Original Article

# Immediate and Short-Term Outcome of Percutaneous Trans-Catheter Device Closure of Atrial Septal Defects in Adults

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## ABSTRACT

**Background:** Atrial septal defect (ASD), one of the most common congenital heart defects, often remains undiagnosed until adulthood, leading to complications like pulmonary hypertension, arrhythmias, and right ventricular (RV) dysfunction. Transcatheter ASD closure offers a minimally invasive option.

**Aim of the Work:** To evaluate the immediate and short-term outcome of transcatheter ASD closure on cardiac functions and functional capacity in adults.

**Methods:** This prospective cohort study included 50 adults who underwent transcatheter ASD closure. Patients were stratified according to age at transcatheter closure into two groups: Group 1 (18–40 years) and Group 2 (>40 years). Comprehensive pre- and post-procedural assessments included echocardiography, 6-minute walk test (6MWT), and coronary angiography.

**Results:** Significant reductions in RV end-diastolic volume (75.20 ± 10.30 to 68.18 ± 9.98 mm³, $P < 0.001$), RV systolic pressure (49.22 ± 4.85 to 35.14 ± 4.77 mmHg, $P < 0.0001$), and mean pulmonary artery pressure (28.82 ± 6.43 to 23.86 ± 5.90 mmHg, $P < 0.001$) were observed at one month. Left ventricular ejection fraction improved significantly ($P < 0.001$), and 6-minute walk test (6MWT) distance increased (464.38 ± 49.61 to 488.80 ± 44.39 m, $P < 0.001$). Younger patients exhibited greater functional capacity improvement ($P = 0.008$). Pre-procedural mPAP negatively correlated with 6MWT performance ($P < 0.05$).

**Conclusions:** Transcatheter ASD closure significantly improves cardiac remodeling, pulmonary hemodynamics, and functional capacity, with younger patients benefiting most.

**Key Words:** Atrial septal defect, echocardiography, functional capacity, pulmonary hemodynamics, transcatheter closure.

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## INTRODUCTION

Atrial septal defect (ASD) is among the most common congenital heart defects, accounting for 6–10% of such malformations and affecting approximately 1.6 per 1000 live births[1]. These defects, the most common form of acyanotic congenital heart disease[2, 3], involve abnormal communications between the atria, allowing blood shunting between systemic and pulmonary circulations. The reported prevalence of ASDs has increased over the past 50 years, likely due to advancements in imaging and practitioner training rather than a true rise in incidence[4]. There are four types of ASDs: ostium secundum (70–80%), ostium primum (15–20%), sinus venosus (5–10%), and coronary sinus (<1%)[5].

ASDs are often asymptomatic for decades, leading to delayed diagnosis and treatment, particularly for larger defects[6]. Untreated large ASDs can result in exercise intolerance, cardiac arrhythmias, palpitations, increased pneumonia incidence, pulmonary hypertension, and elevated mortality rates[7]. A severe complication, Eisenmenger syndrome, arises from chronic left-to-right shunting and vascular remodeling[8]. Smaller defects (<5 mm) are typically asymptomatic, while medium-sized defects (5–10 mm) often present in the fourth or fifth decade, and larger defects manifest earlier, around the third decade, with symptoms such as dyspnea, fatigue, palpitations, and right-sided heart failure. Preoperatively, 20% of adults with ASDs develop atrial tachyarrhythmias[9].

Diagnostic imaging plays a pivotal role in assessing ASDs and guiding treatment decisions, with transthoracic echocardiography serving as the gold standard. This modality enables accurate measurement of defect size, evaluation of blood flow direction, detection of associated abnormalities, assessment of heart structure

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and function, estimation of pulmonary artery pressure, and calculation of the pulmonary/systemic flow ratio (Qp:Qs). Transesophageal echocardiography provides detailed preoperative anatomical assessment and is used intraoperatively to ensure proper device deployment[9].

ASDs smaller than 5 mm often close spontaneously within the first year of life, while defects larger than 1 cm typically require transcatheter or surgical intervention. Although surgical repair has historically been the standard treatment, transcatheter (percutaneous) and hybrid approaches are now widely used for effective closure. However, the transcatheter approach is limited to ostium secundum defects, with surgical intervention necessary for ostium primum, sinus venosus, and coronary sinus defects[10].

## THE AIM OF THE STUDY

Therefore, this study aims to evaluate the immediate and short-term outcome of transcatheter ASD closure on cardiac functions and functional capacity in adults.

## PATIENTS AND METHODS

### Study Design and Population

This prospective cohort study was conducted on 50 participants who successfully underwent trans-catheter closure of secundum ASD at the Catheterization Lab Unit of Cardiology Department in Ain Shams University Hospitals, it was conducted from April till December 2023, with ethical approval from Ain Shams University.

## ETHICAL COMMITTEE

(Approval no: FMASU MS122/2023) (Approval date: 05/03/2023). Written informed consent was obtained from all participants, ensuring privacy and confidentiality.

Eligible participants were adult patients with hemodynamically significant secundum ASD, characterized by right heart dilatation and a significant left-to-right shunt on transthoracic and transesophageal echocardiography. Exclusion criteria were patients with cardiomyopathy, heart failure with reduced ejection fraction (HFrEF), sinus venosus ASD requiring surgical closure, and those with insufficient rims deemed unsuitable for transcatheter ASD closure were excluded. Additionally, patients with congenital structural heart defects other than secundum ASD, ischemic heart disease, chronic obstructive pulmonary disease (COPD), or cor pulmonale that could impair performance on the 6-minute walk test (6MWT) were also excluded.

The participants were divided into two equal groups based on age at the time of transcatheter closure: Group 1 included patients aged 18–40 years, and Group 2 included patients older than 40 years.

### Baseline Patient Assessment

At baseline, all patients underwent comprehensive evaluation, including detailed history taking cardiac history with a focus on new symptoms such as dyspnea, palpitations, or fever, indicative of potential complications such as residual defects, atrial fibrillation, or infective endocarditis. A full clinical examination was performed alongside cardiac evaluation.

### Transesophageal Echocardiography (TEE)

TEE was performed pre- and intraoperatively to assess ASD size and rims using three views: four-chamber (0°), short-axis (45°), and bicaval (90–110°). Measurements included the anterior ventricular (AV) and posterior superior rims in the four-chamber view, the aortic and inferior-posterior rims in the short-axis view, and the inferior vena cava (IVC) and superior vena cava (SVC) rims in the bicaval view. Rims were classified as floppy if they moved with blood flow, deficient if less than 5 mm, and absent if less than 1 mm. The presence of multiple ASDs was also documented[11].

### Transcatheter Device Closure of ASD

Closure was performed under echocardiographic and fluoroscopic guidance. After sterilization with betadine and draping, vascular access was achieved via the right femoral vein using a 5–6 Fr short sheath and Seldinger's technique. Intravenous heparin (100 IU/kg) was administered. The ASD was crossed using a multi-purpose catheter guided by TEE, with the catheter advanced to the left upper pulmonary vein. Device selection depended on rim adequacy, with devices 2–3 mm larger than the ASD diameter for sufficient rims or 4 mm larger for floppy or deficient aortic rims.

The deployment involved advancing a guidewire to the upper pulmonary vein, followed by the delivery sheath. The device was positioned and deployed under fluoroscopic and echocardiographic guidance, ensuring one disk in each chamber and proper alignment with the interatrial septum. Stability and absence of residual shunt or encroachment were verified before releasing the device by counter-clockwise rotation of the delivery cable. In cases of uncertain positioning, the device was recaptured and repositioned.

**Pre- and Post-Procedure Investigations**

Resting 12-lead surface ECGs were performed just before the procedure, one day after, and one month later to monitor for arrhythmias and other abnormalities.

Transthoracic Echocardiographic (TTE) was done using a GE VIVED S5 system at the Echocardiography Unit of Ain Shams University Hospital. Device assessment was conducted through multiple views (subcostal, apical 4-chamber, parasternal short axis, and RV inflow) to evaluate its size, shape, location, relation to adjacent structures, and residual shunts via color Doppler. Right ventricular RV dimensions, including basal diameter, systolic function (via fractional area change, FAC), and right atrial area (RAA), were measured, with normal reference values applied. Tricuspid and pulmonary valve regurgitations were evaluated, along with pulmonary artery dimensions, right ventricular systolic pressure (RVSP), and pulmonary arterial pressure (PAP) using Doppler-based calculations. Left ventricular (LV) systolic function was assessed using Simpson's method, while left atrial volume was determined via the area-length method. LV diastolic function was evaluated through E/A ratios and tissue Doppler imaging, measuring mitral annular velocities (e' velocity) and calculating E/e' ratios[12-14].

The 6MWT assessed functional capacity by measuring the distance walked in six minutes. Vital signs were recorded before and after, and participants could pause if needed. The total distance, typically 400–700 meters in healthy adults, reflected exercise tolerance, with higher scores indicating better fitness[15].

Coronary angiography (CA) was performed for patients above 40 years during the procedure. Non-significant lesions have been defined as <50% luminal stenosis, while obstructive coronary artery disease (CAD) is classified based on the ESC 2024 guidelines[16].

**Statistical analysis**

Data analysis was performed using SPSS software (version 23.0, SPSS Inc., Chicago, Illinois, USA). Quantitative data were presented as mean ± standard deviation (SD) and range for parametric distributions, and as median with interquartile range (IQR) for non-parametric distributions, while qualitative variables were summarized as numbers and percentages. Normality was assessed using the Kolmogorov-Smirnov and Shapiro-Wilk tests. Statistical analyses included the independent-samples t-test for comparing two means, the Chi-square test for qualitative data, and Fisher's exact test when any cell's expected count was <5. Statistical significance was defined as $P < 0.05$, with $P < 0.001$ considered highly significant.

## RESULTS

Baseline characteristics of the studied population are shown in (Table 1).

**Table 1:** Demographic data, ECG, coronary anatomy, and procedural details of the studied patients.

| Parameter | Details | Value | Range |
|---|---|---|---|
| Age (years) | Mean ± SD | 36.28 ± 13.43 | 18 – 62 |
| Weight (kg) | Mean ± SD | 78.62 ± 8.10 | 62 – 92 |
| Height (m) | Mean ± SD | 1.74 ± 0.07 | 1.61 – 1.89 |
| BSA ($m^2$) | Mean ± SD | 1.93 ± 0.10 | 1.67 – 2.15 |
| Rt axis deviation | Count (%) | 13 (26.0%) | - |
| P Pulmonal | Count (%) | 14 (28.0%) | - |
| ST depression (V1, V2) | Count (%) | 5 (10.0%) | - |
| T wave inversion (II, avF) | Count (%) | 6 (12.0%) | - |
| ST depression (II, III) | Count (%) | 6 (12.0%) | - |
| Incomplete RBBB | Count (%) | 4 (8.0%) | - |
| RBBB | Count (%) | 2 (4.0%) | - |
| Normal coronaries | Count (%) | 20 (80.0%) | - |
| RCA high take-off | Count (%) | 1 (4.0%) | - |
| LAD mid-segment bridge | Count (%) | 1 (4.0%) | - |
| Anomalous origin of RCA from LCC | Count (%) | 1 (4.0%) | - |
| Atherosclerotic non-significant lesions | Count (%) | 2 (8.0%) | - |
| Secondum ASD | Count (%) | 50 (100.0%) | - |
| Diameter (mm) | Mean ± SD | 11.94 ± 3.37 | 6 – 19 |
| MPAP (mmHg) | Mean ± SD | 30.94 ± 6.20 | 18 – 49 |
| Device waist size (mm) | Mean ± SD | 12.86 ± 3.61 | 7.5 – 21 |
| Device type | | | |
| Amplatzer | Count (%) | 21 (42.0%) | - |
| Lifetech | Count (%) | 23 (46.0%) | - |
| Occluotech | Count (%) | 5 (10.0%) | - |
| Amplatzer & Lifetech | Count (%) | 1 (2.0%) | - |
| Complications | | | |
| No complications | Count (%) | 45 (90.0%) | - |
| Hematoma | Count (%) | 2 (4.0%) | - |
| Effusion | Count (%) | 1 (2.0%) | - |
| Atrial fibrillation | Count (%) | 1 (2.0%) | - |
| Atrial tachycardia | Count (%) | 1 (2.0%) | - |

ASD: Atrial Septal Defect; BSA: Body Surface Area; ECG: Electrocardiogram; HTN: Hypertension; LAD: Left Anterior Descending; LCC: Left Coronary Cusp; MPAP: Mean Pulmonary Artery Pressure; RBBB: Right Bundle Branch Block; RCA: Right Coronary Artery; Rt: Right; SD: Standard Deviation.

Following transcatheter ASD device closure, significant improvements were observed in right-sided heart function, hemodynamics, and exercise capacity. RV end-diastolic volume index ($P < 0.001$), RV diameter ($P < 0.001$), RV fractional area change ($P < 0.001$), and RA volume index ($P < 0.001$) showed a progressive decline post-procedure and at 1-month follow-up. Hemodynamic parameters, including mean pulmonary artery pressure ($P < 0.001$) and right ventricular systolic pressure ($P < 0.001$), significantly decreased. Left ventricular function improved, with an increase in LV end-diastolic volume index ($P < 0.001$), E/A ratio ($P < 0.001$), and E/e' ratio ($P < 0.001$). LVEF also showed a significant rise ($P < 0.001$). Functional capacity, assessed by the 6-minute walk test, improved significantly ($P < 0.001$). Tricuspid regurgitation was not significant ($P = 0.324$). (Table 2)

**Table 2:** Outcomes of transcatheter ASD device closure on right-sided function, dimensions, hemodynamics, and 6-minute walk test performance, comparing pre-procedural parameters to post-procedural and 1-month follow-up results.

| 2D Echocardiography | | Pre | Post | 1 month | *P-value* |
|---|---|---|---|---|---|
| RV end diastolic volume/Index ($mm^3$) | Mean ± SD | 75.20 ± 10.30 | 71.26 ± 9.86 | 68.18 ± 9.98 | <0.001* |
| | Range | 55 – 95 | 51 – 90 | 50 – 87 | |
| RV diameter (mm) | Mean ± SD | 41.52 ± 2.00 | 39.16 ± 1.49 | 35.14 ± 1.43 | <0.001* |
| | Range | 38 – 46 | 37 – 43 | 33 – 38 | |
| RV FAC | Mean ± SD | 41.04 ± 3.38 | 40.13 ± 3.46 | 40.14 ± 3.40 | <0.001* |
| | Range | 35 – 50.1 | 34.2 – 49.3 | 34.8 – 49.1 | |
| RA volume/index ($mm^3$) | Mean ± SD | 32.42 ± 1.06 | 31.18 ± 1.02 | 29.98 ± 0.84 | <0.001* |
| | Range | 30.9 – 34.7 | 29.5 – 33.8 | 28.2 – 33 | |
| TR | Trivial | 15 (30.0%) | 17 (34.0%) | 23 (46.0%) | 0.324 |
| | Mild | 18 (36.0%) | 20 (40.0%) | 22 (44.0%) | |
| | Moderate | 12 (24.0%) | 10 (20.0%) | 5 (10.0%) | |
| | Severe | 5 (10.0%) | 3 (6.0%) | 0(0.00%) | |
| MPAP (mmhg) | Mean ± SD | 28.82 ± 6.43 | 24.70 ± 5.86 | 23.86 ± 5.90 | <0.001* |
| | Range | 15 – 45 | 14 – 41 | 13 – 40 | |
| RVSP (mmhg) | Mean ± SD | 49.22 ± 4.85 | 40.84 ± 4.82 | 35.14 ± 4.77 | <0.001* |
| | Range | 40 – 57 | 32 – 50 | 27 – 47 | |
| Tissue Doppler | | | | | |
| LVED volume ($mm^3$) | Mean ± SD | 64.40 ± 6.49 | 72.10 ± 7.64 | 72.10 ± 7.64 | <0.001* |
| | Range | 56 – 79 | 62 – 85 | 62 – 85 | |
| E/A ratio | Mean ± SD | 1.05 ± 0.27 | 1.32 ± 0.22 | 1.46 ± 0.20 | <0.001* |
| | Range | 0.7 – 1.6 | 0.9 – 1.7 | 1.1 – 1.9 | |
| E/e` ratio | Mean ± SD | 7.84 ± 0.80 | 9.50 ± 0.75 | 9.68 ± 0.70 | <0.001* |
| | Range | 6.4 – 9.1 | 7.8 – 11 | 7.8 – 11.1 | |
| LVEF | Mean ± SD | 58.70 ± 2.41 | 64.02 ± 2.11 | 64.32 ± 1.79 | <0.001* |
| | Range | 55 – 63 | 61 – 67 | 60 – 67 | |
| 6 Minute Walk test (m) | Mean ± SD | 464.38 ± 49.61 | 473.10 ± 46.57 | 488.80 ± 44.39 | <0.001* |
| | Range | 360 – 600 | 370 – 604 | 395 – 630 | |

ASD: Atrial Septal Defect; E/A: Early to Late Diastolic Filling Velocity Ratio; E/e`: Early Diastolic Velocity to Early Diastolic Mitral Annulus Velocity Ratio; FAC: Fractional Area Change; LVEF: Left Ventricular Ejection Fraction; LVED: Left Ventricular End-Diastolic; MPAP: Mean Pulmonary Artery Pressure; RA: Right Atrium; RV: Right Ventricle; RVSP: Right Ventricular Systolic Pressure; SD: Standard Deviation; TR: Tricuspid Regurgitation; *: Significant *p-value* as $p < 0.05$.

A strong negative correlation was found between preprocedural mPAP and preprocedural 6MWTD ($r = -0.798$, $P < 0.001$). Additionally, a moderate positive correlation was observed between the percentage reduction in postprocedural mPAP and the percentage increase in postprocedural 6MWTD ($r = 0.359$, $P = 0.011$). (Figure 1)

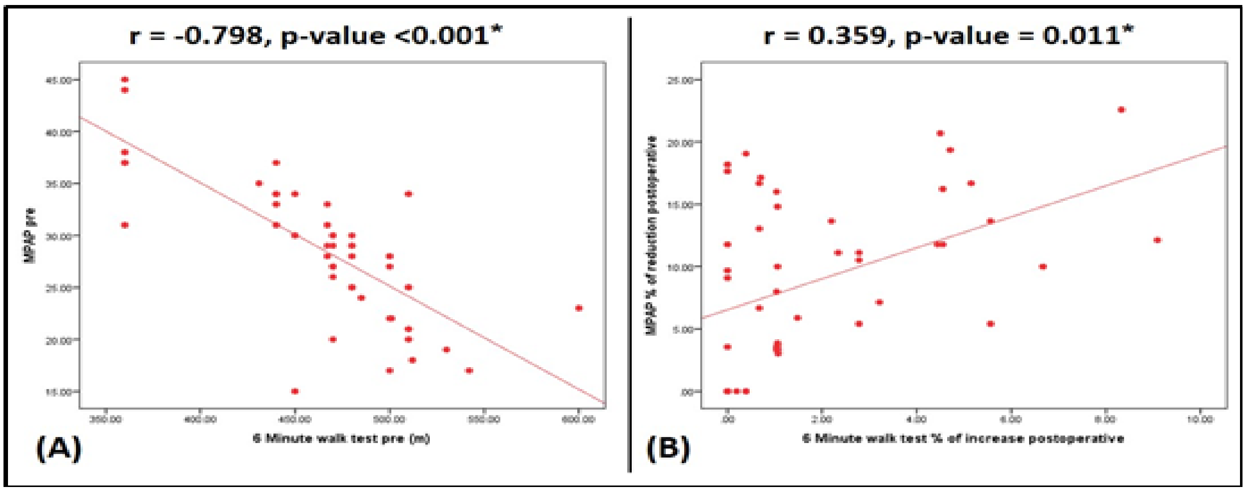


**Fig. 1:** (A) Correlation between preprocedural mPAP and 6MWT pre, (B) Correlation between postprocedural % of reduction of MPAP and postprocedural % of increase of 6MWTD.

Significant correlations were found between patient characteristics and post-procedural outcomes, with weight and age influencing RV diastolic volume, MPAP reduction, and 6-minute walk test improvements, highlighting their role in recovery. (Table 3)

**Table 3:** Correlations between patient characteristics and post procedural outcomes.

| | Age | | Weight (Kg) | | BSA (m²) | |
|---|---|---|---|---|---|---|
| | R | *P-value* | r | *P-value* | r | *P-value* |
| % of change postoperative | | | | | | |
| RV diastolic volume/Index (mm³) | -0.185 | 0.197 | -0.371 | **0.008*** | -0.378 | **0.007*** |
| RV diameter (mm) | -0.216 | 0.132 | -0.010 | 0.946 | -0.185 | 0.199 |
| RV FAC | -0.013 | 0.930 | 0.090 | 0.536 | -0.016 | 0.911 |
| RA volume/index (mm³) | -0.103 | 0.476 | -0.148 | 0.306 | -0.048 | 0.740 |
| LVED volume (mm³) | -0.073 | 0.616 | 0.020 | 0.888 | -0.050 | 0.728 |
| LVEF | 0.172 | 0.233 | -0.078 | 0.588 | -0.015 | 0.919 |
| MPAP % of reduction | 0.434 | **0.002*** | 0.080 | 0.580 | 0.050 | 0.729 |
| E/A ratio | 0.326 | **0.021*** | 0.230 | 0.108 | 0.145 | 0.314 |
| RVSP (mmhg) | -0.230 | 0.107 | -0.140 | 0.330 | -0.251 | 0.078 |
| 6 Minute Walk test % of increase | 0.329 | **0.020*** | -0.184 | 0.200 | -0.181 | 0.208 |
| % of change after 1 month | | | | | | |
| RV diastolic volume/Index (mm³) | -0.085 | 0.555 | -0.209 | 0.145 | -0.283 | **0.047*** |
| RV diameter (mm) | -0.136 | 0.347 | -0.093 | 0.521 | -0.276 | 0.053 |
| RV FAC | 0.105 | 0.467 | -0.077 | 0.597 | -0.175 | 0.223 |
| RA volume/index (mm³) | -0.072 | 0.617 | -0.058 | 0.688 | -0.109 | 0.453 |
| LVED volume (mm³) | -0.086 | 0.554 | 0.011 | 0.938 | -0.059 | 0.686 |
| LVEF | 0.230 | 0.108 | -0.109 | 0.451 | 0.047 | 0.747 |
| MPAP % of reduction | 0.398 | **0.004*** | 0.060 | 0.681 | -0.054 | 0.711 |
| E/A ratio | 0.278 | 0.051 | 0.275 | 0.053 | 0.247 | 0.083 |
| RVSP (mmhg) | -0.176 | 0.222 | -0.149 | 0.302 | -0.230 | 0.108 |
| 6 Minute walk test % of increase | 0.411 | **0.003*** | 0.055 | 0.703 | 0.027 | 0.851 |

BSA: Body Surface Area; E/A: Early to Late Diastolic Filling Velocity Ratio; FAC: Fractional Area Change; LVED: Left Ventricular End-Diastolic; LVEF: Left Ventricular Ejection Fraction; MPAP: Mean Pulmonary Artery Pressure; RA: Right Atrium; RV: Right Ventricle; RVSP: Right Ventricular Systolic Pressure; *: Significant *p-value* as $p < 0.05$.

Older patients (>40 years) exhibited significantly greater improvements in hemodynamic and functional parameters post-procedure and at 1-month follow-up. The percentage reduction in MPAP was significantly higher in the >40 years group both postoperatively (11.76% [7.14–16.67] vs. 3.45% [3.03–11.11], $P = 0.001$) and at

1 month (14.81% [8.82–20.59] vs. 6.9% [6.06–13.04], *P* = 0.006). Additionally, the E/A ratio showed a significantly greater percentage increase in the >40 years group postoperatively (28.57% [22.22–44.44] vs. 18.18% [8.33–21.43], *P* = 0.001) and at 1 month (55.56% [33.33–71.43] vs. 33.33% [21.43–40], *P* = 0.004). Functional capacity, assessed by the percentage increase in the 6-minute walk test, was also significantly greater in the >40 years group at 1 month (6.67% [5.54–9.21] vs. 3.52% [2–6.38], *P* = 0.008). Other parameters were not significant ($p > 0.05$). (Table 4)

**Table 4:** Relation of age groups with percentage of change in hemodynamics and function capacity postoperative and at 1 month follow up.

| | | Age | | *P-value* |
|---|---|---|---|---|
| | | (18 – 40 yrs) | >40 yrs | |
| | | *n* = 25 | *n* = 25 | |
| % of change postoperative | | | | |
| RV diastolic volume/Index (mm$^3$) | Median (IQR) | -4.48 (-6.17 – -3.28) | -5.38 (-6.17 – -4.44) | 0.184 |
| | Range | -11.11 – -1.54 | -10.67 – -2.3 | |
| RV diameter (mm) | Median (IQR) | -5 (-6.98 – -4.76) | -5.13 (-7.32 – -4.76) | 0.397 |
| | Range | -9.76 – 0 | -9.09 – 0 | |
| RV FAC | Median (IQR) | -2.22 (-2.78 – -1.53) | -2.17 (-2.59 – -1.78) | 0.778 |
| | Range | -3.95 – -0.64 | -4.02 – -0.71 | |
| RA volume/index (mm$^3$) | Median (IQR) | -3.23 (-4.13 – -2.5) | -4.13 (-6.34 – -3.09) | 0.177 |
| | Range | -7.6 – 2.27 | -7.65 – 3.17 | |
| LVED volume (mm$^3$) | Median (IQR) | 10.34 (7.81 – 14.93) | 10.71 (2.86 – 17.65) | 0.614 |
| | Range | -4.17 – 31.75 | -13.7 – 51.79 | |
| LVEF | Median (IQR) | 8.93 (5.08 – 10.17) | 9.84 (8.33 – 12.07) | 0.459 |
| | Range | -1.59 – 15.79 | -1.59 – 16.36 | |
| MPAP % of reduction | Median (IQR) | 3.45 (3.03 – 11.11) | 11.76 (7.14 – 16.67) | 0.001* |
| | Range | 0 – 18.18 | 0 – 22.58 | |
| E/A ratio | Median (IQR) | 18.18 (8.33 – 21.43) | 28.57 (22.22 – 44.44) | 0.001* |
| | Range | 6.67 – 71.43 | 6.25 – 85.71 | |
| RVSP (mmhg) | Median (IQR) | 20.88 (13.04 – 30.67) | 17.28 (11.9 – 21.74) | 0.140 |
| | Range | 10.34 – 54.55 | 10.34 – 54.55 | |
| 6 Minute walk test % of increase | Median (IQR) | 1.04 (0.19 – 1.07) | 1.06 (0.67 – 4.44) | 0.105 |
| | Range | 0 – 6.67 | 0 – 9.09 | |
| % of change after 1 month | | | | |
| RV diastolic volume/Index (mm$^3$) | Median (IQR) | -9.09 (-10.45 – -6.78) | -9.46 (-10.84 – -7.32) | 0.946 |
| | Range | -23.53 – -3.08 | -16.22 – -3.45 | |
| RV diameter (mm) | Median (IQR) | -14.29 (-17.07 – -12.5) | -14.63 (-19.51 – -11.63) | 0.892 |
| | Range | -22.22 – -7.32 | -26.67 – -7.32 | |
| RV FAC | Median (IQR) | -2.11 (-2.61 – -1.79) | -1.96 (-2.9 – -1.43) | 0.362 |
| | Range | -4.02 – -0.57 | -4.02 – -0.91 | |
| RA volume/index (mm$^3$) | Median (IQR) | -7.03 (-8.79 – -5.71) | -8.04 (-9.03 – -5.94) | 0.786 |
| | Range | -11.76 – -4.32 | -11.64 – -3.23 | |
| LVED volume (mm$^3$) | Median (IQR) | 10.34 (8.57 – 14.93) | 10.71 (2.86 – 17.65) | 0.547 |
| | Range | -4.17 – 34.92 | -13.7 – 51.79 | |
| LVEF | Median (IQR) | 8.47 (6.56 – 12.5) | 10.17 (6.67 – 12.5) | 0.527 |
| | Range | 3.17 – 14.04 | 3.17 – 18.18 | |
| MPAP % of reduction | Median (IQR) | 6.9 (6.06 – 13.04) | 14.81 (8.82 – 20.59) | 0.006* |
| | Range | 3.57 – 27.27 | 2.94 – 28.57 | |

| | | | | |
|---|---|---|---|---|
| E/A ratio | Median (IQR) | 33.33 (21.43 – 40) | 55.56 (33.33 – 71.43) | 0.004 |
| | Range | -6.67 – 87.5 | 6.25 – 128.57 | |
| RVSP (mmhg) | Median (IQR) | 21.98 (16.09 – 33.33) | 19.44 (16.05 – 22.97) | 0.303 |
| | Range | 12.94 – 56.25 | 12.94 – 56.25 | |
| 6 Minute walk test % of increase | Median (IQR) | 3.52 (2 – 6.38) | 6.67 (5.54 – 9.21) | 0.008* |
| | Range | 1.7 – 9.72 | 1.96 – 13.89 | |

E/A: Early to Late Diastolic Filling Velocity Ratio, FAC: Fractional Area Change, IQR: Interquartile Range, LVED: Left Ventricular End-Diastolic, LVEF: Left Ventricular Ejection Fraction, MPAP: Mean Pulmonary Artery Pressure, RA: Right Atrium, RV: Right Ventricle, RVSP: Right Ventricular Systolic Pressure, *: Significant *p-value*.

## DISCUSSION

ASD is a common adult congenital heart disease (ACHD) that, if untreated, increases the risk of atrial fibrillation, stroke, heart failure, and pulmonary hypertension. Often underdiagnosed due to mild symptoms, it is usually detected incidentally or later in life[17]. Early diagnosis and closure improve life expectancy, cardiac function, and exercise capacity while reducing complications. Though echocardiography is accurate, its labor-intensive nature limits widespread screening[18]. Advances in minimally invasive percutaneous closure, introduced in 1974, have made it the preferred treatment due to shorter recovery times and reduced invasiveness. Untreated ASD leads to worse outcomes in functional capacity, arrhythmias, heart failure, and survival[14].

Our study included 50 patients aged 18 to 62 years, with a majority being females. The mean body weight was 78.62 ± 8.10 kg, height 1.74 ± 0.07 meters, and BSA 1.93 ± 0.10 m². These findings align with the CONCOR national registry for adults with congenital heart disease, which identified 1267 patients with ASD, 62% of whom were females, out of 7414 patients[19].

Various ECG changes were observed, including right bundle branch block (RBBB) in 4% of patients, incomplete RBBB in 8%, ST segment depression in leads II, III in 12%, T wave inversion in leads II and aVF in 12%, ST segment depression in leads V1, V2 in 10%, P pulmonale in 28%, and right axis deviation in 26%. ***Nermin Bayar et al.***[20] emphasized the diagnostic importance of ECG findings in ASD, studying 61 ASD patients and 66 controls. They reported a higher prevalence of incomplete RBBB (56% vs. 5%), defective T wave (48% vs. 3%), and R wave crochetage in inferior leads (57% vs. 8%) among ASD patients, with specificities of 95%, 97%, and 92%, respectively, for these findings.

Preprocedural CA was performed for all patients aged ≥40 years, revealing normal coronaries in 80%, atherosclerotic vessels with non-significant obstruction in 8%, myocardial bridging in the LAD mid-segment in 4%, RCA high take-off in 4%, and anomalous RCA origin from the left coronary cusp in 4%. These findings align with a study by ***Christopher Olesovsky et al.***[21], which included 398 ASD closure patients, 300 of whom underwent CA. Mild CAD was found in 11%, moderate in 7.7%, and severe in 8.3%, with subsequent interventions or management changes in select cases. The study concluded that routine CA during ASD closure should target patients with higher cardiovascular risk profiles.

Our results revealed a significant reduction in RV and RA volumes following the procedure, as indicated by decreases in RV end-diastolic volume, RV basal diameter, and RA volume index (RAVi). These reductions were observed both immediately after the procedure and at the one-month follow-up, demonstrating the procedure's effectiveness in improving right heart remodeling with highly significant outcomes ($P < 0.001$).

Our investigations indicated a significant improvement in RV function and pulmonary pressures following percutaneous ASD closure. RV systolic function, assessed by FAC, showed a slight but significant reduction ($P < 0.001$). RVSP and mPAP both decreased significantly post-procedure and at one-month follow-up ($P < 0.0001$). Tricuspid regurgitation also improved, with severe cases eliminated and moderate cases reduced from 24% to 10%, though changes in mild and trivial regurgitation were not statistically significant ($P = 0.324$). These findings are consistent with those of ***Bosshard et al.***[22], who reported significant reductions in RV and RA dimensions within 24 hours and further improvements at follow-up ($P < 0.001$), and ***Schoen et al.***[23], whose MRI-based study demonstrated decreases in RV volumes, mass, and pressures after transcatheter ASD closure ($P < 0.001$).

A reduction in post-procedural RV systolic function, assessed by FAC and tricuspid annular plane systolic excursion (TAPSE), was observed, consistent with findings ***Akula et al.***[24] who attributed the decrease in TAPSE to reduced preload after ASD closure, as the high preload prior to closure leads to elevated values for load-dependent parameters like TAPSE. Post-procedural reductions in these parameters likely reflect the normalization of RV geometry rather than a true loss of RV function.

Our study demonstrated a significant improvement in functional capacity, as assessed by 6MWTD, following transcatheter ASD device closure. The 6MWTD increased at the 1-month follow-up ($P < 0.001$). These findings align with those of ***Brochu et al.***[25], who observed a significant increase in maximal oxygen uptake (Vo2max) after ASD closure, from 23.5 ± 6.4 to 26.9 ± 6.9 mL/kg per minute ($P < 0.0001$), with marked improvem ents across all subgroups, including asymptomatic patients, those with smaller shunts, and older adults (all $P < 0.0001$). Additionally, 35 of 37 patients improved to NYHA class I at 6 months post-closure, with significant reductions in right ventricular dimensions ($P < 0.0001$). These results highlight the benefits of ASD closure even in asymptomatic adults.

Our study revealed a highly significant increase in LV dimensions following ASD closure, with LVED increasing at one month ($P < 0.001$). LVEF also improved significantly at one month ($P < 0.001$). Additionally, the trans-mitral valve inflow E/A ratio increased ($P < 0.001$), and the E/e` ratio rose ($P < 0.001$), indicating increased left atrial pressure post-closure. These findings align with ***Kumar et al.***[26], who reported significant improvements in LV end-diastolic diameter ($P = 0.04$), LVEF ($P = 0.0001$), and LV myocardial performance index ($P < 0.0001$) at six months post-ASD correction in a cohort study of 32 patients.

Our study demonstrated a negative correlation between patient age and the percentage improvement in functional capacity, as assessed by 6MWTD, following ASD closure. Younger patients (Group 1: 18–40 years) showed significantly greater improvement in Δ6MWTD compared to older patients (Group 2: >40 years) ($P = 0.008$). These findings align with ***Ghosh et al.***[27], who reported that surgical ASD closure improved NYHA functional class more effectively in younger patients, with 86.2% of Group I (35–50 years) achieving NYHA class I–II postoperatively, compared to 71.5% of Group II (>50 years) ($P < 0.05$). They concluded that younger patients experience greater clinical benefit and prevention of right ventricular dilatation after ASD closure.

Our study identified a negative correlation between pre-procedural mPAP and functional capacity, as assessed by 6MWTD ($P < 0.05$). These findings align with the study by ***Supomo et al.***[28], which analyzed pulmonary hemodynamic profiles in 46 ASD patients. They observed significantly lower 6MWTD in patients with pulmonary hypertension (PH) compared to those without PH ($P = 0.0119$). A cut-off value of mPAP >24 mmHg was associated with abnormal functional capacity ($P = 0.0243$; AUC = 0.681), and pulmonary vascular resistance (PVR) >3.42 WU showed high specificity for predicting reduced functional capacity ($P = 0.0069$; AUC = 0.713).

Our study showed a significant difference in the improvement of functional capacity, assessed by 6MWTD, between Group 1 and Group 2 ($P = 0.008$). These findings align with the study by ***Marie-Claude Brochu et al.***[25], which also reported significant functional improvements after ASD closure, highlighting the greater benefits observed in younger patients.

Despite our notable findings, the study has several limitations. As a single-center study, its generalizability is limited, and future multicenter studies with larger sample sizes are needed. The study focused on early and intermediate procedural outcomes, leaving long-term effectiveness unexplored. Lastly, the absence of cardiac magnetic resonance imaging (CMR), the gold standard for RV assessment, limits the precision of our RV evaluation.

## CONCLUSION

Transcatheter ASD closure significantly improves cardiac function and functional capacity in adults with secundum ASD. The procedure reduces right ventricular and atrial volumes, enhances left ventricular function, and improves pulmonary hemodynamics and exercise tolerance, with younger patients benefiting more.

## CONFLICT OF INTERESTS

There is no conflicts of interest.

## DECLARATION OF CONFLICTING INTERESTS

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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## CONTRIBUTION

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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# النتائج الفورية وعلى المدى القصير لإغلاق عيب الحاجز الأذيني بالجهاز عبر القسطرة في البالغين


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**المقدمة:** يُعدّ عيب الحاجز الأذيني من أكثر أمراض القلب الخلقية شيوعًا، وغالبًا ما يبقى غير مُشخَّص حتى مرحلة البلوغ، مما قد يؤدي إلى مضاعفات مثل فرط ضغط الدم الرئوي، واضطرابات النظم، وضعف وظيفة البطين الأيمن. يُعتبر إغلاق العيب عبر القسطرة إجراءً طفيف التوغل يوفر خيارًا علاجيًا فعالًا.

**هدف الدراسة:** تقييم النتائج الفورية وعلى المدى القصير لإغلاق عيب الحاجز الأذيني عبر القسطرة على وظائف القلب والسعة الوظيفية لدى البالغين.

**الطرق:** شملت هذه الدراسة المستقبلية ٥٠ مريضًا بالغًا خضعوا لإغلاق عيب الحاجز الأذيني عبر القسطرة. تم تقسيم المرضى إلى مجموعتين وفقًا للعمر عند الإجراء: المجموعة الأولى (١٨–٤٠ عامًا) والمجموعة الثانية (< ٤٠ عامًا). تضمنت التقييمات الشاملة قبل وبعد الإجراء تخطيط صدى القلب، واختبار المشي لمدة ٦ دقائق، وتصوير الأوعية التاجية.

**النتائج:** لوحظت انخفاضات ملحوظة في حجم نهاية الانبساط للبطين الأيمن (من ٧٥.٢٠ ± ١٠.٣٠ إلى ٦٨.١٨ ± ٩.٩٨ مم$^3$، وضغط البطين الأيمن الانقباضي (من ٤٩.٢٢ ± ٤.٨٥ إلى ٣٥.١٤ ± ٤.٧٧ مم زئبقي، P<0.001) ومتوسط ضغط الشريان الرئوي (من ٢٨.٨٢ ± ٦.٤٣ إلى ٢٣.٨٦ ± ٥.٩٠ مم زئبقي،P<0.001 ) بعد شهر من الإجراء. كما تحسنت الكسر القذفي للبطين الأيسر بشكل ملحوظ P< 0.001 ، وزادت المسافة المقطوعة في اختبار المشي لمدة ٦ دقائق (من ٤٦٤.٣٨ ± ٤٩.٦١ إلى ٤٨٨.٨٠ ± ٤٤.٣٩ مترًا،P< 0.001). أظهرت الفئة العمرية الأصغر تحسنًا أكبر في السعة الوظيفية (P=0.008)، وكان هناك ارتباط عكسي بين متوسط ضغط الشريان الرئوي قبل الإجراء وأداء اختبار المشي (P< 0.05).

**الاستنتاجات:** يؤدي إغلاق عيب الحاجز الأذيني عبر القسطرة إلى تحسن ملحوظ في إعادة تشكيل القلب، والهيموديناميكا الرئوية، والسعة الوظيفية، مع استفادة أكبر لدى المرضى الأصغر سنًا.