Original Article

Comparison of Cardiac Structural Changes After Surgical and Transcatheter Atrial Septal Defect Closure With Color Doppler Echocardiography

Tuğçe Akın,[1] Zeynep Bilge Yılmaz Dere,[1] Yılmaz Yozgat,[1] Halil Türkoğlu,[1] Murat Ugurlucan[2]

İstanbul Medipol Üniversitesi,[1] Fatih, Istambul – Turkey

Liv Hospital Vadi İstanbul,[2] Istambul – Turkey

Abstract

Background: Surgical and transcatheter techniques represent the two principal approaches for atrial septal defect (ASD) closure. Although both are widely used, comparative evidence regarding their mid-term effects on cardiac remodeling and right ventricular (RV) function remains limited.

Objectives: To compare mid-term cardiac structural remodeling and right ventricular functional recovery after surgical versus transcatheter ASD closure in pediatric patients using serial color Doppler echocardiographic assessment. Additionally, to determine whether either technique leads to faster or greater improvement in right heart morphology and function.

Methods: We retrospectively evaluated 69 pediatric patients who underwent ASD closure at a single center. A total of 39 patients underwent surgical repair (Group 1), and 30 patients underwent transcatheter closure (Group 2). Transthoracic color Doppler echocardiography was performed before the procedure and at 3 and 12 months after intervention. Measures of atrial and ventricular morphology and function were analyzed.

Results: At 3 months, the surgical group showed significantly greater improvement in right atrium (RA) major axis, RA volume, interventricular septal thickness in diastole, interventricular septal thickness in systole, and RV end-diastolic diameter (RVEDd) compared with the transcatheter group (all $p < 0.05$). At 12 months, surgical repair remained superior regarding improvement in RA major axis, RA volume, and RVEDd (all $p < 0.05$). Residual shunt was identified in only one patient in each group at 12 months.

Conclusions: Surgical ASD closure was associated with earlier and more consistent recovery of right atrial and ventricular geometry and function compared with transcatheter closure. These findings indicate that surgical closure may offer advantages for selected patients, particularly in relation to right heart remodeling during the first postoperative year.

Keywords: Atrial Heart Septal Defects; Operative Surgical Procedures; Echocardiography.

Introduction

Although multiple subtypes of atrial septal defect (ASD) exist, ostium secundum defects account for approximately 80% of all ASDs.[1,2] Echocardiography remains the cornerstone for diagnosis and longitudinal follow-up in this population.[3] Depending on the defect type and anatomical location, both surgical repair and transcatheter device closure are well-established therapeutic strategies.[4,5] Surgical repair is required for sinus venosus, coronary sinus, and ostium primum defects, whereas most secundum defects are suitable for transcatheter closure. The advent of color Doppler echocardiography has enabled a more comprehensive evaluation of myocardial function and cardiac chamber remodeling compared with conventional two-dimensional imaging.[5]

Previous investigations have demonstrated significant reductions in right atrial and right ventricular dimensions following ASD closure with either technique.[6-16] Nevertheless, comparative evidence describing the temporal trajectory of atrial and ventricular remodeling after surgical versus transcatheter closure, particularly in pediatric populations, remains limited.

Accordingly, this study aimed to evaluate the effects of surgical and transcatheter ASD closure on cardiac structure and myocardial function using transthoracic color Doppler echocardiography, with predefined assessments at baseline, 3 months, and 12 months after the procedure (Central Illustration).

Mailing Address: Tuğçe Akın •
İstanbul Medipol Üniversitesi, Department of Anatomy. Göztepe Mah, Kavacık, Atatürk, Cd. No:40, 34810. Beykoz, Fatih, Istanbul – Turkey
E-mail: tugceeaakin@gmail.com
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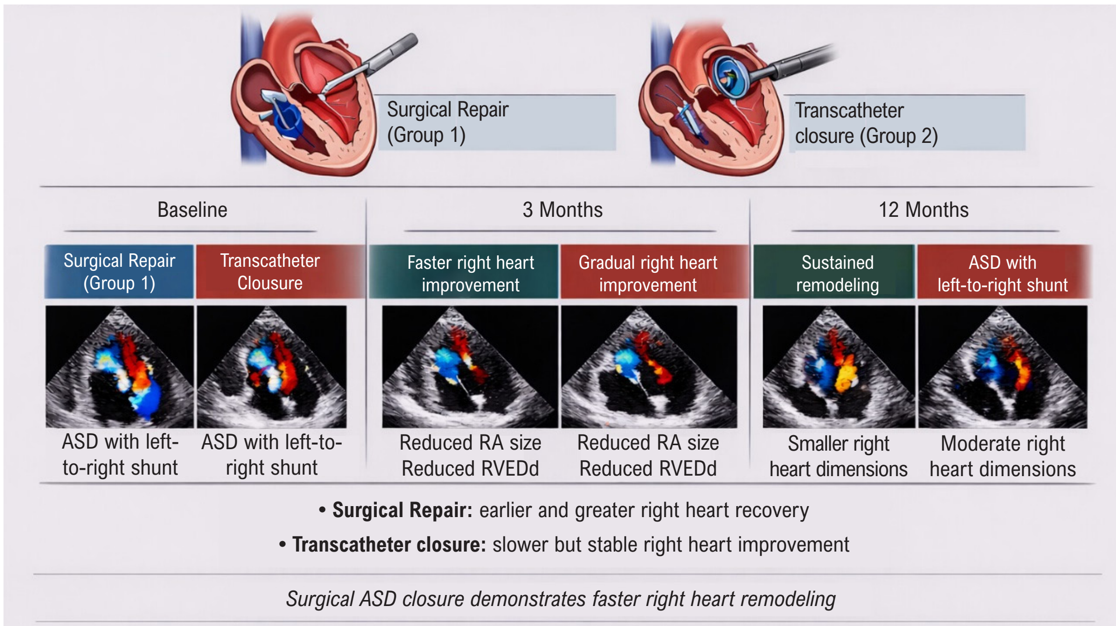
Central Illustration: Comparison of Cardiac Structural Changes After Surgical and Transcatheter Atrial Septal Defect Closure With Color Doppler Echocardiography



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Comparison of Cardiac Structural Changes After Surgical and Transcatheter Atrial Septal Defect Closure With Color Doppler Echocardiography. ASD: atrial septal defect; RA: right atrium; RVEDd: right ventricle end-diastolic diameter.

Methods

Patient selection

This retrospective study was conducted at the Department of Pediatric Cardiology, Medipol Mega University Hospital. Data were obtained from the institutional electronic echocardiography database. A total of 69 patients who underwent ASD closure between 2013-2019 were included. Patients were categorized into two groups: surgical repair (Group 1, n = 39) and transcatheter closure (Group 2, n = 30).

Patients younger than 10 years, those with complex congenital cardiac anomalies, chronic comorbidities (e.g., anemia, hypothyroidism, cystic fibrosis), or those who underwent emergent surgical procedures were excluded.

The study was approved by the Human Research Ethics Committee at the Ethics Committee of Istanbul Medipol University, Istanbul, Turkey, and conducted in accordance with the Declaration of Helsinki.

Echocardiographic evaluation

All echocardiographic examinations were performed using transthoracic echocardiography (Vivid S6, M4S-RS 1.5-3.6 MHz probe, GE HealthCare, New York, USA) and analyzed with EchoPAC software (GE HealthCare, New York, USA). Imaging protocols followed the recommendations of the American Society of Echocardiography.

Parameters assessed included:

- Atrial morphology: right atrium (RA) and left atrium (LA) major/minor axes, RA and LA volumes, and tricuspid valve annular diameters (apical 4-chamber view) (Figure 1; Figure 2).
- Ventricular morphology and function: left ventricle (LV) end-diastolic diameter (LVEDd), LV end-systolic diameter (LVESd), right ventricle (RV) end-diastolic diameter (RVEDd), RV end-systolic diameter (RVESd), interventricular septal thickness in diastole, and interventricular septal thickness in systole (IVSs) (parasternal long-axis view, M-mode).
- Derived indices: LV ejection fraction and fractional shortening (FS).

Measurements were obtained before the procedure and at 3 and 12 months after the intervention.

Statistical analysis

Data were analyzed using IBM SPSS Statistics for Windows, version 20 (IBM Corp., Armonk, N.Y., USA). Continuous variables were expressed as mean ± standard deviation or median (minimum-maximum), depending on distribution, and categorical variables as number and percentage. Group comparisons were performed using Student's *t* test or the Mann-Whitney *U* test. Paired comparisons across time points were assessed using the paired samples *t*-test or Wilcoxon test.

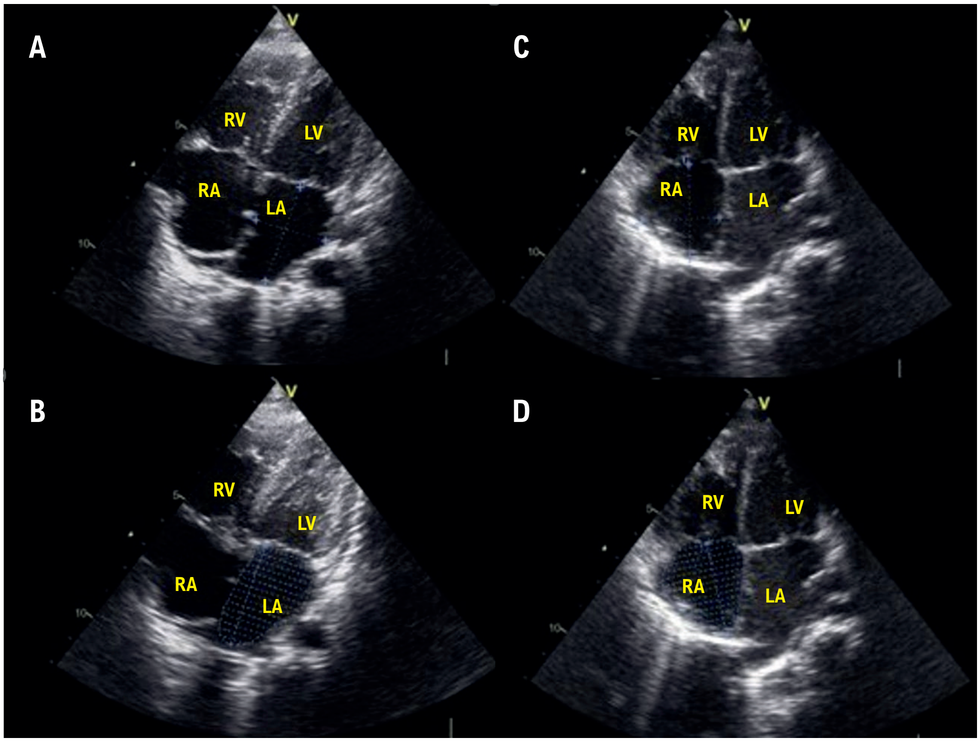

Figura 1 – *Measurement of major and minor axes (A) and volume (B) of the LA, and major and minor axes (C) and volume (D) of the RA. RA: right atrium; RV: right atrium; LA: left atrium; LV: left atrium.*

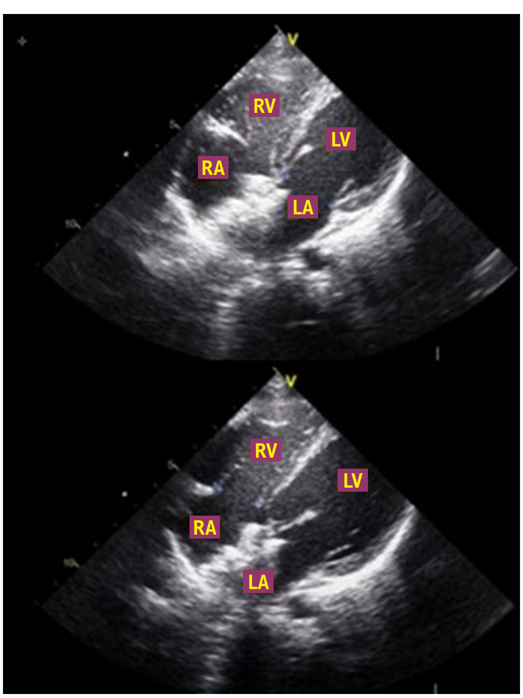

Figura 2 – *Mitral and tricuspid valve annuli measurements. RA: right atrium; RV: right atrium; LA: left atrium; LV: left atrium.*

A two-sided p-value < 0.05 was considered statistically significant. Power analysis using G*Power (v3.1.9.7) estimated an effect size of 0.56, which indicates that 57 participants per group would be required to achieve 95% power at $\alpha = 0.05$. Owing to data availability, 39 surgical and 30 transcatheter patients were included, which is acknowledged as a limitation.

Results

A total of 69 patients were included (38 women [55.1%], 31 men [44.9%]; mean age of 57.0 ± 26.6 months). The surgical group (n = 39) comprised 61.5% of women with a mean age of 50.4 ± 26.7 months, whereas the transcatheter group (n = 30) included 46.6% of women with a mean age of 65.6 ± 24.2 months. The mean ASD diameter was larger in the surgical group than in the transcatheter group (18.3 ± 6.2 mm vs. 12.3 ± 3.2 mm, p < 0.05). Secundum ASDs accounted for 71.8% of surgical cases and all transcatheter cases, while sinus venosus defects were present only in the surgical group (28.2%). Table 1 summarizes patient demographics.

At 3 months postoperatively in Group 1, significant reductions were observed in RA major axis, RA minor axis, RA volume, RVEDd, and RVESd, together with increases in FS, IVSs, and LV dimensions (all p < 0.05). These improvements largely persisted at 12 months, with further reductions in RA and RV dimensions and continued increases in LV diameters. Detailed comparisons are presented in Table 2.

At 3 months in Group 2, RA major and minor axes, RA volume, and RVEDd significantly decreased, whereas LV dimensions increased (all $p < 0.05$). At 12 months, only LVEDd and LVESd continued to increase significantly compared with 3 months, while most right-sided parameters remained stable. Results are shown in Table 1.

Tabela 1 – Características demográficas dos pacientes

Variables	Surgical repair group (n = 39)	Transcatheter group (n = 30)
Age, months	50.40 ± 26.70	65.61 ± 24.20
Sex, n (%)		
Male	15 (38.4%)	16 (53.4%)
Female	24 (61.5%)	14 (46.6%)
ASD diameter, mm	18.33 ± 6.17	12.33 ± 3.18
Type of ASD		
Ostium secundum, n (%)	28 (71.79%)	30 (100%)
Sinus venosus, n (%)	11 (28.2%)	

ASD: atrial septal defect.

When changes from baseline were compared between groups, surgical repair demonstrated significantly greater improvement in RA major axis, RA volume, IVSs, and RVEDd at 3 months (all $p < 0.05$). At 12 months, RA major axis, RA volume, and RVEDd remained significantly more improved in the surgical group (all $p < 0.05$). Group comparisons are detailed in Table 4.

Discussion

In this single-center study, we compared postoperative cardiac remodeling in patients undergoing surgical versus transcatheter closure of ASDs. The main findings were: i) surgical closure resulted in faster improvement in right atrial dimensions and RVEDd during the early postoperative period; ii) these advantages persisted at 12 months; and iii) residual shunt rates were similarly low in both groups.

Our findings align with previous reports demonstrating rapid right heart reverse remodeling after ASD closure.[10-16] Chen et al.[10] reported significant reductions in right atrial dimensions following transcatheter repair, consistent with our observations in the device closure group. However, unlike Chen et al.,[10] we did not detect significant changes in LA parameters after transcatheter closure.

Hausdorf et al.[11] and Sezer et al.[12] described early improvements in RVEDd accompanied by gradual increases in LV dimensions after closure. Similarly, we observed marked reductions in RVEDd and increases in LVEDd

Table 2 – Echocardiographic parameters before and after surgical closure of atrial septal defect at 3 and 12 months

Parameter	Baseline	Postoperative (3 months)	Postoperative (12 months)	Baseline vs 3 months	Baseline vs 12 months	3 vs 12 months
LA major axis, mm	31.30 ± 3.41	29.30 ± 4.13	29.07 ± 3.94	0.011[a]	0.005[a]	0.788[a]
LA minor axis, mm	20.71 ± 3.45	21.71 ± 2.82	23.20 ± 3.06	0.064[a]	0.001[a]	0.024[a]
LA volume, cm^2	6.50 ± 1.29	6.06 ± 1.20	6.68 ± 1.20	0.054[a]	0.000[b]	0.004[a]
MVDL, mm	16.00 (14.00-18.00)	17.00 (15.00-19.00)	18.00 (17.00-20.00)	0.150[b]	0.000[b]	0.005[a]
RA major axis, mm	36.10 ± 5.01	28.76 ± 3.47	27.97 ± 4.64[a]	0.000[a]	0.000[a]	0.311[a]
RA minor axis, mm	30.23 ± 4.15	23.64 ± 3.07	23.32 ± 4.19[a]	0.000[a]	0.000[a]	0.667[a]
RA volume, mm^2	11.00 (8.40-12.20)	6.20 (5.40-6.90)	7.20 (6.40-7.67)[b]	0.000[b]	0.000[a]	0.000[b]
TVDL, mm	19.48 ± 4.16	17.79 ± 2.33	18.82 ± 2.62[a]	0.016[a]	0.489[a]	0.054[a]
RVESd, mm	20.27 ± 3.14[a]	16.35 ± 2.03[a]	15.52 ± 1.60[a]	0.000[a]	0.000[b]	0.021[a]
RVEDd, mm	29.05 ± 4.88[a]	20.87 ± 3.20[a]	19.90 ± 3.03[a]	0.000[a]	0.000[a]	0.087[a]
LVEDd, mm	28.61 ± 4.03	30.34 ± 4.37	33.24 ± 5.07	0.020[a]	0.000[a]	0.000[b]
LVEDs, mm	17.20 ± 2.24	19.23 ± 2.05	20.89 ± 2.89	0.000[a]	0.000[a]	0.001[a]
FS, %	35.94 ± 3.94	37.20 ± 3.64	37.56 ± 4.60	0.034[a]	0.119[a]	0.695[a]
IVSs, mm	9.36 ± 1.89	8.23 ± 1.44	9.82 ± 1.44	0.000[a]	0.235[a]	0.000[b]

[a]Paired samples t-test; mean ± standard deviation; [b]Wilcoxon test; median (minimum-maximum). FS: fractional shortening; IVSs: interventricular septal thickness in systole; LA: left atrium; LVEDd: left ventricular end-diastolic diameter; LVEDs: left ventricular end-systolic diameter; MVDL: mitral valve diameter (lateral); RA: right atrium; RVEDd: right ventricular end-diastolic diameter; RVESd: right ventricular end-systolic diameter; TVDL: tricuspid valve diameter (lateral).

Table 3 – Echocardiographic parameters before and after transcatheter closure of atrial septal defect at 3 and 12 months

Parameter	Baseline	Postoperative (3 months)	Postoperative (12 months)	Baseline vs 3 months	Baseline vs 12 months	3 vs 12 months
LA major axis, mm	31.80 ± 4.67	32.40 ± 3.73	32.76 ± 4.54	0.555[a]	0.389[a]	0.726[a]
LA minor axis, mm	21.30 ± 3.14	21.50 ± 3.00	22.70 ± 4.26	0.743[a]	0.076[a]	0.067[a]
LA volume, cm^2	6.47 ± 1.42	6.57 ± 1.18	6.78 ± 1.58	0.721[a]	0.182[a]	0.459[a]
MVDL, mm	18.60 ± 2.67	20.96 ± 2.73	20.00 (18.75-24.00)	0.000[a]	0.000[b]	0.664[a]
RA major axis, mm	33.63 ± 3.92	29.50 ± 4.35	29.63 ± 4.43	0.000[a]	0.000[a]	0.875[a]
RA minor axis, mm	28.00 (26.00-30.25)	22.50 (19.75-26.25)	23.16 ± 3.42	0.000[b]	0.000[a]	0.695[a]
RA volume, mm^2	8.52 ± 1.61	6.49 ± 2.02	6.35 (5.97-6.87)	0.000[a]	0.000[b]	0.275[b]
TVDL, mm	20.40 ± 3.61	20.13 ± 4.04	19.26 ± 3.81	0.738[a]	0.226[a]	0.361[a]
RVESd, mm	20.00 (18.00-22.25)	17.00 (15.75-19.25)	16.73 ± 3.41	0.001[b]	0.000[a]	0.195[a]
RVEDd, mm	25.98 ± 4.24	21.37 ± 3.10	20.16 ± 4.47	0.000[a]	0.000[a]	0.112[a]
LVEDd, mm	29.10 ± 5.74	32.88 ± 4.39	34.55 ± 3.07	0.000[a]	0.000[a]	0.015[a]
LVEDs, mm	17.00 (15.75-19.00)	19.00 (18.00-21.00)	21.44 ± 3.00	0.004[b]	0.000[a]	0.000[a]
FS, %	35.94 ± 3.94	37.20 ± 3.64	38.20 ± 5.23	0.034[a]	0.964[a]	0.289[b]
IVSs, mm	9.36 ± 1.89	8.23 ± 1.44	10.43 ± 1.67	0.000[a]	0.800[a]	0.600[b]

[a]Paired samples t-test; mean ± standard deviation; [b]Wilcoxon test; median (minimum-maximum). FS: fractional shortening; IVSs: interventricular septal thickness in systole; LA: left atrium; LVEDd: left ventricular end-diastolic diameter; LVEDs: left ventricular end-systolic diameter; MVDL: mitral valve diameter (lateral); RA: right atrium; RVEDd: right ventricular end-diastolic diameter; RVESd: right ventricular end-systolic diameter; TVDL: tricuspid valve diameter (lateral).

Tabela 4 – Comparação entre GC e GP

Parameter	SG: baseline (3 months)	TG: baseline (3 months)	SG: baseline (12 months)	TG: baseline (12 months)	SG: 3-12 months	TG: 3-12 months	p-value (baseline vs 3 months)	p-value (baseline vs 12 months)	p-value (3 vs 12 months)
LA major axis, mm	–2.00 ± 4.67	0.60 ± 5.49	–2.23 ± 4.72	0.96 ± 6.04	–0.23 ± 5.31	0.36 ± 5.68	0.038[a]	0.016[a]	0.655[a]
RA major axis, mm	–7.33 ± 5.42	–4.13 ± 3.79	–8.15 ± 5.39	–4.00 ± 5.09	–0.82 ± 4.99	0.13 ± 4.61	0.008[a]	0.002[a]	0.419[a]
RA volume, mm^2	–4.10 ± 2.69	–2.03 ± 2.17	–3.33 ± 2.51	–1.41 ± 3.48	0.80 (0.12 to 1.50)	0.55 (–1.12 to 1.45)	0.001[a]	0.010[a]	0.247[b]
RVEDd, mm	–8.28 ± 4.31	–4.61 ± 3.67	–9.28 ± 5.31	–5.82 ± 4.48	–1.00 ± 3.56	–1.21 ± 4.06	0.000[a]	0.006[a]	0.816[a]
IVSd, mm	–1.00 (–1.00 to 1.00)	0.00 (–1.00 to 1.43)	0.00 (–1.00 to 1.00)	0.00 (–1.00 to 1.00)	0.00 (–0.82 to 1.00)	0.00 (–1.25 to 1.00)	0.062[b]	0.568[b]	0.167[b]
IVSs, mm	–1.00 (–2.00 to 0.00)	0.00 (–1.00 to 1.00)	0.45 ± 2.34	0.10 ± 2.13	2.00 (0.00 to 3.00)	0.00 (–1.00 to 2.00)	0.006[b]	0.521[a]	0.006[b]

[a]Teste t pareado; média ± desvio padrão; [b]teste de Wilcoxon; mediana (mínimo-máximo). AD: átrio direito; AE: átrio esquerdo; dDFVD: diâmetro diastólico final do ventrículo direito; GC: grupo cirúrgico; GP: grupo percutâneo; SIVd: espessura do septo interventricular na diástole; SIVs: espessura do septo interventricular na sístole.

in both groups. Notably, this remodeling occurred more rapidly in the surgical group, suggesting that hemodynamic unloading of the right ventricle may be more effective with surgical repair, particularly in patients with larger defects or sinus venosus ASDs.

Our findings partially differ from those of Pawelec-Wojtalik et al.,[16] who reported greater increases in LVEDd and greater reductions in RVEDd in the transcatheter group. In our cohort, RVEDd improvement was significantly greater in the surgical group at both 3 and 12 months. This discrepancy may be explained by differences in patient age, baseline defect size, and the inclusion of sinus venosus ASDs, which are treated exclusively with surgery.

These results suggest that surgical closure may provide superior early and mid-term right ventricular remodeling, particularly in patients with large or complex ASDs. For appropriately selected secundum defects, transcatheter closure remains safe and effective; however, our data indicate that surgical repair may result in faster recovery of right-sided geometry and function.

Study limitations

This study has some limitations. First, the sample size was relatively small and did not meet the target identified in the power analysis, which may limit generalizability. Second, the retrospective single-center design introduces the possibility of selection bias. Third, all echocardiographic evaluations were performed using a single imaging platform, and advanced modalities (e.g., cardiac magnetic resonance) were not available.

Conclusion

Surgical closure of ASDs resulted in earlier and more consistent improvement in right atrial and right ventricular geometry compared with transcatheter closure. These advantages were evident as early as 3 months and persisted at 12 months after the procedure. Both approaches were safe and associated with similarly low residual shunt rates. Our findings suggest that surgical repair may be preferable for patients with larger defects or complex anatomy, whereas transcatheter closure remains an effective alternative for appropriately selected secundum ASDs.

Author Contributions

Conception and design of the research and acquisition of data: Akın T, Yozgat Y, Türkoğlu H, Ugurlucan M; analysis and interpretation of the data, writing of the manuscript and critical revision of the manuscript for intellectual content: Akın T; statistical analysis: Dere ZBY.

Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

Sources of Funding

There were no external funding sources for this study.

Study Association

This study is not associated with any thesis or dissertation work.

Ethics Approval and Consent to Participate

This study was approved by the Ethics Committee on Animal Experiments of the Istanbul Medipol University under the protocol number 790.

Use of Artificial Intelligence

The authors did not use any artificial intelligence tools in the development of this work.

Availability of Research Data

All datasets supporting the results of this study are available upon request from the corresponding author.

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