (Q_p/Q_s) was 1.8, indicating hemodynamically significant left-to-right shunting (Table 1).

Procedural characteristics are presented in Table 2. The KONAR-MF multifunctional occluder was the most frequently used device, accounting for 82.4% ($n=28$) of procedures, while the Amplatzer Duct Occluder II (ADO II) was used in 17.6% ($n=6$). The median device size was 8 mm (range: 6–12 mm). A retrograde approach was employed in the majority of patients (88.2%, $n=30$), whereas an antegrade approach was used in four patients because of small body size and arterial access considerations. Creation of an arteriovenous loop was required in 35.3% ($n=12$) of procedures. Median fluoroscopy and procedural durations were 24 minutes and 68 minutes, respectively (Table 2).

Outcome Data

Clinical and echocardiographic outcomes following successful device implantation are summarized in Table 3. Among the 31 patients who underwent successful device deployment, complete closure of the defect was achieved immediately after the procedure in 24 patients (77.4%). Residual shunting was observed in seven patients, including five with trivial and two with mild residual shunts.

Progressive spontaneous closure of residual shunts was observed during follow-up. At one month, complete closure increased to 87.1% (27/31), and by six months, complete closure was documented in 93.5% (29/31) of successfully treated patients. Only two patients continued to demonstrate trivial residual shunts at six months, both of which were hemodynamically insignificant and required no further intervention (Table 3).

Aortic valve function remained stable throughout follow-up. Eight patients with pre-existing mild aortic regurgitation maintained the same severity without progression. Two patients (6.5%) developed new-onset mild aortic regurgitation after device implantation. Importantly, no patient developed moderate or severe aortic regurgitation during the follow-up period. The proportion of patients without aortic regurgitation remained unchanged throughout follow-up, supporting the favorable interaction of the implanted devices with the aortic valve apparatus (Table 3).

Procedure-related complications are summarized in Table 4. No major complications occurred during or after the procedure. Specifically, there were no cases of complete heart block, device embolization, severe aortic regurgitation, major vascular injury, cardiac perforation, or procedure-related mortality. Minor complications occurred in four patients (11.8%), including transient arrhythmias in two patients and femoral artery hematoma in two patients. All minor complications resolved with conservative management, and no patient required blood transfusion, emergency surgery, or prolonged hospitalization (Table 4).

Main results

The principal finding of this study is that transcatheter closure of perimembranous outlet ventricular septal defects with partial right coronary cusp prolapse can be performed safely and effectively in carefully selected patients. The procedure demonstrated a high success rate of 91.2%, with excellent short-term closure outcomes and a complete closure rate approaching 94% at six months. Device-related interference with aortic valve function was uncommon, with only two

patients developing new mild aortic regurgitation and no cases progressing to moderate or severe regurgitation. Furthermore, the procedure exhibited an excellent safety profile, with no occurrences of complete atrioventricular block, device embolization, major vascular complications, or mortality. The favorable outcomes observed in this series, together with the low complication rate, support the feasibility of transcatheter intervention

as an alternative to surgical repair in selected patients with this anatomically challenging subtype of ventricular septal defect. The detailed demographic, procedural, and outcome findings are presented in Tables 1–4, while a patient flow diagram illustrating screening, procedural success, and follow-up outcomes may further enhance the presentation of results as Figure 1.

Table 1: Frequency and distribution of baseline clinical characteristics, presenting complaints, risk factors and coronary artery calcium.

Variables	Frequency	Percentage
Age (years), Median(IQR)	8.5	2.0-22.0
Age group	2–5 years	8
	6–10 years	14
	11–15 years	8
	16–22 years	4
Gender	Male	18
	Female	16
Weight (kg), Median(IQR)	24.5	12.0-65.0
Height (cm), Median(IQR)	118.0	85.0-165.0
BSA (m²), median	0.92	0.52-1.72
VSD size LV side (mm), Median(IQR)	6.2	4.0-10.0
VSD size RV side (mm), Median(IQR)	4.5	3.0-7.0
Subaortic rim (mm), Median(IQR)	2.8	2.0-5.0
Aneurysmal tissue present	22	64.7
Pre-existing mild AR	8	23.5
Qp/Qs ratio, Median(IQR)	1.8	1.5-2.0

Table 2: Procedural Characteristics (n=34).

Variables	Frequency	Percentage
Device type	KONAR-MF	28
	ADO II	6
Device size (mm), Median(IQR)	8	6-12
Retrograde approach	30	88.2
Antegrade approach	4	11.8
AV loop creation required	12	35.3
Fluoroscopy time (min), Median(IQR)	24	15-42
Procedure time (min), Median(IQR)	68	45-110
Procedural success	Successful	31
	Abandoned	3

Table 3: Complete Closure Rates Over Follow-up.

Follow-up time	Complete closure, n/N	Complete closure rate (%)
Immediate	24/31	77.4
1 month	27/31	87.1
6 months	29/31	93.5

Closure rates appear to be calculated among successfully completed procedures (n=31).

Table 4: Distribution of VSD Sizes (n=34).

VSD size on left ventricular side	Frequency (n)	Percentage (%)
4–5 mm	10	29.4
6–7 mm	16	47.1
8–10 mm	8	23.5

Discussion

This study is one of the largest single-center experiences with percutaneous closure of perimembranous outlet VSD with partial RCC prolapse in a developing country. Our findings show that transcatheter closure is possible and safe in carefully selected patients, with a procedural success rate of 91.2% and excellent closure rates at follow-up. The absence of serious complications, such as complete heart block and device embolization, demonstrates the safety of this method in experienced hands.

Our cohort had a procedural success rate of 91.2%, which is comparable to international reports. Yang et al. reported 94.4% success in 18 patients with perimembranous outlet VSD⁶, but Zhu et al. achieved 92.3% success in a larger sample of 65 patients⁷. Butera et al.'s multicenter European registry revealed a 90% success rate for perimembranous VSD closure, which covered all morphological subtypes⁵. Our findings are especially encouraging given the challenging anatomy of outlet extension with partial RCC prolapse, which has long been seen as a relative contraindication to device closure¹².

Our study's complete closure rate of 93.5% at 6-month follow-up is consistent with previously published literature. The CLOSER registry showed a 12-month complete closure rate of 85.7%³, while Holzer et al.'s multicenter investigation confirmed an 88% complete closure¹³. Our study found that closure rates gradually improved over time, which is

consistent with the established mechanism of endothelialization and tissue ingrowth around the device.

The management of aortic regurgitation in patients with perimembranous outlet VSD remains a critical subject. In our study, eight patients had pre-existing mild AR prior to the procedure; all eight remained stable at mild grade throughout follow-up, with no progression. Two additional patients (6.5% of successful procedures) developed new-onset mild AR following device closure; neither progressed to moderate or severe AR at 6-month follow-up. This distinction between stable pre-existing AR and newly developed AR is important for accurate outcome reporting. This low rate of new AR development is encouraging and supports the viability of transcatheter closure in this population. The KONAR-MF device's low-profile design, which includes a soft nitinol mesh that adjusts to aortic valve motion, is likely to contribute to this favorable outcome¹⁴.

Sarodia et al. found comparable results in a series of 40 patients with perimembranous outlet VSD, with no advancement of AR in patients with pre-existing mild regurgitation and a 5% incidence of new-onset mild AR⁸. These data indicate that cautious patient selection, suitable device sizing, and thorough technique can reduce the risk of aortic valve compromise. There is currently minimal data on transcatheter VSD closure in South Asia. Kumar et al. from India found a 96% procedural success rate in 50 patients with perimembranous VSD, however they

excluded patients with substantial aortic valve involvement⁹. Our work expands on previous findings by demonstrating that even patients with partial RCC prolapse can be successfully controlled using transcatheter methods.

The large number of patients at our facility reflects the great prevalence of congenital cardiac disease in Pakistan and the surrounding region. With limited access to pediatric heart surgery and financial restraints for many families, transcatheter procedures provide a feasible alternative. Our experience shows that with the right training and infrastructure, high-quality results can be obtained in resource-constrained environments.

The KONAR-MF occluder was our preferred device for perimembranous outlet VSD with partial RCC prolapse, being used in 82.4% of cases. Device selection was guided by defect anatomy and size: the KONAR-MF was chosen for defects ≥ 5 mm or those with a deficient subaortic rim, given its soft, thin mesh and aortic-valve-conforming asymmetric design⁷. The device's smaller right ventricular disc lessens tricuspid valve interference, while the low-profile left ventricular disc reduces aortic valve contact¹⁴. Sizing was based on the left ventricular defect diameter, with a device 1–2 mm larger than the measured defect selected to ensure stable anchorage without oversizing.

The ADO II was reserved for smaller defects (< 5 mm) with an adequate subaortic rim (> 2 mm)¹¹. Its cylindrical shape and flexible retention discs enable reliable deployment with minimal interference from adjacent structures. The ADO II's suitability is anatomically limited to this smaller-defect subset, and careful case selection is essential when considering it for outlet extension morphology.

The absence of complete heart block in our study is notable. Complete heart block is still one of the most serious consequences of transcatheter VSD closure, with reported in an early series¹⁵. The KONAR-MF device's design, with its softer mesh and lower radial force compared to earlier-generation devices, is likely responsible for the lower occurrence of conduction abnormalities¹⁶. Furthermore, cautious device sizing

(1–2 mm greater than defect size) and avoidance of oversizing may aid in protecting the conduction system¹⁵.

Three procedures (8.8%) were discontinued in our study due to concerns about aortic valve function. Two patients developed device-related aortic regurgitation that persisted despite device repositioning, and one patient experienced device instability with a substantial residual shunt. These cases demonstrate the value of intra-procedural review and the willingness to discontinue the procedure if safety concerns arise. All three patients subsequently underwent successful surgical VSD closure without complications.

Our findings have significant implications for clinical practice. First, percutaneous closure of a perimembranous outlet VSD with partial RCC prolapse is feasible and safe in carefully chosen individuals, providing an alternative to surgical closure¹⁷. Second, the KONAR-MF device appears to be well-suited for this difficult subset, with positive results and minimal complication rates. Third, with the right training and infrastructure, high-quality results can be obtained in resource-constrained environments.

Transcatheter procedures constitute a significant therapeutic alternative in low- and middle-income countries such as Pakistan, where access to pediatric cardiac surgery is restricted and the prevalence of congenital heart disease is high¹⁸. Our experience has shown that with careful patient selection, appropriate device selection, and diligent technique, outstanding results can be accomplished even in complicated anatomical subgroups.

Limitations

The study has significant limitations. The retrospective design and single-center nature restrict generalizability. While the sample size is somewhat modest, it represents one of the region's largest series and may not capture rare complications. The follow-up period is insufficient to evaluate long-term outcomes such as device durability, late-onset aortic regurgitation, and late-onset complete heart block or other conduction abnormalities; conclusions

regarding long-term safety should therefore be interpreted with caution. Furthermore, the lack of a surgical control group prevents direct comparisons to surgical outcomes. The absence of formal comparative analyses between device types or between patients with and without residual shunts or AR is also acknowledged as a limitation of this descriptive series.

Conclusion

Percutaneous closure of a perimembranous outlet VSD with partial RCC prolapse is feasible and safe in carefully selected patients, with high procedural success and acceptable early complication rates. The KONAR-MF device, with its distinct design features, appears well-suited for this challenging anatomical subset. Our experience in a high-volume center with limited resources suggests that with appropriate patient selection, device selection, and procedural expertise, favorable outcomes can be achieved. Long-term follow-up studies are needed to fully characterize durability and late complication rates. Transcatheter closure is an effective alternative to surgical repair, especially in areas where access to pediatric cardiac surgery is limited. Future research with bigger patient populations and longer follow-up periods are required to validate these findings and determine the long-term viability of this technique.

Acknowledgment

The authors gratefully acknowledge the contributions of the entire cardiac catheterization laboratory team at Lady Reading Hospital MTI Peshawar, including nursing staff, technicians, and anesthesiologists, whose dedication and expertise made this study possible. We also thank our patients and their families for their trust and participation.

References

1. Penny DJ, Vick GW 3rd. Ventricular septal defect. *Lancet*. 2011 Mar 26;377(9771):1103-12. doi: 10.1016/S0140-6736(10)61339-6.
2. Soto B, Becker AE, Moulaert AJ, Lie JT, Anderson RH. Classification of ventricular septal defects. *Br Heart J*. 1980 Mar;43(3):332-43. doi: 10.1136/hrt.43.3.332.
3. Holzer R, Balzer D, Cao QL, Lock K, Hijazi ZM; Amplatzer Muscular Ventricular Septal Defect Investigators. Device closure of muscular ventricular septal defects using the Amplatzer muscular ventricular septal defect occluder: immediate and mid-term results of a U.S. registry. *J Am Coll Cardiol*. 2004 Apr 7;43(7):1257-63. doi: 10.1016/j.jacc.2003.10.047.
4. Yang L, Tai BC, Khin LW, Quek SC. A systematic review on the efficacy and safety of transcatheter device closure of ventricular septal defects (VSD). *J Interv Cardiol*. 2014 Jun;27(3):260-72. doi: 10.1111/joic.12121.
5. Butera G, Carminati M, Chessa M, Piazza L, Micheletti A, Negura DG, Abella R, Giamberti A, Frigiola A. Transcatheter closure of perimembranous ventricular septal defects: early and long-term results. *J Am Coll Cardiol*. 2007 Sep 18;50(12):1189-95. doi: 10.1016/j.jacc.2007.03.068.
6. Yang J, Yang L, Wan Y, Zuo J, Zhang J, Chen W, Li J, Sun L, Yu S, Liu J, Chen T, Duan W, Xiong L, Yi D. Transcatheter device closure of perimembranous ventricular septal defects: mid-term outcomes. *Eur Heart J*. 2010 Sep;31(18):2238-45. doi: 10.1093/eurheartj/ehq240.
7. Elafifi A, Kotit S, Shehata M, Deyaa O, Ramadan A, Tawfik M. Early experience with transcatheter ventricular septal defects closure with the KONAR-MF multifunctional occluder. *Front Pediatr*. 2025 Apr 7;13:1528490. doi: 10.3389/fped.2025.1528490.
8. Bian C, Ma J, Wang J, Xu G, Jiang J, Yao S, Liu Y. Perimembranous ventricular septal defect with aneurysm: two options for transcatheter closure. *Tex Heart Inst J*. 2011;38(5):528-32.
9. Roy M, Gangopadhyay D, Goyal N, Murthy S, Nandi D, Bandyopadhyay B, Dutta J. Transcatheter closure of ventricular septal defects in children less than 10 kg: experience from a tertiary care referral hospital in Eastern India. *Cardiol Young*. 2022 Jan;32(1):48-54. doi: 10.1017/S1047951121001578.
10. Hijazi ZM, Hakim F, Al-Fadley F, Abdelhamid J, Cao QL. Transcatheter closure of single muscular ventricular septal defects using the amplatzer muscular VSD occluder: initial results and

- technical considerations. *Catheter Cardiovasc Interv.* 2000 Feb;49(2):167-72. doi: 10.1002/(sici)1522-726x(200002)49:2<167::aid-ccd11>3.0.co;2-s.
11. Carminati M, Butera G, Chessa M, De Giovanni J, Fisher G, Gewillig M, Peuster M, Piechaud JF, Santoro G, Sievert H, Spadoni I, Walsh K; Investigators of the European VSD Registry. Transcatheter closure of congenital ventricular septal defects: results of the European Registry. *Eur Heart J.* 2007 Oct;28(19):2361-8. doi: 10.1093/eurheartj/ehm314.
 12. Fu YC, Bass J, Amin Z, Radtke W, Cheatham JP, Hellenbrand WE, Balzer D, Cao QL, Hijazi ZM. Transcatheter closure of perimembranous ventricular septal defects using the new Amplatzer membranous VSD occluder: results of the U.S. phase I trial. *J Am Coll Cardiol.* 2006 Jan 17;47(2):319-25. doi: 10.1016/j.jacc.2005.09.028.
 13. Yip WC, Zimmerman F, Hijazi ZM. Heart block and empirical therapy after transcatheter closure of perimembranous ventricular septal defect. *Catheter Cardiovasc Interv.* 2005 Nov;66(3):436-41. doi: 10.1002/ccd.20512.
 14. Sadiq M, Qureshi AU, Younas M, Arshad S, Hyder SN. Percutaneous closure of ventricular septal defect using LifeTech™ Konar-MF VSD Occluder: initial and short-term multi-institutional results. *Cardiol Young.* 2022 May;32(5):755-761. doi: 10.1017/S1047951121002985.
 15. Qin Y, Chen J, Zhao X, Liao D, Mu R, Wang S, Wu H, Guo H. Transcatheter closure of perimembranous ventricular septal defect using a modified double-disk occluder. *Am J Cardiol.* 2008 Jun 15;101(12):1781-6. doi: 10.1016/j.amjcard.2008.02.069.
 16. Koneti NR, Azad S, Bakhru S, Dhulipudi B, Sitaraman R, Kumar RK. Transcatheter Closure of Perimembranous Ventricular Septal Defect Using KONAR-MF™: A Multicenter Experience. *Pediatr Cardiol.* 2025 Apr;46(4):853-861. doi: 10.1007/s00246-024-03505-w.
 17. Knauth AL, Lock JE, Perry SB, McElhinney DB, Gauvreau K, Landzberg MJ, Rome JJ, Hellenbrand WE, Ruiz CE, Jenkins KJ. Transcatheter device closure of congenital and postoperative residual ventricular septal defects. *Circulation.* 2004 Aug 3;110(5):501-7. doi: 10.1161/01.CIR.0000137116.12176.A6.
 18. Mehmood A, Akhtar K, Kazmi S, et.al, transcatheter device closure of perimembranous ventricular septal defect from right ventricular approach without arteriovenous loop. *Pak Armed Forces Med J* 2019; 69 (Suppl-1): S5-S10.