Original Article

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Immediate and Short-Term Variations in the Echocardiographic Cardiac Hemodynamic Parameters after the Transcatheter Atrial Septal Defect Device Closure and its Procedural Success

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Abstract

Background and Aims: Transcatheter closure of the secundum atrial septal defect (ASD) has become an accepted alternative to surgical repair. We aimed to analyze and compare the changes in cardiac hemodynamics with transthoracic echocardiography (TTE) before, within 48 hours, and after 3 months of ASD closure.

Methods: This was a prospective, single-centered study of 43 patients who underwent ASD device closure in the Manmohan Cardiothoracic Vascular and Transplant Center during June 2020 to June 2021 with Amplatzer Septal Occluder under transesophageal and fluoroscopic guidance. The patients were evaluated with TTE before, at 48 hours, and 3 months after the procedure.

Results: At 48 hours and 3 months of device closure, the right atrial major dimension, the maximum blood flow velocity at the pulmonary valve orifice, mean flow velocity, velocity time integral, and E peak and A peak blood flow velocity at the tricuspid valve orifice were significantly reduced ($P < 0.001$). At 3 months, the dimensions and ejection fraction of the left ventricle showed significant increment ($P < 0.001$). Likewise, the right atrial minor dimension and area, right ventricular basal, mid, and longitudinal dimensions, tricuspid annular plane systolic excursion, right ventricular Tei Index, and fractional area change were significantly reduced ($P < 0.001$). The main pulmonary artery diameter, pulmonary artery systolic and mean pressure, and the pulmonary vascular resistance and index were significantly reduced ($p <0.001$). The procedural success rate was 97.6%.

Conclusions: Echocardiographic evaluation demonstrated that cardiac hemodynamics and loading conditions improved significantly at 3 months after percutaneous closure of ASD. The transcatheter closure of ASD was safe with good short-term outcomes.

Keywords: Atrial septal defect, Transcatheter closure, Amplatzer septal occluder

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Introduction

Atrial septal defect (ASD) is the second most common congenital heart disease in adults, accounting for approximately 8 to 10% of all congenital heart lesions[1]. An isolated, asymptomatic, and small sized ASD does not require treatment. The moderate to large sized ASD with right ventricular volume overload and increased pulmonary blood flow without significant pulmonary hypertension should be closed. The closure is considered necessary to prevent the development of pulmonary vascular disease and atrial arrhythmias[2].

The surgical approach was once considered the standard of care for the ostium secundum ASD. However, over the past 15 years, closure of ostium secundum ASD has made its motion from a surgical approach to a percutaneous transcatheter based approach[3]. Since its inception in 1976 by Mills and King[4], the transcatheter closure of ASD with Amplatzer septal occluder has become an accepted alternative to surgical repair[5]. The results of transcatheter closure of ostium secundum ASD have shown significant improvement in the cardiac dimensions and functions, the right ventricular systolic pressure, the blood flow velocities across the pulmonary and tricuspid valves, and the pulmonary artery systolic pressure[6].

It is not uncommon to find a patient with ASD-secundum in our premises who warrants a closure of the defect. Needless to say, a study of this sort emphasizing the detailed comparison of the hemodynamic parameters before and after ASD device closure is scarce in our Center. We thus aimed to analyze and compare the changes in cardiac hemodynamics before and after ASD device closure and its procedural success rate.

Methods

This was a single-centered, prospective observational study. A total of 43 ASD secundum patients aged more than 18 years who visited the out-patient room and the emergency department of the Manmohan Cardiothoracic Vascular and Transplant Center (MCVTC), Institute of Medicine (IOM), Nepal, during June 2020 to June 2021 and who had clinical indications for ASD device closure formed the core of the study population. The patients with ASD other than secundum variety and Eisenmenger syndrome were excluded. A proforma was designed to collect the transthoracic echocardiographic information with GE7 vivid and Philips iE33 echo machines about the left and right heart dimensions and functions, pulmonary and tricuspid valve blood flow velocities, main pulmonary artery diameter, and pulmonary artery systolic and mean pressures before, at 48 hours, and 3 months after ASD device closure. The pulmonary vascular resistance [PVR = 10(TR velocity/RVOT vti) + 0.16 Wood Units)] and index (PVRI = PVR x BSA) were calculated at baseline and 3 months after procedure. In order to have the final confirmation regarding suitability for the ASD device closure, a Transesophageal Echocardiography (TEE) was performed in the catheterization lab to further accurately assess the ASD defect size and the sizes of different rims. All echocardiographic measurements were performed by a team of an experienced cardiologists of the center according to the recent American Society of Echocardiography guidelines. The Amplatzer Septal Occluder (ASO) device size was selected in such a way that the device size to TEE ASD size ratio was approximately 1.5. Finally, percutaneous closure of ASD was performed via right femoral vein under general anesthesia with a TEE (GE7 vivid), and fluoroscopic guidance. The research proposal was approved by the Institutional Review Board (IRB) of the Tribhuvan University Institute of Medicine, Kathmandu, Nepal. Statistical analysis was performed using SPSS version 20.0 (SPSS, Chicago, IL, USA). Continuous variables were expressed as mean ± standard deviation and categorical variables were expressed as number (percentage). Standard descriptive statistics was used to describe the variables. Variables for the patients at different time frames (such as at baseline, 48 hours, and 3 months) were compared using McNemar's test or paired t-test as appropriate. Pearson's correlation analysis was performed to find association between continuous variables. A p-value of <0.05 was considered statistically significant.

Results

The mean age of the patients (n=43, 13 males and 30 females) was 31.2 ± 10.2 years and the range extended from 18 years to 50 years. The female-to-male ratio was 2.3:1. The mean height and weight of the patients were 163.2 ± 3.1 cm and 48.9 ± 3.7 kg, respectively with a mean Body Surface Area (BSA) of 1.49 ± 0.06 m2. Exertional dyspnea was the commonest presentation (65.1%). Most of the study patients (93%) were in sinus rhythm. Only 3 patients (7%) had baseline atrial fibrillation with a well-controlled rate.

The increment in the mean left ventricular (LV) diastolic and systolic dimensions and ejection fraction (EF) was not statistically significant at 48 hours after ASD device closure but the increment was statistically significant at 3 months post closure. This is shown in the Table 1 below.

Table 1: LV size and function before and after ASD device closure

LV size parameters	Before closure			P-value
LVIDd (mm)	39.6 ± 2.4	Within 48h	39.9 ± 2.4	0.23
		After 3 months	45.6 ±2.4	<0.001
LVISd (mm)	26.3 ± 1.9	Within 48h	26.4 ± 1.9	0.76
		After 3 months	28.1 ± 2.0	<0.001
LVEF (%)	55.8 ± 4.5	Within 48h	56.6 ± 4.4	0.12
		After 3 months	61.8 ± 3.9	<0.001

At 48 hours after ASD device closure, the RA major dimension showed a statistical significant decrement (p <0.001) but the RA minor dimensions and RA area had only slightly decreased and the differences were not statistically significant (p > 0.05). At 3 months after procedure, the RA major and minor dimensions and RA area were significantly reduced (p < 0.001). Similarly, a statistically insignificant decrement was found in the RV basal, mid, and longitudinal dimensions at 48 hours but the decrement was significant at 3 months after the procedure. This is shown in the Table 2 below.

Table 2: RA and RV dimensions before and after ASD device closure

RA size parameters	Before closure			P value
Major dimension	59.1 ± 4.6	Within 48h	55.5 ± 4.6	<0.001
		After 3 months	41.7 ±4.8	<0.001
Minor dimension	52.8 ±3.7	Within 48h	52.0 ± 3.8	0.21
		After 3 months	34.2 ± 4.2	<0.001
RA area (cm^2)	25.2 ±2.1	Within 48h	24.6 ± 2.0	0.11
		After 3 months	17.2 ± 2.2	<0.001
RV size parameters	Before closure			P value
Basal diameter	47.4 ± 4.2	Within 48h	46.5 ± 4.3	0.09
		After 3 months	37.6 ± 4.6	<0.001
Mid-cavity diameter	39.1 ± 3.6	Within 48h	37.9 ± 3.7	0.07
		After 3 months	31.3 ± 3.9	<0.001
Longitudinal diameter	80.7 ±4.7	Within 48h	79.4 ± 4.9	0.18
		After 3 months	70.3 ± 4.9	<0.001

The RV function indices like tricuspid annular plane systolic excursion (TAPSE), systolic annulus velocity of the lateral tricuspid annulus (S'), RV pulsed doppler Myocardial Performance Index (MPI) or Tei index, and RV fractional area change also didn't decrease significantly at 48 hours (P > 0.05) but there was a significant decrement in all indices at 3 months after ASD closure. (P < 0.001). This is shown in Table 3 below.

Table 3 RV function before and after ASD device closure

RV function	Before closure			P value
TAPSE (mm)	23.2 ± 2.1	Within 48h After 3 months	22.5 ± 2.1 19.6 ± 2.1	0.10 <0.001
S' (cm/sec)	14.5 ± 1.7	Within 48h After 3 months	13.9 ± 1.8 10.7 ± 1.9	0.13 <0.001
PWD MPI (Tei Index)	0.47 ± 0.04	Within 48h After 3 months	0.46 ± 0.04 0.41 ± 0.05	0.10 <0.001
RV FAC (%)	47.2 ± 1.9	Within 48h After 3 months	47.0 ± 2.0 38.6 ± 3.0	0.19 <0.001

Unlike other parameters, the decrement in the tricuspid and pulmonary valve blood flow parameters was distinct. There was a significant reduction in the maximum (Vmax) and mean (Vmean) velocities and the velocity time integral (VTI) at pulmonary valve along with the diastolic E peak and A peak blood flow velocities at the tricuspid valve at 48 hours and 3 months after ASD device closure. This is shown in the table 4 below.

Table 4 Pulmonary and Tricuspid valve blood flow parameters before and after ASD device closure

Pulmonary valve blood flow	**Before closure**			**P-value**
Vmax (cm/sec)	141.8 ± 15.0	Within 48h After 3 months	102.9 ± 17.7 95.6 ± 17.9	<0.001 <0.001
Vmean (cm/sec)	101.6 ±12.4	Within 48h After 3 months	78.1 ± 12.6 62.1 ± 14.0	<0.001 <0.001
VTI (cm)	33.8 ± 4.3	Within 48h After 3 months	25.5 ± 4.4 22.9 ± 4.4	<0.001 <0.001
Tricuspid valve blood flow	**Before closure**			**P value**
E peak (cm/sec)	92.9 ± 8.3	Within 48h After 3 months	66.4 ±9.9 60.5 ± 10.1	<0.001 <0.001
A peak (cm/sec)	65.4 ± 8.2	Within 48h After 3 months	48.7 ± 10.2 40.6 ± 9.9	<0.001 <0.001

The baseline diameter of the main pulmonary artery was 26.0 ± 2.3 mm which decreased to 25.9 ± 2.3 (P = 0.32) at 48 hours and to 21.7 ± 2.2 mm at 3 months post closure (P < 0.001). All the subject cohorts had moderate pulmonary hypertension before closure (PASP/mPAP: 55.6 ± 5.5/35.8 ± 3.5mmHg) that had significantly decreased only after 3 months post procedure (PASP/mPAP: 37.4 ± 5.1/24.8 ± 3.1mmHg) (P < 0.001). Likewise, the PVR and PVRI before closure was 3.3 ± 0.1 Wood Units (WU) and 4.9 ± 0.2WUm2 respectively that decreased to 1.3 ± 0.1 Wood Units (WU) and 1.9 ± 0.2 WUm2 at 3 months after ASD device closure. Figure 1 below shows the changes in pulmonary pressure.

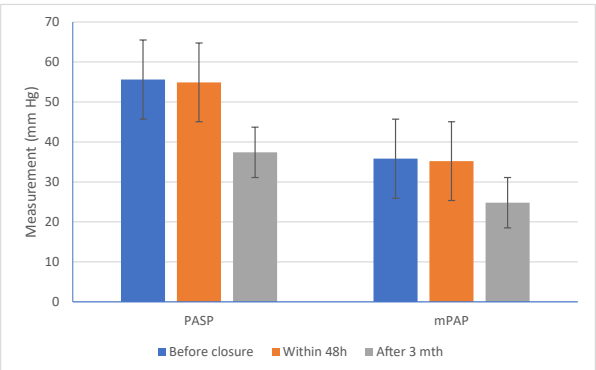

Figure 1 PASP and mPAP before and after ASD device closure

The median pulmonary to systemic flow (Qp/Qs) ratio was 2.5 and the range extended from 1.6 to 3.2. The mean ASD sizes as measured by TTE and TEE were 19.44 ± 6.04 mm and 19.84 ± 6.09 mm respectively and the measurements of ASD size by TTE and TEE showed an excellent correlation (Pearson's r = 0.974, P < 0.001) as shown in the figure 2 below. The mean device size was 29.5 +/- 7.8 mm. The median device size to TEE ASD defect ratio was 1.53 (1.21 – 1.82). None of the subject patients had a floppy ASD rim. All ASD rims were adequate in the majority of patients. Only 19 patients (44.2%) had deficient aortic rim.

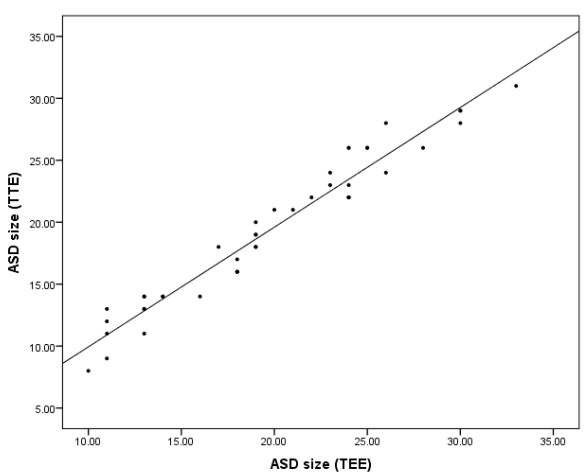

Figure 2 Scatterplot demonstrating correlation between ASD size measurement by TTE and TEE

The mean procedure time for ASD device closure was 52.4 ± 5.8 minutes. The mean fluoroscopy time was 6.5 ± 2.5 minutes. A successful closure of secundum ASD was achieved in 97.6%. The median duration of hospital stay was 3 (2 – 4) days.

Only two patients (4.7%) developed complication after ASD device closure. One case was of device embolization to the right pulmonary artery (RPA) in a 42-year-old female who was managed with surgical excision of the device followed by surgical closure of the defect in the same center. The other case was of a 23-year-old female who developed right Femoro-Femoral AV fistula (AVF) who was managed with right AVF takedown with interposition graft of superficial femoral artery with a PTFE graft in the same center.

There was no evidence of other complications like- thrombus and vegetation formation in and around the implanted device, cardiac perforation, pericardial effusion or cardiac tamponade, heart block or tachyarrhythmias, retroperitoneal hematoma, and death in any of the subject patients. Also, none of the patient's had echocardiographic evidence of residual leak from the ASD device site at 48 hours and at 3 months after the device closure.

Discussion

Transcatheter device closure is recommended as the method of choice for secundum ASD when technically suitable[7]. The transcatheter approach avoids cardiopulmonary bypass, results in a shorter hospital stay, reduces the need for blood products, lessens patient discomfort, produces similar clinical outcomes compared with surgery, and decreases the overall cost[8].

Our study revealed that the cardiac hemodynamics and loading conditions significantly improved at 3 months after ASD device closure. A few parameters like RA major dimension, pulmonary and tricuspid valve blood flow velocities showed an immediate significant decrement. A study conducted by Chen et al[9] also showed that increment of LV dimensions was statistically non-significant at 1 week after the procedure but it was statistically significant after 3 months of procedure. A study conducted by Veldtman et al[10] too showed that the mean RA dimension didn't decrease significantly at 1 month after device closure ($p = 0.081$) but it had decreased significantly following 6 months after device closure ($p < 0.001$) - a finding somewhat consistent with the results of our study. It is possible that the ASO may influence RA geometry by stiffening the inter-atrial septum, and this change may be reflected by a persistent increase in RA minor diameter and RA area. Similarly, a study done by Schussler et al[11] showed that the reduction of RV size occurred immediately after ASD closure but statistically significant reduction occurred only within the following 3 to 6 months of ASD device closure – findings that exactly agree with the findings of our study. The reduction in right heart size is secondary to removal of left-to-right shunt and reduction of preload. The decrease of RV dimensions positively correlates to both LV dimensions and LV ejection fraction improvement[12]. Our observations eventually suggested that the right ventricular volume load reduces gradually after the device closure.

The supra-normal right ventricular function before intervention in ASD patients most probably reflects right ventricular volume loading. The RV function indices decreased significantly ($p < 0.001$) at 3 months after device closure although they had remained within the normal range during the entire study period. A study done by Akula et al[13] also reported that the TAPSE, S', and RV-FAC decreased significantly only after 1 month of device closure.

Our findings are somewhat comparable to the earlier similar study conducted by Chen et al wherein he reported significant decrease in the pulmonary and tricuspid blood flow velocities at 1 week after the procedure[9]. The left-to-right shunt would immediately disappear after device closure of ASD that would eventually lead to decrease in the blood flow velocities at tricuspid and pulmonary valve orifices, respectively.

Our study depicted that the baseline moderate pulmonary hypertension did not reduce significantly at 48 hours but did reduce significantly at 3 months after the procedure. In a study conducted by Yalonetsky et al[14], it was shown that a significant reduction in PA pressure started at 10 days after ASD closure and this reduction had continued for 1 month, 6 months, and up to 1 year which again supported the findings of our study in regards to non-significant decrement in PA pressure at 2 days after procedure.

Our strategy of non-invasive calculation of PVR and PVRI was supported by an earlier study which demonstrated a significant correlation between TR velocity/RVOT vti and invasive PVR in patients with PVR less than 8 WU[15]. In our study, there was a significant reduction of PVR and PVRI at 3 months after of device closure. There are hardly any studies that have compared the values of echocardiographically derived PVR before and after procedure.

In general, the complication rate of transcatheter ASD closure is low. The complication rate in our study was 4.7%. A study conducted by Chessa et al[16] showed an overall incidence of complications to be 8.6% and the device embolization had occurred in 3.5%.

The success rate of percutaneous ASD closure in our study was 97.6% with treatment failure in 1 patient (dislodgement of device). A similar success rate of 97% with treatment failure in 2 cases was documented in an earlier study[17] conducted by Hildick-Smith et al.

Our study has several limitations. First, the right heart catheterization was not done to calculate the pulmonary artery pressure and resistance. Second, it is a single-centered study with a small sample size affected due to COVID-19 pandemic during the study period and the final limitation was potential bias and imprecision in measurement of the different variables.

Conclusion

Our study showed that the transcatheter ASD closure can be safely and successfully performed in adults which lead to a significant improvement in the right and left sided cardiac chamber dimensions and functions in the short-term follow-up and it proved to be an effective method in the treatment of the secundum ASD with a high procedural success rate of 97.6%.

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Disclosure

The authors report no conflicts of interest in this work

References

1. Dickinson D, Arnold R, Wilkinson J. Congenital heart disease among 160 480 liveborn children in Liverpool 1960 to 1969. Implications for surgical treatment. Heart. 1981;46(1):55-62. https://doi.org/10.1136/hrt.46.1.55

2. Attie F, Rosas M, Granados N, Zabal C, Buendía A, Calderón J. Surgical treatment for secundum atrial septal defects in patients> 40 years old: a randomized clinical trial. Journal of the American College of Cardiology. 2001;38(7):2035-42. https://doi.org/10.1016/S0735-1097(01)01635-7

3. Berger F, Ewert P, Boöjrnstad PG, Dähnert I, Krings G, Brilla-Austenat I, et al. Transcatheter closure as standard treatment for most interatrial defects: experience in 200 patients treated with the Amplatzer™ Septal Occluder. Cardiology in the young. 1999;9(5):468-73. https://doi.org/10.1017/S1047951100005369

4. Mills NL, King TD. Nonoperative closure of left-to-right shunts. The Journal of thoracic and cardiovascular surgery. 1976;72(3):379-82. https://doi.org/10.1016/S0022-5223(19)40065-2

5. Du Z-D, Hijazi ZM, Kleinman CS, Silverman NH, Larntz K, Investigators A. Comparison between transcatheter and surgical closure of secundum atrial septal defect in children and adults: results of a multicenter nonrandomized trial. Journal of the American College of Cardiology. 2002;39(11):1836-44. https://doi.org/10.1016/S0735-1097(02)01862-4

6. Schoen SP, Kittner T, Bohl S, Braun MU, Simonis G, Schmeisser A, et al. Transcatheter closure of atrial septal defects improves right ventricular volume, mass, function, pulmonary pressure, and functional class: a magnetic resonance imaging study. Heart. 2006;92(6):821-6. https://doi.org/10.1136/hrt.2005.070060

7. Baumgartner H, De Backer J, Babu-Narayan SV, Budts W, Chessa M, Diller G-P, et al. 2020 ESC Guidelines for the management of adult congenital heart disease: The Task Force for the management of adult congenital heart disease of the European Society of Cardiology (ESC). Endorsed by: Association for European Paediatric and Congenital Cardiology (AEPC), International Society for Adult Congenital Heart Disease (ISACHD). European heart journal. 2021;42(6):563-645. https://doi.org/10.1093/eurheartj/ehaa554

8. Cowley CG, Lloyd TR, Bove EL, Gaffney D, Dietrich M, Rocchini AP. Comparison of results of closure of secundum atrial septal defect by surgery versus Amplatzer septal occluder. American Journal of Cardiology. 2001;88(5):589-91. https://doi.org/10.1016/S0002-9149(01)01750-7

9. Chen Q, Sun X-D, Cao H, Zhang G-C, Chen L-W, Hu Y-N. Echocardiographic evaluation of changes in cardiac Hemodynamics and loading conditions after transthoracic minimally invasive device closure of Atrial Septal defect. PloS one. 2015;10(7). https://doi.org/10.1371/journal.pone.0128475

10. Veldtman GR, Razack V, Siu S, El-Hajj H, Walker F, Webb GD, et al. Right ventricular form and function after percutaneous atrial septal defect device closure. Journal of the American College of Cardiology. 2001;37(8):2108-13. https://doi.org/10.1016/S0735-1097(01)01305-5

11. Schussler JM, Anwar A, Phillips SD, Roberts BJ, Vallabhan RC, Grayburn PA. Effect on right ventricular volume of percutaneous Amplatzer closure of atrial septal defect in adults. The American journal of cardiology. 2005;95(8):993-5. https://doi.org/10.1016/j.amjcard.2004.12.046

12. Giardini A, Donti A, Formigari R, Specchia S, Prandstraller D, Bronzetti G, et al. Determinants of cardiopulmonary functional improvement after transcatheter atrial septal defect closure in asymptomatic adults. Journal of the American College of Cardiology. 2004;43(10):1886-91. https://doi.org/10.1016/j.jacc.2003.10.067

13. Akula VS, Durgaprasad R, Velam V, Kasala L, Rodda M, Erathi HV. Right ventricle before and after atrial septal defect device closure. Echocardiography. 2016;33(9):1381-8. https://doi.org/10.1111/echo.13250

14. Yalonetsky S, Lorber A. Comparative changes of pulmonary artery pressure values and tricuspid valve regurgitation following transcatheter atrial septal defect closure in adults and the elderly. Congenital heart disease. 2009;4(1):17-20. https://doi.org/10.1111/j.1747-0803.2008.00245.x

15. Rajagopalan N, Simon MA, Suffoletto MS, Shah H, Edelman K, Mathier MA, et al. Noninvasive estimation of pulmonary vascular resistance in pulmonary hypertension. Echocardiography. 2009;26(5):489-94. https://doi.org/10.1111/j.1540-8175.2008.00837.x

16. Chessa M, Carminati M, Butera G, Bini RM, Drago M, Rosti L, et al. Early and late complications associated with transcatheter occlusion of secundum atrial septal defect. Journal of the American College of Cardiology. 2002;39(6):1061-5. https://doi.org/10.1016/S0735-1097(02)01711-4

17. Hildick-Smith D, O'sullivan M, Wisbey C, Mackay J, Lee E, Shapiro L. Amplatzer device closure of atrial septal defects in mature adults: analysis of 76 cases. Heart. 2004;90(3):334-5. https://doi.org/10.1136/hrt.2002.008516