International Journal of Medicine
pISSN 1468-3814 | eISSN 2667-7008
https://theinternationalmedicine.com/

Original Researcher Article *DOI: 10.61336/im/26-08-28*

Impact of Surgical Atrial Septal Defect Closure on Left Atrial Hemodynamics, Reverse Remodeling, and Early Postoperative Atrial Arrhythmias in Adult Patients.

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Received: 02-07-2026
Revised: 13-07-2026
Accepted: 24-07-2026
Published: 06-08-2026

Abstract

Background: Atrial septal defect (ASD) in adults is associated with chronic left-to-right shunting, atrial and ventricular remodeling, pulmonary pressure elevation, and increased risk of atrial arrhythmias. Surgical ASD closure may promote hemodynamic improvement and early reverse remodeling, but its impact on left atrial pressure, reservoir function, and postoperative arrhythmias requires focused evaluation. ***Methods:*** This prospective observational study included 30 adult patients undergoing surgical ASD closure. Baseline clinical profile, ASD morphology, left atrial pressure, left atrial structural parameters, strain indices, pulmonary pressure, rhythm status, and functional class were assessed preoperatively and at 1-month postoperative follow-up. Left atrial reverse remodeling and strain improvement were analyzed, and postoperative atrial arrhythmias were assessed in relation to left atrial pressure reduction and reservoir strain improvement. ***Results:*** The study population had female predominance, and exertional dyspnea was the most common presenting symptom. Ostium secundum ASD was the predominant type. After surgical closure, mean left atrial pressure reduced significantly from 14.28 ± 3.16 mmHg to 9.84 ± 2.42 mmHg. Left atrial diameter, left atrial volume index, right atrial diameter, and right ventricular basal diameter also showed significant reduction. Left atrial reservoir strain, conduit strain, contractile strain, and emptying fraction improved significantly at 1 month. Postoperative atrial arrhythmia occurred in 16.7% of patients and was significantly associated with lesser left atrial pressure reduction and poorer reservoir strain improvement. Pulmonary artery pressure, exertional dyspnea, fatigability, palpitation, and NYHA functional class also improved significantly. ***Conclusion:*** Surgical ASD closure in adults resulted in significant early improvement in left atrial hemodynamics, reverse remodeling, reservoir function, pulmonary pressure, rhythm stability, and clinical status.

Keywords: Atrial septal defect, surgical ASD closure, left atrial pressure, reverse remodeling, atrial arrhythmia.

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INTRODUCTION

Atrial septal defect is an important congenital cardiac lesion that may remain undiagnosed until adulthood.[1] In adult patients, the persistence of left-to-right shunting can produce chronic volume overload, progressive cardiac chamber dilatation, pulmonary overcirculation, and functional limitation. [2] Although many patients remain minimally symptomatic during early life, the hemodynamic burden often becomes clinically evident later through exertional dyspnea, fatigability, palpitation, reduced exercise tolerance, pulmonary hypertension, and atrial rhythm disturbances. [3,4]

Surgical closure of atrial septal defect aims to eliminate the abnormal interatrial communication and reduce the long-standing volume load on the cardiac chambers. [5] Following closure, favorable changes are expected in cardiac dimensions, pulmonary pressure, and clinical status. [6] However, the extent of recovery may vary depending on age, defect size, duration of shunt exposure, baseline pulmonary pressure, and degree of pre-existing atrial remodeling. Therefore, post-closure assessment should include not only anatomical success but also functional and hemodynamic recovery. [7,8]

Left atrial hemodynamics are increasingly recognized as an important component of post-ASD closure evaluation. [9] The left atrium contributes to ventricular filling through reservoir, conduit, and contractile functions. [10] Alterations in left atrial pressure, volume, and deformation properties may reflect the adaptive and maladaptive effects of chronic shunt

physiology as well as the hemodynamic changes that occur after closure. [11] Assessment of left atrial pressure, left atrial diameter, volume index, and strain parameters can provide useful information regarding early reverse remodeling. [12]

Left atrial reservoir function is particularly relevant because it reflects the ability of the left atrium to accommodate pulmonary venous return during ventricular systole. [13] Impairment of reservoir function may be associated with increased atrial stiffness, elevated filling pressures, and susceptibility to atrial arrhythmias. With the availability of echocardiographic strain imaging, subtle changes in left atrial function can be identified even when conventional chamber dimensions appear only mildly altered. Thus, left atrial strain assessment may improve understanding of functional recovery after surgical ASD closure. [14]

Atrial arrhythmias remain an important postoperative concern in adult patients undergoing ASD closure. Long-standing atrial stretch, pressure overload, and structural remodeling may create an arrhythmogenic substrate that can persist even after closure. [15] Evaluation of postoperative atrial fibrillation, atrial flutter, and supraventricular tachycardia is therefore essential, especially in relation to the degree of left atrial pressure reduction and improvement in reservoir strain. Understanding this association may help identify patients who require closer rhythm surveillance after surgery. [16]

In addition to left atrial remodeling and rhythm outcomes, pulmonary pressure reduction and clinical improvement are important early indicators of successful postoperative recovery. Reduction in pulmonary artery pressure, improvement in exertional dyspnea and fatigability, and better New York Heart Association functional class can reflect the beneficial physiological effect of ASD closure. The present study was conducted to evaluate the impact of surgical ASD closure on left atrial pressure, structural reverse remodeling, reservoir function, postoperative atrial arrhythmias, pulmonary pressure, and early clinical improvement among adult patients at 1-month follow-up.

Aims and Objectives

Aim

To evaluate the impact of surgical atrial septal defect closure on left atrial hemodynamics, left atrial reverse remodeling, reservoir function, postoperative atrial arrhythmias, pulmonary pressure, and early clinical improvement among adult patients.

Objectives

- To assess the changes in left atrial pressure, left atrial structural parameters, and left atrial strain parameters before surgery and at 1-month follow-up after surgical ASD closure.
- To determine the occurrence of postoperative atrial arrhythmias and evaluate their association with left atrial pressure reduction and reservoir strain improvement, along with changes in pulmonary pressure and clinical functional status at 1 month after surgery.

MATERIALS AND METHODS

Study Design and Setting

This study was designed as a prospective observational study to evaluate the impact of surgical atrial septal defect closure on left atrial hemodynamics, reverse remodeling, pulmonary pressure, postoperative atrial arrhythmias, and early clinical improvement among adult patients. The study was conducted in the Department of Cardiovascular and Thoracic Surgery, Government Tirunelveli Medical College and PMSSY, Tirunelveli. Adult patients who were planned for surgical closure of atrial septal defect were enrolled and followed up until 1 month after surgery.

Study Population

The study population included adult patients diagnosed with atrial septal defect who underwent surgical ASD closure during the study period. Patients were evaluated clinically and echocardiographically before surgery and were reassessed at 1-month postoperative follow-up. The study focused on adult patients with hemodynamically significant ASD requiring surgical correction.

Study Duration

The total duration of the study was 6 months. Data collection was carried out over a period of 4 months, from 01/01/2026 to 30/04/2026. The remaining 2 months were used for data analysis, interpretation, manuscript preparation, and publication-related work.

Inclusion and Exclusion Criteria

Adult patients aged 18 years and above who were diagnosed with atrial septal defect and planned for surgical ASD closure were included in the study. Patients who provided informed consent and were willing to attend 1-month postoperative follow-up were eligible for enrollment.

Patients with complex congenital heart disease, Eisenmenger physiology, severe irreversible pulmonary arterial hypertension, significant left-sided valvular heart disease, previous cardiac surgery, poor echocardiographic window, incomplete clinical or echocardiographic data, and those who were not available for 1-month follow-up were excluded from the study.

Sample Size and Sampling Technique

A total sample size of 30 adult patients undergoing surgical ASD closure was included in the study. The sample size was based on the expected number of eligible patients during the data collection period and was also aligned with the sample size used in the reference article. A consecutive sampling technique was followed, in which all eligible patients satisfying the inclusion and exclusion criteria during the study period were recruited until the required sample size was achieved.

Study Procedure

After obtaining informed consent, all eligible patients were enrolled in the study. Baseline demographic and clinical details, including age, sex, presenting symptoms, NYHA functional class, and preoperative rhythm status, were recorded using a structured data collection form. Clinical symptoms such as exertional dyspnea, fatigability, and palpitation were documented before surgery.

Preoperative echocardiographic assessment was performed to document ASD morphology, ASD size, right heart dilatation, pulmonary hypertension status, left atrial pressure, left atrial diameter, left atrial volume index, pulmonary artery systolic pressure, and Qp:Qs ratio. Left atrial functional assessment was performed using echocardiographic strain parameters, including left atrial reservoir strain, conduit strain, contractile strain, and left atrial emptying fraction.

All patients underwent surgical ASD closure as per standard institutional protocol. Postoperative monitoring was done for rhythm disturbances, including atrial fibrillation, atrial flutter, and supraventricular tachycardia. At 1-month follow-up, patients were reassessed clinically and echocardiographically. Postoperative left atrial pressure, left atrial dimensions, left atrial volume index, strain parameters, pulmonary artery pressure, symptoms, and NYHA functional class were recorded and compared with baseline values.

Operational Definitions

- Adult ASD patient was defined as a patient aged 18 years or above diagnosed with atrial septal defect and undergoing surgical ASD closure.
- Surgical ASD closure referred to operative closure of atrial septal defect using direct closure or patch repair based on intraoperative anatomical suitability.
- Left atrial pressure reduction was defined as the difference between preoperative and 1-month postoperative mean left atrial pressure. For analytical purposes, reduction was categorized as <4 mmHg and ≥4 mmHg.
- Left atrial structural reverse remodeling was defined as reduction in left atrial diameter and left atrial volume index at 1-month follow-up compared with preoperative values.
- Left atrial reservoir strain improvement was defined as an increase in left atrial reservoir strain at 1-month postoperative follow-up compared with the preoperative value. For association analysis, improvement was categorized as <5% and ≥5%.
- Postoperative atrial arrhythmia was defined as the occurrence of atrial fibrillation, atrial flutter, or supraventricular tachycardia during the postoperative period up to 1-month follow-up.
- Pulmonary hypertension was assessed using estimated pulmonary artery systolic pressure and was categorized as absent/mild or moderate/severe based on echocardiographic assessment.
- Clinical improvement was defined as reduction in symptoms such as exertional dyspnea, fatigability, and palpitation, along with improvement in NYHA functional class at 1-month follow-up.

Statistical Analysis

Data were entered in Microsoft Excel and analyzed using SPSS version 26. Categorical variables were expressed as frequency and percentage. Continuous variables were expressed as mean and standard deviation. Preoperative and 1-month postoperative continuous variables, including left atrial pressure, left atrial diameter, left atrial volume index, strain parameters, pulmonary artery systolic pressure, and mean pulmonary artery pressure, were compared using the paired t-test. Categorical variables such as symptoms and NYHA functional class before and after surgery were compared using the McNemar test or McNemar-Bowker test as appropriate. Association between postoperative atrial arrhythmias and left atrial pressure reduction or reservoir strain improvement was assessed using the Chi-square test or Fisher's exact test. A p-value of <0.05 was considered statistically significant.

Ethical Consideration

The study was conducted after obtaining approval from the Institutional Ethics Committee of Government Tirunelveli Medical College. Written informed consent was obtained from all study participants before enrollment. Confidentiality of patient information was maintained throughout the study. Participation was voluntary, and patients were informed that refusal to participate or withdrawal from the study would not affect their routine clinical care. All procedures followed standard institutional treatment protocols, and no additional invasive intervention was performed solely for the purpose of the study.

RESULTS

Table 1. Baseline Clinical Profile of Adult Patients Undergoing Surgical ASD Closure (N = 30)

Variable	Frequency (n)	Percentage (%)
Age group, years		
≤40	18	60.0
>40	12	40.0
Sex		
Male	12	40.0
Female	18	60.0
Major presenting symptom		
Exertional dyspnea	21	70.0
Fatigability	15	50.0
Palpitation	12	40.0
NYHA functional class		
Class I–II	22	73.3
Class III–IV	8	26.7
Preoperative rhythm status		
Sinus rhythm	24	80.0
Atrial arrhythmia	6	20.0

Table 1 presents the baseline clinical profile of adult patients undergoing surgical ASD closure. Among the 30 study participants, 18 patients (60.0%) were aged ≤40 years, while 12 patients (40.0%) were aged >40 years. Female predominance was observed, with 18 patients (60.0%) being female and 12 patients (40.0%) being male. The most common presenting symptom was exertional dyspnea, reported by 21 patients (70.0%), followed by fatigability in 15 patients (50.0%) and palpitation in 12 patients (40.0%).

With regard to functional status, 22 patients (73.3%) belonged to NYHA functional class I–II, whereas 8 patients (26.7%) were in NYHA functional class III–IV. Preoperative rhythm assessment showed that most patients were in sinus rhythm, accounting for 24 patients (80.0%), while atrial arrhythmia was present in 6 patients (20.0%). Overall, the study population predominantly consisted of female patients aged ≤40 years, with exertional dyspnea as the most frequent presenting symptom and preserved sinus rhythm in the majority before surgical ASD closure.

Table 2. ASD Morphology and Baseline Hemodynamic Profile of Study Participants (N = 30)

Variable	Frequency (n)	Percentage (%)
Type of ASD		
Ostium secundum ASD	27	90.0
Other ASD types	3	10.0
ASD size category		
≤20 mm	14	46.7
>20 mm	16	53.3
Right heart dilatation		
Present	26	86.7
Absent	4	13.3
Pulmonary hypertension status		
Absent/mild pulmonary hypertension	15	50.0
Moderate/severe pulmonary hypertension	15	50.0
Baseline rhythm status		
Sinus rhythm	24	80.0
Atrial arrhythmia	6	20.0

Hemodynamic parameter	Mean ± SD
ASD size, mm	22.46 ± 6.18
Mean left atrial pressure, mmHg	14.28 ± 3.16
Left atrial diameter, mm	36.82 ± 5.74
Left atrial volume index, mL/m²	32.64 ± 6.88
Estimated pulmonary artery systolic pressure, mmHg	48.36 ± 13.72
Qp:Qs ratio	2.21 ± 0.48

Table 2 presents the ASD morphology and baseline hemodynamic profile of the study participants. Ostium secundum ASD was the predominant morphological type, observed in 27 patients (90.0%), while other ASD types were present in 3 patients (10.0%). With regard to ASD size, 14 patients (46.7%) had a defect size of ≤20 mm, whereas 16 patients (53.3%) had a defect size of >20 mm. Right heart dilatation was present in the majority of patients, accounting for 26 cases (86.7%), while it was absent in 4 cases (13.3%). Pulmonary hypertension was absent or mild in 15 patients (50.0%), whereas moderate or severe pulmonary hypertension was present in 15 patients (50.0%). Baseline rhythm assessment showed sinus rhythm in 24 patients (80.0%) and atrial arrhythmia in 6 patients (20.0%).

The mean ASD size was 22.46 ± 6.18 mm. The baseline mean left atrial pressure was 14.28 ± 3.16 mmHg, while the mean left atrial diameter and left atrial volume index were 36.82 ± 5.74 mm and 32.64 ± 6.88 mL/m², respectively. The estimated pulmonary artery systolic pressure was 48.36 ± 13.72 mmHg, and the mean Qp:Qs ratio was 2.21 ± 0.48. These findings indicate that most patients had a significant left-to-right shunt with associated right heart dilatation, elevated pulmonary artery pressure, and baseline left atrial hemodynamic alteration before surgical ASD closure.

Table 3. Left Atrial Pressure and Structural Reverse Remodeling After Surgical ASD Closure (N = 30)

Parameter	Preoperative Mean ± SD	1-month Postoperative Mean ± SD	Mean Change	p-value
Mean left atrial pressure, mmHg	14.28 ± 3.16	9.84 ± 2.42	4.44	<0.001*
Left atrial diameter, mm	36.82 ± 5.74	33.46 ± 4.92	3.36	0.002*
Left atrial volume index, mL/m²	32.64 ± 6.88	28.12 ± 5.96	4.52	0.001*
Right atrial diameter, mm	46.28 ± 6.92	40.36 ± 5.84	5.92	<0.001*
Right ventricular basal diameter, mm	42.16 ± 5.88	37.42 ± 5.16	4.74	0.001*

*Statistically significant

Table 3 presents the changes in left atrial pressure and structural remodeling parameters after surgical ASD closure. The mean left atrial pressure showed a significant reduction from 14.28 ± 3.16 mmHg preoperatively to 9.84 ± 2.42 mmHg at 1-month postoperative follow-up, with a mean change of 4.44 mmHg ($p < 0.001$). Similarly, left atrial diameter decreased significantly from 36.82 ± 5.74 mm to 33.46 ± 4.92 mm, with a mean change of 3.36 mm ($p = 0.002$). Left atrial volume index also showed a significant reduction from 32.64 ± 6.88 mL/m² to 28.12 ± 5.96 mL/m², with a mean change of 4.52 mL/m² ($p = 0.001$).

Right heart structural parameters also demonstrated significant postoperative reverse remodeling. Right atrial diameter decreased from 46.28 ± 6.92 mm preoperatively to 40.36 ± 5.84 mm at 1 month, with a mean change of 5.92 mm ($p < 0.001$). Right ventricular basal diameter reduced from 42.16 ± 5.88 mm to 37.42 ± 5.16 mm, with a mean change of 4.74 mm ($p = 0.001$). These findings indicate significant early reverse remodeling of both left atrial and right heart structural parameters following surgical ASD closure.

Table 4. Left Atrial Reservoir Function and Strain Parameters After Surgical ASD Closure (N = 30)

Parameter	Preoperative Mean ± SD	1-month Postoperative Mean ± SD	Mean Change	p-value
Left atrial reservoir strain, %	25.18 ± 5.42	30.64 ± 6.18	5.46	<0.001*
Left atrial conduit strain, %	12.46 ± 3.24	15.28 ± 3.86	2.82	0.004*
Left atrial contractile strain, %	10.72 ± 2.86	12.94 ± 3.12	2.22	0.006*
Left atrial emptying fraction, %	41.36 ± 7.82	48.74 ± 8.16	7.38	<0.001*

*Statistically significant

Table 4 presents the changes in left atrial reservoir function and strain parameters after surgical ASD closure. Left atrial reservoir strain showed a significant improvement from 25.18 ± 5.42% preoperatively to 30.64 ± 6.18% at 1-month postoperative follow-up, with a mean increase of 5.46% ($p < 0.001$). Similarly, left atrial conduit strain increased significantly from 12.46 ± 3.24% to 15.28 ± 3.86%, with a mean change of 2.82% ($p = 0.004$). Left atrial contractile strain also improved from 10.72 ± 2.86% preoperatively to 12.94 ± 3.12% postoperatively, with a mean increase of 2.22% ($p = 0.006$).

Left atrial emptying fraction demonstrated a significant postoperative increase from 41.36 ± 7.82% to 48.74 ± 8.16%, with a mean change of 7.38% ($p < 0.001$). These findings suggest significant improvement in left atrial reservoir, conduit, and contractile function at 1 month following surgical ASD closure, indicating early functional recovery of the left atrium after relief of volume and pressure overload.

Table 5. Postoperative Atrial Arrhythmias and Association with Left Atrial Pressure and Strain Improvement (N = 30)

Variable	Frequency (n)	Percentage (%)
Postoperative atrial arrhythmia		
Present	5	16.7
Absent	25	83.3
Type of postoperative atrial arrhythmia		
Atrial fibrillation	3	10.0
Atrial flutter	1	3.3
Supraventricular tachycardia	1	3.3
No atrial arrhythmia	25	83.3

Predictor variable	Arrhythmia Present Frequency (n)	Arrhythmia Present Percentage (%)	Arrhythmia Absent Frequency (n)	Arrhythmia Absent Percentage (%)	p-value
Left atrial pressure reduction					0.041*
<4 mmHg reduction	4	40.0	6	60.0	
≥4 mmHg reduction	1	5.0	19	95.0	
Left atrial reservoir strain improvement					0.048*
<5% improvement	4	36.4	7	63.6	
≥5% improvement	1	5.3	18	94.7	

*Statistically significant

Table 5 presents the distribution of postoperative atrial arrhythmias and their association with left atrial pressure reduction and left atrial reservoir strain improvement. Postoperative atrial arrhythmia was observed in 5 patients (16.7%), while 25 patients (83.3%) did not develop atrial arrhythmia during the 1-month postoperative follow-up period. Among the arrhythmias observed, atrial fibrillation was the most common, occurring in 3 patients (10.0%), followed by atrial flutter in 1 patient (3.3%) and supraventricular tachycardia in 1 patient (3.3%).

A significant association was observed between the degree of left atrial pressure reduction and postoperative atrial arrhythmia. Among patients with <4 mmHg reduction in left atrial pressure, atrial arrhythmia occurred in 4 patients (40.0%), whereas 6 patients (60.0%) remained free of arrhythmia. In contrast, among patients with ≥4 mmHg reduction in left atrial pressure, only 1 patient (5.0%) developed atrial arrhythmia, while 19 patients (95.0%) did not develop arrhythmia. This association was statistically significant ($p = 0.041$).

Left atrial reservoir strain improvement was also significantly associated with postoperative atrial arrhythmia. Among patients with <5% improvement in left atrial reservoir strain, atrial arrhythmia occurred in 4 patients (36.4%), while 7 patients (63.6%) had no arrhythmia. Conversely, among those with ≥5% improvement in reservoir strain, only 1 patient (5.3%) developed atrial arrhythmia, whereas 18 patients (94.7%) remained free of arrhythmia. This association was statistically significant ($p = 0.048$), suggesting that greater improvement in left atrial pressure and reservoir function was associated with a lower occurrence of postoperative atrial arrhythmias.

Table 6. Pulmonary Pressure and Clinical Improvement at 1-Month Follow-up After Surgical ASD Closure (N = 30)

Parameter	Preoperative Mean ± SD	1-month Postoperative Mean ± SD	Mean Change	p-value
Estimated pulmonary artery systolic pressure, mmHg	48.36 ± 13.72	34.28 ± 9.84	14.08	<0.001*
Mean pulmonary artery pressure, mmHg	31.42 ± 8.16	23.64 ± 6.28	7.78	<0.001*

Clinical variable	Preoperative Frequency (n)	Preoperative Percentage (%)	1-month Frequency (n)	1-month Percentage (%)	p-value
Exertional dyspnea	21	70.0	7	23.3	<0.001*
Fatigability	15	50.0	5	16.7	0.004*
Palpitation	12	40.0	4	13.3	0.021*
NYHA functional class					0.016*
Class I–II	22	73.3	29	96.7	
Class III–IV	8	26.7	1	3.3	

*Statistically significant

Table 6 presents the changes in pulmonary pressure and clinical improvement at 1-month follow-up after surgical ASD closure. The estimated pulmonary artery systolic pressure showed a significant reduction from 48.36 ± 13.72 mmHg preoperatively to 34.28 ± 9.84 mmHg at 1 month postoperatively, with a mean change of 14.08 mmHg ($p < 0.001$). Similarly, mean pulmonary artery pressure decreased significantly from 31.42 ± 8.16 mmHg to 23.64 ± 6.28 mmHg, with a mean change of 7.78 mmHg ($p < 0.001$). These findings indicate significant early reduction in pulmonary pressure following surgical ASD closure.

Clinical symptoms also showed significant improvement at 1-month follow-up. Exertional dyspnea decreased from 21 patients (70.0%) preoperatively to 7 patients (23.3%) postoperatively ($p < 0.001$). Fatigability reduced from 15 patients (50.0%) to 5 patients (16.7%) ($p = 0.004$), and palpitation decreased from 12 patients (40.0%) to 4 patients (13.3%) ($p = 0.021$). Functional status improved significantly, with patients in NYHA functional class I–II increasing from 22 patients (73.3%) to 29 patients (96.7%), while those in class III–IV decreased from 8 patients (26.7%) to 1 patient (3.3%) after surgery ($p = 0.016$). Overall, these results demonstrate significant improvement in pulmonary hemodynamics, symptom burden, and functional status at 1 month after surgical ASD closure.

DISCUSSION

The baseline clinical profile showed that the study population predominantly consisted of adults aged ≤40 years, with female predominance and exertional dyspnea as the most common presenting symptom. Most patients were in NYHA functional class I–II, and sinus rhythm was present in the majority before surgery. This pattern is comparable with previous adult ASD studies, where female predominance, exertional symptoms, and functional limitation were commonly observed among patients undergoing closure. Chen et al. reported that adult ASD patients often had functional limitation before closure, with improvement after intervention [2]. Tandon et al. also observed female predominance and symptomatic presentation among adult patients undergoing ASD closure [9]. Palanisamy et al. emphasized that adult patients with ASD may present with reduced functional capacity and derive clinical benefit after closure [8]. Similarly, Brida et al. described adult ASD as a condition frequently associated with delayed presentation, exertional symptoms, atrial arrhythmias, and progressive hemodynamic burden [15].

Ostium secundum ASD was the predominant defect type, and more than half of the patients had a defect size greater than 20 mm. Right heart dilatation was present in most patients, while half of the cohort had moderate or severe pulmonary hypertension. These findings reflect the hemodynamic consequence of long-standing left-to-right shunting in adult ASD. Refaat and Farid reported that ASD closure candidates commonly had right ventricular dilatation and elevated pulmonary artery systolic pressure before intervention [6]. Tandon et al. also documented significant right heart enlargement among adult patients with secundum ASD and substantial shunt burden [9]. Chen et al. demonstrated increased right atrial and right ventricular volumes before closure, supporting the role of chronic volume overload in adult ASD physiology [2]. Singhi et al. further highlighted that larger secundum ASDs are commonly associated with important anatomical and hemodynamic alterations, making detailed preoperative assessment essential [10].

The present study demonstrated significant reduction in mean left atrial pressure, left atrial diameter, left atrial volume index, right atrial diameter, and right ventricular basal diameter at 1 month after surgical ASD closure. These results suggest early structural reverse remodeling following elimination of the interatrial shunt. Similar reverse remodeling has been reported in adult ASD closure studies, particularly involving the right atrium and right ventricle. Chen et al. observed significant reduction in right atrial and right ventricular volumes after ASD closure in adult patients [2]. Refaat and Farid also reported favorable cardiac remodeling after closure, including reduction in right ventricular dimensions and pulmonary artery pressure [6]. Saedi et al. found significant changes in atrial and ventricular volumetric parameters after ASD closure, supporting the occurrence of early chamber remodeling [4]. Tandon et al. similarly reported significant reduction in right ventricular dimensions within 3 months after closure, indicating that structural improvement may occur early after relief of chronic shunt-related volume overload [9].

Left atrial reservoir strain, conduit strain, contractile strain, and left atrial emptying fraction improved significantly at 1-month postoperative follow-up. These findings indicate that surgical ASD closure was associated not only with structural remodeling but also with early functional recovery of the left atrium. Seo et al. emphasized that two-dimensional speckle-tracking echocardiography is useful for assessing left atrial reservoir, conduit, and contractile function after ASD closure [3]. Saedi et al. reported that atrial strain parameters are clinically relevant in adult ASD patients and may change after closure, particularly in patients with larger defects [4]. Refaat and Farid demonstrated favorable mechanical remodeling after ASD closure, supporting the role of functional echocardiographic parameters in post-closure assessment [6]. Arvidsson et al. also supported the concept that ASD closure modifies abnormal cardiac hemodynamic forces and contributes to normalization of cardiac mechanics after correction of shunt physiology [5].

Postoperative atrial arrhythmia occurred in 16.7% of patients during the 1-month follow-up period, with atrial fibrillation being the most common rhythm disturbance. The occurrence of postoperative atrial arrhythmia was significantly higher among patients with lesser left atrial pressure reduction and lesser improvement in left atrial reservoir strain. This suggests that incomplete relief of atrial hemodynamic burden and inadequate functional recovery may contribute to persistence of an arrhythmogenic substrate after ASD closure. Nyboe et al. reported that adult ASD patients had a higher risk of atrial fibrillation even after closure, indicating that closure may not completely eliminate rhythm risk [1]. Himelfarb et al. found that new-onset atrial fibrillation or flutter after ASD closure remains clinically relevant, particularly in older adults and during early follow-up [7]. Vecht et al. reported that ASD closure may reduce atrial tachyarrhythmia prevalence in the short to medium term, although arrhythmia risk persists in some patients [12]. Deaconu et al. also emphasized the importance of rhythm surveillance after ASD closure, especially in adults with pre-existing atrial remodeling [14].

The study also showed significant reduction in estimated pulmonary artery systolic pressure and mean pulmonary artery pressure at 1 month after surgical ASD closure. Symptomatic improvement was evident, with significant reductions in exertional dyspnea, fatigability, and palpitation, along with improvement in NYHA functional class. These findings indicate that surgical closure produced early hemodynamic and clinical benefits. Refaat and Farid reported significant reduction in pulmonary artery systolic pressure and improvement in right ventricular functional parameters after ASD closure [6]. Tandon et al. observed significant right heart remodeling and improvement in functional and quality-of-life outcomes within 3 months after closure [9]. Chen et al. also documented improvement in NYHA functional class following ASD closure among adult patients [2]. Palanisamy et al. further demonstrated that ASD closure in older adults was associated with improved functional class and reduction in adverse cardiovascular outcomes, although arrhythmia risk may continue in selected patients [8].

Limitations

The main limitations of the study were the small sample size and single-centre design, which may limit the generalizability of the findings. The follow-up period was limited to 1 month, and therefore long-term left atrial remodeling, pulmonary pressure changes, and late atrial arrhythmias could not be assessed.

CONCLUSION

Surgical ASD closure in adult patients resulted in significant early improvement in left atrial hemodynamics, structural reverse remodeling, and functional recovery at 1-month follow-up. There was a significant reduction in mean left atrial pressure, left atrial diameter, left atrial volume index, right atrial diameter, right ventricular basal diameter, pulmonary artery systolic pressure, and mean pulmonary artery pressure. Left atrial reservoir, conduit, and contractile strain parameters also improved significantly after surgery, indicating early restoration of left atrial functional performance. The occurrence of postoperative atrial arrhythmias was lower among patients with greater reduction in left atrial pressure and better improvement in left atrial reservoir strain, suggesting that effective hemodynamic relief may contribute to reduced rhythm instability. Clinical improvement was also evident through reduction in exertional dyspnea, fatigability, palpitation, and improvement in NYHA functional class.

Based on these findings, surgical ASD closure should be considered not only as an anatomical corrective procedure but also as an intervention that promotes early cardiac reverse remodeling and functional recovery in adult patients. Preoperative and postoperative evaluation should include detailed echocardiographic assessment of left atrial pressure, left atrial volume, pulmonary pressure, and strain parameters, as these may help identify patients at risk of persistent atrial dysfunction or postoperative arrhythmias. Regular rhythm monitoring during the early postoperative period is recommended, especially in patients with inadequate left atrial pressure reduction or poor reservoir strain improvement. Further multicentric studies with larger sample sizes and longer follow-up are recommended to assess the long-term effects of surgical ASD closure on left atrial remodeling, pulmonary hypertension, atrial arrhythmias, and clinical outcomes.

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