Open Access

Original Article

ASD Device Size to Patient Weight Ratio and Effect on Immediate Complications After Trans Catheter Closure in Pediatric Patients

Madeeha Ikram, Amjad Mehmood, Maimoona Saeed, Aziz Ullah, Hafiz Muhammad Murtaza

Department of Paediatric Cardiology, Armed Forces Institute of Cardiology/National Institute of Health Disease/National University of Medical Sciences (NUMS), Rawalpindi Pakistan

ABSTRACT

Objective: To determine ASD device size to patient weight ratio and its effect on immediate complications after transcatheter ASD closure in pediatric patients.

Study Design: Analytical cross sectional study

Place and Duration of Study: Department of Pediatric Cardiology, Armed Forces Institute of Cardiology/ National Institute of Health, Rawalpindi, from August 2025 to December 2025.

Methodology: Thirty-eight pediatric patients (aged 1–12 years, 10–25 kg) with suitable ASD anatomy and symptomatic children were enrolled. Patients with > 25 kg, associated cardiac lesions requiring surgery, active infection, bleeding disorders, or contraindications to catheter intervention were excluded. Defect size was assessed by transthoracic echocardiography, and the ASD device size-to- patient weight ratio of patients was calculated. Patients were monitored for 24 hours postprocedure for immediate complications. Based on observed outcomes, patients were stratified according to device size-to- patient weight ratio for comparative analysis.

Results: The ASD device size-to-patient weight ratio demonstrated a significant association with immediate complications. An optimal cut-off value of 1.53 was identified, dividing patients into a lower-risk group (≤1.53; 21(55.3%)) and a higher-risk group (>1.53; 17 (44.7%)). Overall, immediate complications occurred in 21.1% of patients. Complications were observed in 4.8% of patients in the lower-risk group compared with 41.2% in the higher-risk group, highlighting a substantially higher complication rate associated with increased device-to- patient weight ratios.

Conclusion: An increased ASD device size-to- patient weight ratio is associated with a higher frequency of immediate complications following transcatheter ASD closure. Ratios exceeding 1.53 should be considered cautiously and reserved for cases where clinical benefits outweigh potential risks.

Keywords: Atrial Septal Defect, Cardiac Catheterization, Heart Septal Defects, Pediatrics, Postoperative Complications.

How to Cite This Article: *Ikram M, Mehmood A, Saeed M, Ullah A, Murtaza HM. Asd Device Size to Patient Weight Ratio and Effect On Immediate Complications After Trans Catheter Closure in Pediatric Patients. Pak Armed Forces Med J 2026; 76(Suppl-4): S702-S707.*
DOI: https://doi.org/10.51253/pafmj.v76i2.14171

INTRODUCTION

Atrial septal defect (ASD) is one of the most common congenital cardiac defects, accounting for approximately 10–15% of all congenital heart malformations with secundum ASD being most frequent.[1] Although many patients remain asymptomatic during early childhood and the condition is often detected incidentally on routine clinical examination, untreated defects may result in significant morbidity later in life, including right heart enlargement, pulmonary hypertension, and arrhythmias.[2] Transcatheter closure has become the primary treatment option in patients with suitable anatomy, while large defects and those with deficient rims are still referred for surgical repair.[3] Several factors influence procedural success, including ASD anatomy, patient age, body weight, and suitability for device closure.[4] In certain cases, transcatheter closure can be challenging due to unfavorable anatomy. Although ASD closure is rarely indicated before four years of age, some infants and young children may be symptomatic, particularly those born prematurely, those with chronic lung disease, or those with associated comorbidities or genetic syndromes.[5] In small children and sick infants, closure of relatively large defects may require implantation of larger devices, increasing procedural complexity and risk. Such cases are considered high risk, particularly when the device-to-weight ratio is ≥1.5.[6] Previous studies have reported acceptable outcomes with device size-to-weight ratios up to 1.5 and less than 2, whereas ratios exceeding 2 have been associated with difficult deployment and higher complication rates.[7] Despite the overall safety and efficacy of ASD device closure in children, the importance of accurate

Correspondence: Dr Madeeha Ikram, Department of Paediatric Cardiology, AFIC/NIHD Rawalpindi Pakistan

echocardiographic assessment, appropriate patient selection, and longer follow-up remains critical for improving procedural outcomes.[8]

While earlier studies suggest that a device size-to- patient weight ratio of approximately 1.5 is safe, evidence remains limited regarding the optimal ratio threshold in symptomatic, low-weight children. The ASD (Atrial Septal Defect) device size-to- patient weight ratio in transcatheter closure represents the device diameter (mm) relative to the patient's weight (kg). A higher ratio indicates a larger device in relation to patient size, typically required to close bigger defects. Given that children with comorbidities are often underweight and may require closure of relatively large defects, defining a safe and predictive device size-to- patient weight ratio is clinically important. This study was therefore undertaken to determine the association between ASD device size-to-patient weight ratio and immediate complications in our population, with the aim of guiding safer device selection in pediatric patients weighing less than 25kg.

METHODOLOGY

This analytical cross sectional study was conducted in Armed Force Institute of Cardiology /National Institute of Heart Diseases over the period of August to December 2025 after approval from institutional ethical review board (IERB Ltr# 9/2/R&D/2025/377, Dated: 21st August 2025). A sample size of 38 was calculated using the WHO sample size calculator, based on a 2.5% complication rate in ASD patients[3] after Trans catheter closure, with a 95% confidence level and a 5% margin of error. The study used non probability consecutive sampling.

Inclusion Criteria: Children aged 1–12 years and weighing 10–25 kg, scheduled for elective transcatheter closure of secundum ASD, were considered for the study. Only those with suitable anatomy for device closure—defined as adequate septal rims (>5 mm) and sufficient total septal length (enough septum to safely accommodate the selected device without affecting adjacent structures) to accommodate the selected device on transthoracic echocardiography—were considered. Symptomatic children younger than four years, including those with exertional dyspnea, right heart enlargement, a history of prematurity with recurrent respiratory infections, or failure to thrive, were also assessed for inclusion.

Exclusion Criteria: Patients with associated congenital heart lesions, requiring surgical correction, active infection, bleeding disorders, contraindications to catheter-based intervention were excluded. Children younger than one year or older than twelve years were also excluded from the study.

After obtaining written informed consent from parents or legal guardians, eligible patients were evaluated clinically and echocardiographically. Patients were evaluated clinically, detailed chocardiography was performed to confirm the diagnosis, assess defect size, rim adequacy, and total septal length. Device size was selected based on echocardiographic measurements. Device size was determined by ensuring the presence of all septal rims measuring approximately 5 mm. The total septal length was assessed, and the selected device was chosen to be 2–5 mm larger than the measured defect size, taking into consideration the total septal length and the availability of appropriate device sizes. The ASD device size-to- patient weight ratio was calculated for each patient and divided in two groups; ≤1.53 and >1.53 ASD device size-toweight ratio. Transcatheter closure was performed in patients meeting anatomical and clinical suitability criteria. In cases with higher device-to-weight ratios, the procedure was chosen based on medical indications for early defect closure and right heart volume overload. Larger defects were closed percutaneously when septal morphology and rim adequacy were favorable, while surgical referral was reserved for patients with unsuitable anatomy or contraindications to transcatheter intervention. All procedures were performed under general anesthesia using fluoroscopic and echocardiographic guidance via femoral venous access. Following device deployment and confirmation of appropriate positioning, patients were monitored in the post-catheterization ward for 24 hours according to institutional protocol. Immediate complications occurring within 24 hours of the procedure, as well as duration of hospital stay, were recorded.

The data analysis was using SPSS (Statistical Package for social sciences) version 23.00 conducted. To identify a clinically relevant threshold for the ASD device size-to-weight ratio associated with immediate complications, receiver operating characteristic (ROC) curve analysis was performed. Based on the optimal cut-off value derived, patients were stratified into two groups: a group with a ratio at or below the cut-off value 1.53 and a ratio exceeding the cut-off value of 1.53. Normality was tested using Shapiro-wilk test; and age, height, BSA, septal length, ASD device size to

patient Weight Ratio, Defect size to weight ratio were normally distributed hence mean SD are reported whereas weight, device size, fluoroscopy time, and hospital stay duration were not normally distributed hence Median (IQR) are reported. Comparative analysis of immediate complications, and demographic variables was then carried out between the two groups using Mann Whitney U test.

RESULTS

A total of 38 pediatric patients who underwent transcatheter ASD device closure were included in the study. The demographic and procedural characteristics of the cohort are summarized in Table I. Mean of ASD device size implanted was 21.1 ± 5.6 mm. The primary variable of interest, the ASD device size to patient weight ratio, had a mean value of 1.41 ± 0.28.

The analysis showed that the ASD device size to patient weight ratio was a significant predictor of complications, with an Area under the Curve (AUC) of 0.802 (95% CI: 0.635 – 0.969; p = 0.009) as shown in Figure 1. Review of the ROC curve coordinates identified a ratio of 1.530 as the optimal cut-off point, corresponding to a sensitivity of 87% and a specificity of 66.7% (1 – specificity = 0.333). The study population was dichotomized into two groups for further analysis;

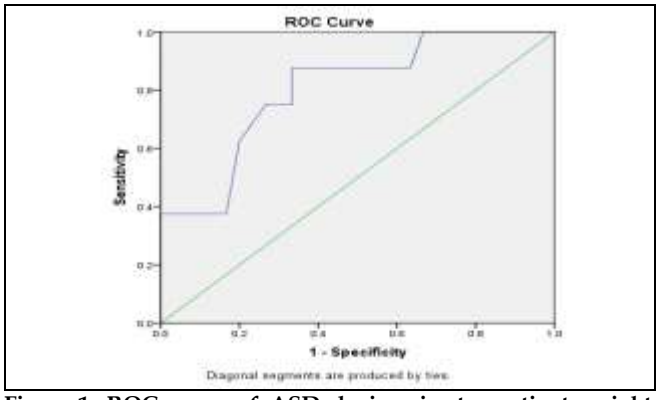

Figure-1: ROC curve of ASD device size-to- patient weight ratio predicting early complications.

Group 1: ASD device size-to- patient weight ratio ≤ 1.53 (n = 21; 55.3%); Group 2: ASD device size-to weight ratio > 1.53 (n = 17; 44.7%).

A highly significant difference was observed in the ASD device size–to–weight ratio and defect size–to–weight ratio, both of which were higher in the high-ratio group as shown by the results of independent sample t-test for normally distributed variables and Mann Whitney U test for not normally distributed variables (Table II). BSA showed a borderline trend toward lower values in the high-ratio group (p = 0.051). Sheath size was also significantly larger among patients with a higher ratio (p = 0.033). No statistically significant differences were found between the groups in terms of age, weight, height, total septal length, device size, hospital stay, or fluoroscopy time.

The primary outcome of immediate complications occurred in 10 out of 38 patients (26.3%). A chi-square test of independence revealed a stark and statistically significant association between the ratio group and the incidence of complications. Only 1 patient (4.8%) in the low-ratio group experienced a complication. In contrast, 7 patients (41.2%) in the high-ratio group suffered from an immediate complication refer to Table-II.

DISCUSSION

In this study of 38 pediatric patients undergoing transcatheter closure of secundum atrial septal defects, the mean ASD device size-to-patient weight ratio was 1.41 ± 0.28. Patients were stratified into a lower-risk group (ratio ≤1.53; n = 21, 55.3%) and a higher-risk group (ratio >1.53; n = 17, 44.7%) based on an ROC-derived cut-off. Immediate complications occurred in 26.3% of patients overall, with a marked difference between groups: only 4.8% of patients in the low-ratio group experienced a complication, compared with 41.2% in the high-ratio group. Device retrieval was required in four patients, and other minor complications included hematoma, mild atrioventricular valve regurgitation, and transient arrhythmias. No major adverse events, such as device embolization, pericardial effusion, or need for urgent surgical intervention, were observed. Overall, higher device size-to-weight ratios were significantly associated with an increased risk of immediate post-procedural complications.

ASD closure is generally recommended in children, ASDs up to 8mm can close spontaneously as per natural history of ASD.[9] However larger defects do not tend to close spontaneously and need either surgical or transcatheter closure.[10] The indications for early closure of ASD in smaller children including failure to thrive, recurrent respiratory infections and worsening right heart enlargement in small children with less weight. Large ASD device can cause difficulty in deployment due to large LA disc and lack of space to accommodate the larger device.[10]

Present study demonstrated fewer rates of immediate complications with ASD device size to patient weight ratio of 1.53 ie 4.8% percent. Only one patient in the low ratio group experienced the complication. Existing studies in small children generally report high procedural success and low major complication rates but differ regarding thresholds of concern for device/weight ratio as shown by Tanghöj *et al*.[11] who observed that larger ASD size was associated with minor arrhythmic complications but did not identify marked excess risk in children <15 kg compared with older children.

In contrast seven patients 41.2% suffered from immediate complications with device retrieval in four (10.5%) patients in the group with the device size to weight ratio exceeding 1.53. Device retrieval was done due to different reasons. In one patient device impinged on mitral valve causing significant mitral regurgitation so it was down sized and other 3 retrievals required upsizing of the device size as the device was not held by the thin rims. However no serious adverse events including device embolization or pericardial effusion causing prolongation of hospital stay occurred in these patients. Approximately 2.5mm ± 3.5mm was the mean upsizing of the device.[12] According to Amin et al., the echocardiography is sufficient for the sizing of ASD but due to general anesthesia requirement for transesophageal echocardiography and adequate imaging with transthoracic echocardiography, ASD device sizing can be relied upon upsizing is done in the range of 2-4 mm, with the mean of 3mm ± SD 3.5, as is correlated better.[13] While the mathematical relation of sizing of device which is apparently significant in ASD device closure is evident from the past studies. It is therefore concluded that a deep dive focused study is needed which should formally establish the relationship of sizing of device and ASD closure success.[14]

Houeijeh *et al.*,[6] specifically targeted the "high-risk" group with device/weight ratio ≥1.5 and reported acceptable complication rates (5% serious events), suggesting that, with careful selection and experienced operators, large devices can be safely used even in small, symptomatic children with pulmonary hypertension. Kalyanasundaram's single-center experience in infants <2 years with ASD >8 mm, again with high success and no major complications, reinforces this view.[4] In present study, 5.3% patients in high ratio group that is device size to weight ratio >1.53 developed new left AV valve regurgitation without impingement of the device on left atrioventricular valve. ASD closure leads to right ventricular remolding and change in position of Inter ventricular septum and left ventricular geometry thus leading to new onset of mitral regurgitation.[15] This paves the way to study long term hemodynamic effects of ASD device closure on left ventricle.

Table-I: Descriptive Characteristics of the Study Population (n=38)

Variable			Mean ± SD
	Demographics		
Age (years	)		5.32 ± 2.40
Height (cm)			100.61 ± 14.65
BSA (m^2)			0.65 ± 0.12
			Median (IQR)
Weight (kg)			16.00 (12.00-18.00)
			Frequency (%)
Gender	Male		20 (52.6%)
	Female		18 (47.4%)
ASD Characteristics			
			Mean ± SD
Total Septal Length (mm)			37.55 ± 5.05
ASD Device Size / Weight Ratio			1.41 ± 0.28
Defect Size / Weight Ratio			1.13 ± 0.24
			Median (IQR)
Device Size (mm)			18.00 (14.00-22.00)
Procedure Details			
			Frequency (%)
Sheath Size (mm)	8		4 (10.5%),
	9		6 (15.8%),
	10		15 (39.5%)
	12		12 (31.6%),
	13		1 (2.6%)
			Median (IQR)
Fluoroscopy Time (min)			8.00(6.00-8.00)
Hospital Stay Duration (hours)			24.00(24.00-24.00)
Complications			
			Frequency (%)
Hematoma / Bleeding			3 (7.9%)
Rhythm Disturbance			1 (2.6%)
AV Valve Regurgitation			2 (5.3%)
Device Embolization			-
Pericardial Effusion			-
Pulmonary Vein Occlusion			-
Device Retrieval			4 (10.5%)
Immediate Surgical Intervention			-
Overall Complication			8 (21.1%)
Ratio Group	1 (≤1.53)		21 (55.3%)
	2 (>1.53)		17 (44.7%)

BSA; Body surface area, ASD; Atrial Septal Defect, AV valve ; Atrioventricular Valve

Generally, the determinant cause of late cardiac morbidity in the patients is atrial arrhythmia in cases of transcatheter ASD device closure. Past studies reveal that in such cases post ASD device closure these arrhythmias are higher.[16] Only one patient in higher ratio group (2.6%) developed transient arrhythmia with bradycardia and third degree heart block that

recovered spontaneously within 48 hours, transient arrythmias may trigger due to stretched atrial wall or edema due to large ASD device size that resolves spontaneously in many cases.[17,18] Another study suggests no relationship occurs between device size and onset of rhythm disturbance however prolonged early onset arrhythmias may be the result of local inflammatory response of foreign body reaction of device.[8] In our study cohort, there were no instances of device erosion or pericardial effusion.

Table-II: Baseline and Procedural Characteristics by ASD Device Size-to-Weight Risk Category (n=38)

Variable	Group 1 (Ratio ≤ 1.53) (n=21)	Group 2 (Ratio > 1.53) (n=17)	*p*-value
	Mean±SD		
Age (years)	5.83 ± 2.74	4.68 ± 1.79	0.142
Height (cm)	104.00 ± 15.77	96.41 ± 12.32	0.114
BSA	0.68 ± 0.13	0.60 ± 0.08	0.051
Total Septal Length (mm)	37.95 ± 5.71	37.06 ± 4.22	0.594
ASD Device/Weight Ratio	1.21 ± 0.21	1.65 ± 0.08	<0.001*
Defect size/Weight Ratio	0.98 ± 0.19	1.32 ± 0.14	<0.001*
Sheath size (mm)	9.90±1.41	10.88±1.26	0.033*
	Frequency (%)		
Complications	1(4.8%) 7(41.2%)		0.013*
	Median (IQR)		
Weight (kg)	16.00(12.00-18.00)	13.76(2.66)	0.88
Device Size (mm)	16.00(12.00-18.00)	18.00 (15.00-22.00)	0.052
Hospital Stay (hours)	24.00(24.00-24.00)	24.00 (24.00-24.00)	0.236
Fluoroscopy time (min)	6.00 (6.00-8.00)	10.00 (6.00-12.00)	0.103
**Significant variables with p value ≤0.05*			

This study demonstrates that the atrial septal defect (ASD) device size-to- patient weight ratio is a key predictor of immediate complications following transcatheter ASD closure in pediatric patients. A ratio exceeding 1.53 was associated with a higher probability of minor complications, such as device retrieval, transient arrhythmias, and mild atrioventricular valve regurgitation, while major adverse events remained rare. These findings provide a practical tool for pre-procedural risk stratification, particularly in low-weight or symptomatic children requiring larger devices, and underscore the importance of careful device selection, echocardiographic assessment, and operator experience to ensure safer outcomes.

LIMITATIONS OF STUDY

This study has certain limitations. The relatively small sample size and single-center design may limit the generalizability of the findings and contributed to wide confidence intervals for some estimates. The assessment was restricted to immediate complications within 24 hours of the procedure; therefore, late complications could not be evaluated. Complications were monitored for 24 hours. Although no device erosion or pericardial effusion occurred, monitoring beyond 24 hours may be needed to capture these rare events. In addition, reliance on transthoracic echocardiography for device sizing without routine balloon sizing may have influenced device selection in borderline cases. Larger, multicenter studies with longer follow-up are required to validate the proposed device size-to- patient weight ratio cut-off and assess long-term safety outcomes.

CONCLUSION

The atrial septal defect device size-to-patient weight ratio demonstrated a statistically significant association with immediate post-procedural complications following transcatheter ASD closure in pediatric patients. A ratio exceeding 1.53 was associated with a markedly higher frequency of early complications. While transcatheter closure using larger devices may be necessary in selected symptomatic children with low body weight, exceeding this ratio should be approached cautiously and reserved for cases in which the anticipated clinical benefit outweighs the potential procedural risks. These findings support the use of device size-to-patient weight ratio as a practical adjunct in pre-procedural risk stratification.

ACKNOWLDGEMENT

We want to share our gratitude for Comdt. Exec Dir. AFIC/NIHD & R&D dept for their support and contribution in completion of research paper.

Conflict of Interest: None.

Funding Source: None.

Authors' Contribution

Following authors have made substantial contributions to the manuscript as under:

MI & AM: Data acquisition, data analysis, critical review, approval of the final version to be published.

MS & AU: Study design, data interpretation, drafting the manuscript, critical review, approval of the final version to be published.

HMM: Conception, data acquisition, drafting the manuscript, approval of the final version to be published.

Authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

REFERENCES

1. Brida M, Chessa M, Celermajer D, Li W, Geva T, Khairy P, et al. Atrial septal defect in adulthood: a new paradigm for congenital heart disease. Eur Heart J. 2022;43(28):2660– 2671. http://dx.doi.org/10.1093/eurheartj/ehab646
2. Munjal R, H Frishman W. Management of atrial septal defect in the adult population. Cardiol Rev. 2025; Available from: http://dx.doi.org/10.1097/CRD.0000000000001044
3. Hansen JH, Duong P, Jivanji SGM, Jones M, Kabir S, Butera G, et al. Transcatheter correction of superior sinus venosus atrial septal defects as an alternative to surgical treatment. J Am Coll Cardiol. 2020;75(11):1266–1278. http://dx.doi.org/10.1016/j.jacc.2019.12.070

4. Kalyanasundaram M. Safety and efficacy of larger ASD devices in small children of less than 2 years. Indian Heart J.2021;73(5):637–639. http://dx.doi.org/10.1016/j.ihj.2021.07.006
5. Hadders-Algra M. Emerging signs of autism spectrum disorder in infancy: Putative neural substrate. Dev Med Child Neurol. 2022;64:1344–1350. https://doi.org/10.1111/dmcn.15333
6. Houeijeh A, Hascoët S, Bouvaist H, Hadeed K, Petit J, Godart F, et al. Transcatheter closure of large atrial septal defects (ASDs) in symptomatic children with device/weight ratio ≥1.5. Int J Cardiol. 2018;267:84–87. http://dx.doi.org/10.1016/j.ijcard.2018.05.069
7. Joseph SP, Mirza SUR, Krupa J, Varghese SI, Kartha GB, George OK, et al. Original article--clinical and procedural characteristics of successful transcatheter device closure of ostium secundum atrial septal defect in symptomatic children weighing <15 kg: A retrospective study spanning one decade from south India. J Saudi Heart Assoc. 2024;36(1):14–22. http://dx.doi.org/10.37616/2212-5043.1365
8. Kashyap T, Sanusi M, Momin ES, Khan AA, Mannan V, Pervaiz MA, et al. Transcatheter occluder devices for the closure of atrial septal defect in children: How safe and effective are they? A systematic review. Cureus. 2022;14(5):e25402. http://dx.doi.org/10.7759/cureus.25402
9. Noori N, Teimouri A. Evaluation of clinical course in children and adolescents with atrial septal defects. International Journal of Pediatrics [Internet]. 2020 [cited 2026 Jan 2];8(4):11103–11114. Available from: https://jpp.mums.ac.ir/article_13951.html
10. Pillai AA, Satheesh S, Pakkirisamy G, Selvaraj R, Jayaraman B. Techniques and outcomes of transcatheter closure of complex atrial septal defects - single center experience. Indian Heart J. 2014;66(1):38–44. http://dx.doi.org/10.1016/j.ihj.2013.12.016
11. Tanghöj G, Odermarsky M, Naumburg E, Liuba P. Correction to: Early complications after percutaneous closure of atrial septal defect in infants with procedural weight less than 15 kg. Pediatr Cardiol. 2021;42(2):468. http://dx.doi.org/10.1007/s00246-02102550-z
12. Kitano M, Fujimoto K, Kato A, Kurosaki K-I, Shiraishi I. Efficacy and safety of the atrial septal defect closure for patients with absent or malaligned aortic rim using a figulla flex II device flared and straddling behind the aorta. Congenit Heart Dis. 2021;16(3):269–283. http://dx.doi.org/10.32604/chd.2021.015308
13. Amin Z, Hijazi ZM, Bass JL, Cheatham JP, Hellenbrand WE, Kleinman CS. Erosion of Amplatzer septal occluder device after closure of secundum atrial septal defects: review of registry of complications and recommendations to minimize future risk. Catheter Cardiovasc Interv. 2004;63(4):496–502. http://dx.doi.org/10.1002/ccd.20211
14. Kanwal A, Shiekh AM, Azim K, Khattak KK. Procedural technicalities and outcome of transcatheter closure of atrial septal defect using occlutech device in tertiary care centre. Pak Armed Force Med J. 2021;71(6):2170–2174. http://dx.doi.org/10.51253/pafmj.v71i6.3342
15. Furugen M, Watanabe N, Nishino S, Kimura T, Ashikaga K, Kuriyama N, et al. Unique mechanism of mitral valve prolapse in atrial septal defect: Three-dimensional insights into mitral complex geometry using real-time transesophageal echocardiography. Echocardiography. 2020;37(3):445–452.: http://dx.doi.org/10.1111/echo.14623
16. Deaconu S, Deaconu A, Marascu G, Stanculescu MO, Cozma D, Cinteza E, et al. Arrhythmic risk and treatment after transcatheter atrial septal defect closure. Diagnostics (Basel). 2023;14(1):33. http://dx.doi.org/10.3390/diagnostics14010033
17. Dalvi B, Pinto R, Gupta A. Device closure of large atrial septal defects requiring devices≥ 20 mm in small children weighing< 20 kg. Catheterization and Cardiovascular Interventions. 2008;71:679–686. https://doi.org/10.1002/ccd.21450
18. Moore J, Hegde S, El-Said H, Beekman R 3rd, Benson L, Bergersen L, et al. Transcatheter device closure of atrial septal defects: a safety review. JACC Cardiovasc Interv. 2013;6(5):433–442. http://dx.doi.org/10.1016/j.jcin.2013.02.005