Transcatheter Device Closure of Atrial Septal Defect and Patent Ductus Arteriosus: Single Center Experience from Central India

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Abstract: _Background:Transcatheter closure of Atrial Septal Defect (ASD) and Patent Ductus Arteriosus (PDA) are one of the most commonly and widely performed cardiac interventional procedures. With plethora of devices available for the closure of the defects, data regarding outcomes post procedure remains limited and more scarcer in Central India. Hence, the present study was planned to study the outcomes using three different set of brands of devices. Methods: The study was a prospective hospital based single center study including 28 patients of ASD and PDA admitted in a tertiary care hospital in Central India during September 2017 to August 2019 to evaluate the outcomes of transcatheter device closure of these congenital heart defects. Results:The median age of the patients with ASD was 18 years (range 4 – 52 years) while that with PDA was 8 years (range 1.5 – 50 years). The mean ASD and PDA diameter was 18.8 ± 6.3 mm (range 10 – 30 mm) and 6 ± 3.6 mm (range 2 – 14 mm) respectively.Cocoon Septal Occluder was deployed in 3 cases of ASD while HeartR and Floret ASD Occluder were implanted in 3 and 5 cases of ASD respectively. Cocoon Ductal Occluder was deployed in 6 cases of PDA while HeartR, Cera and Floret PDA Occluder were implanted in 4,1, and 4 cases of PDA respectively. The implantation success rate of ASD and PDA occluder was 84.6% and 100% respectively. Immediate closure rates were 90.9% for ASD and 86.7% for PDA which improved to 100% for both procedures at 1 month follow-up. Only 1 case of inadvertent left atrial appendage rupture leading to cardiac tamponade occurred during ASD closure and ASD closure device was withdrawn in another case. On short and intermediate term follow-up (2 - 24 months), no device related complications were observed. No death occurred in the present study. Conclusion: Transcatheter ASD and PDA device closure is an effective and safe procedure with rare complications which can be prevented by careful patient selection along with meticulous imaging. Performance of all the three employed device brands is almost similar with excellent success rate._

Keywords: Transcatheter device closure, atrial septal defect, patent ductus arteriosus, outcomes, complications

1. Introduction

Atrial Septal Defect (ASD) and Patent Ductus Arteriosus (PDA) are one of the most frequently encountered congenital cardiac defects in the clinical practice, both accounting for 5-10% of all congenital heart defects individually with a higher female preponderance of 2:1 ratio.[1-3] Surgery has been the mainstay of therapy for these common cardiac defects and still remains the gold standard.[4] PDA was the first congenital heart disease to be treated percutaneously.[5] Portsmann etal in 1967 reported the first successful non-surgical closure of PDA in a 17 year old boy using an Ivalon plug.[6] In another breakthrough, Mills and King first described the successful transcatheter closure of ostium secundum ASD in 5 patients in 1976 using a double umbrella device.[7]In 1979, Rashkind developed wire hook single disc device for PDA closure but with discouraging results.[8] Later, his group in 1987 reported the successful deployment of a double disc umbrella device.[9] Since then, variety of improvements in device and innovative techniques have been developed thereby establishing the transcathter closure of ASD and PDA as the mainstay of treatment whenever feasible rather than surgery in most of the institutions worldwide.

Despite plethora of advancements, only ostium secundum type of ASD (OS-ASD) can be closed percutaneously with the currently available devices while all other anatomic subtypes of ASD, viz., ostium primum, sinus venosus ASD and unroofed coronary sinus still require surgical closure. Also, barring type-B also known as Aorto-pulmonary (AP) window type of PDA, most PDA are amenable for percutaneous closure. Several studies have demonstrated comparable outcomes of both surgical and transcatheter device closure of the defect after careful selection of pediatric and adult patients. Moreover, transcatheter device closure of both ASD and PDA are associated with lower rate of complications, shorter anaesthetic times and shorter duration of hospital stay.[10]

Literature regarding data on outcomes of transcatheter device closure of ASD and PDA in India is limited and data is much more scarcer as far as Central India is concerned. The present study was planned to study the outcomes of transcatheter device closure of ASD and PDA in patients from Central India in order to fill the void in the current Indian literature. The present study was unique in the sense that majority of the patients were followed-up for longer duration in order to evaluate short and intermediate term complications. Also, three different set of brands of closure

devices were employed in the study according to the institutional procurement rules thereby offering valuable insight regarding difference in performance of the different brands of closure devices.

2. Materials and Methods

2.1 Study design

The present study was conducted in the Department of Cardiology, Government Medical College and Super Speciality Hospital, Nagpur, Maharashtra, India, which was a prospective hospital based single center study.

2.2 Study population

The study population was selected from the patients admitted indoor in the department of Cardiology of Government Medical College and Super Speciality Hospital, Nagpur, Maharashtra, India during September 2017 to August 2019.

Inclusion criteria:
The patients were included in the study if they fulfilled the following criteria:
1) Patients with Atrial Septal Defect (ASD) or Patent Ductus Arteriosus (PDA) suitable for device closure as per indications of the American Heart Association based on clinical and imaging findings.[10]
2) Patients or legal guardians in case of minors who gave written informed consent for undergoing device closure.

Exclusion criteria:
The patients were excluded from the study if:
1) Weight < 10 kg in case of ASD or < 6 kg in case of PDA.
2) Age < 2 years in case of ASD or < 6 months in case of PDA.
3) Patients with ASD measuring > 38 mm.
4) Multiple ASD.
5) Patients with PDA with no audible murmur appreciated by the standard auscultation techniques (Silent PDA).
6) Type B (Aorto-pulmonary window type) PDA.
7) Pregnant females.
8) Patient known to have sepsis within 1 month prior to implantation, or any systemic infection that cannot be treated successfully prior to device implantation.
9) Intracardiac thrombi demonstrated by echocardiography.

2.3 Ethical Approval

The study was approved by the institutional ethical committee and written informed consent was obtained from all the participants or legal guardians in case of minors.

2.4 Data Collection

All patients underwent thorough clinical and imaging evaluation before proceeding to transcatheter defect closure. Information on age and sex were obtained by patient's self-report or by report from the parents or legal custodians of the children included in the study. Anthropometric measurement and physical examination were carried out for each participant. Detailed echocardiographic analysis to locate and measure the size of the defect and assess their hemodynamic sequelae was performed in every patient. Routine right heart catheterization was performed in all the selected patients to ensure the presence of normal pulmonary vascular resistance and to calculate the left-to-right shunt.

Atrial Septal Defect

All patients were subjected to detailed transthoracic echocardiography to locate the defect and size it accurately. In addition, transesophageal echocardiography was performed in most of the adult patients of ASD to accurately determine the size of the defect and assess the septal rims before proceeding to transcatheter closure of ASD. Patients with deficient (defined as size < 5mm) supero-posterior/superior vena cava (SVC), infero-posterior/ inferior vana cava (IVC) and coronary sinus, posterior/ right upper and lower pulmonary vein or infero-anterior/ atrioventricular valve rims were excluded from undergoing transcatheter device closure. However, all the patients with deficient supero-anterior/ aortic rim were selected for the transcatheter device closure.[11] All the patients posted for ASD device closure were started on Aspirin 75 mg, 24 hours before planned procedure and continued for atleast 6 months post procedure. Procedure was started with a right femoral vein access. An arterial monitoring line was inserted in the right femoral artery. Patient was fully heparinized with intravenous heparin dosage of 70 U/kg throughout the procedure to achieve activated clotting time (ACT) of more than 250 seconds at the time of device deployment. ASD was crossed with a 6 Fr Multipurpose catheter (MPA, Medtronic Inc., USA) and was positioned in the left upper pulmonary vein (LUPV). A 0.035 inch J – tip super stiff guide wire (Amplatz Super Stiff, Boston Scientific Co., Heredia, Costa Rica) was subsequently parked in LUPV. Device measuring 2 mm larger than the defect diameter was selected if the defect had adequate rims while device 4 mm larger than the defect diameter was selected in case of deficient aortic rim (< 5mm). Balloon sizing technique was not employed in any case. Delivery sheath was advanced over the guidewire to the LUPV. Both dilator and guidewire were then removed. Device was screwed to the tip of the delivery cable and was drawn into the loader under normal saline. Delivery cable with device was then advanced to the distal tip of the sheath under fluoroscopic guidance. The Left atrial disc and part of the connecting waist was deployed under both transesophageal echocardiographic and fluoroscopic guidance and device was pulled gently against the atrial septum. With application of tension on the delivery cable, sheath was pulled back to deploy the right atrial disc (Figure – 1). Stability of the device was confirmed by performing the Minnesota wiggle (by pushing cable gently forward and pulling it backward). Device was subsequently released by counterclockwise rotation of the delivery cable using a pin vise after ensuring proper apposition and stability. All procedures were carried out under transesophageal echocardiographic guidance.

The ASD closure device employed was a self-expandable dual disc separated by a central waist. Devices of three different brands, viz., Cocoon Septal Occluder (Vascular Innovations Co., Nonthaburi, Thailand), HeartR ASD

Occluder (LifeTech Scientific Co., Shenzhen, China) and Floret ASD Occluder (Meril Life Sciences Pvt. Ltd., Gujarat, India) were used as per institutional procurement rules.

Cocoon Septal Occluder is made up of braided nitinol wire coated with platinum that prevent nickel release and enhance radio-opacity and biocompatibility. The 2 discs are filled with polypropylene fabric to aid in total occlusion of the defect. The wide range of sizes according to central waist is available ranging from 8 mm upto 40 mm with 2 mm increment. HeartR ASD Occluder is made by nitinol wire mesh covered by polyethylene terephthalate (PET) membrane to minimize thrombus formation. Sizes ranging from 6 mm with 2 mm increment upto 42 mm are available. Floret ASD Occluder is manufactured from braided nitinol wires with three Polyester fabric insert facilitating tissue growth over the occluder. Sizes ranging from 6 mm with 2 mm increment upto 42 mm are available.

Patent Ductus Arteriosus

All patients were subjected to detailed transthoracic echocardiography before posting them for PDA closure. Procedure was started with both right femoral artery and venous access. Patient was fully heparinized with intravenous heparin dosage of 70 U/kg throughout the procedure. Aortogram was done to demonstrate PDA anatomy by passing a Pigtail catheter (PIG, Boston Scientific Co., Baja California, Mexico) into the Proximal descending aorta via right femoral artery. Size and length of the communication was measured. Device measuring (pulmonary end) 2mm larger than the diameter of the duct was selected. Guide wire was placed at the tip of the descending aorta via pulmonary artery across PDA. Delivery sheath and dilator was advanced over the guide wire into the descending aorta. Both dilator and guidewire were then removed. Delivery cable was passed through the loader and occlusion device was screwed into the tip of the delivery cable. Loader was then introduced into the delivery sheath under fluoroscopic guidance. Retention disc was deployed completely in the descending aorta and pulled firmly against the aortic orifice of PDA. Delivery sheath was then retracted and cylindrical portion of the device was deployed securely in PDA. Delivery cable was then unscrewed after ensuring adequate positioning by repeat aortography (Figure – 2).

The PDA closure device is a self-expandable cone-shaped device that tapers from a larger-circumference rimmed edge or cap. Devices of three different brands, viz., Cocoon Duct Occluder (Vascular Innovations Co., Nonthaburi, Thailand), Cera or HeartR PDA Occluder (LifeTech Scientific Co., Shenzhen, China) and Floret PDA Occluder (Meril Life Sciences Pvt. Ltd., Gujarat, India) were used as per institutional procurement rules.

Cocoon Ductal Occluder is made up of similar materials as Cocoon Septal Occluder. It is available in sizes as measured by the pulmonary end ranging from 4 mm (4/6) upto 18 mm (18/20). Aortic end is always 2 mm larger than the pulmonary end. HeartR PDA Occluder is made by nitinol wire mesh covered by polytetrafluoro ethylene (PTFE) membrane. Sizes ranging from 4 mm (4/6) with 2 mm increment upto 22 mm (22/24) are available. Cera PDA Occluder is manufactured from nitinol wire frame coated with titanium nitride which decrease the dissolution of nickel ion efficiently. Sizes ranging from 4 mm (4/6) with 2 mm increment upto 22 mm (22/24) are available. Floret PDA Occluder is made up of braided nitinol wire mesh with Polyester fabric insert. Sizes ranging from 4 mm (4/6) with 2 mm increment upto 22 mm (22/24) are available.

Followup

All patients were followed-up at 24 hours, before discharge, 1 week and 1 month post procedure. Majority of them were also evaluated at 6 and 12 months post procedure. Patients were evaluated clinically to look for development of complications if any resulting due to transcatheter device closure. Also, echocardiography was performed at every visit.

Statistical Analysis

Excel data analysis tool was employed for the descriptive statistical analysis. Results were reported as mean ± standard deviation and median. Categorical variables were expressed as frequency (percentage).

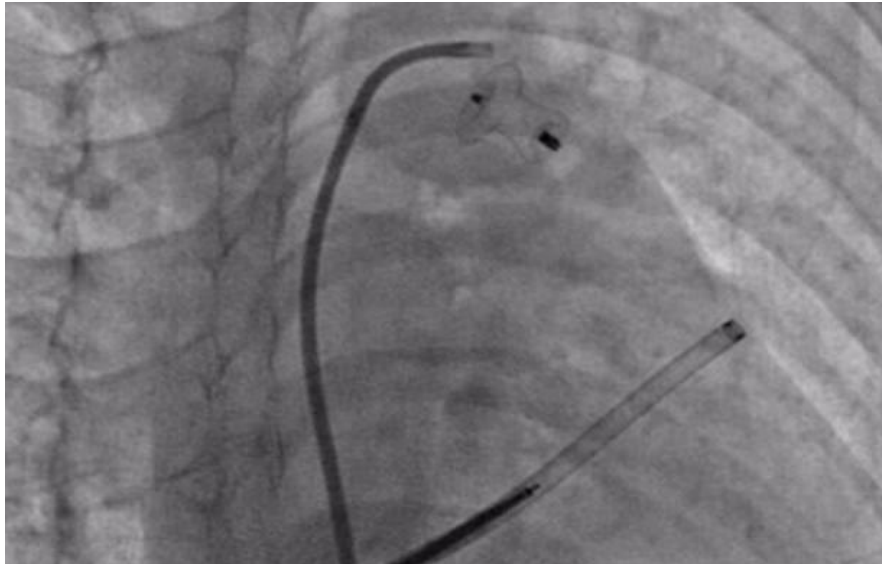**Figure 1:** Floret ASD Occluder after implantation and before release

Figure 2: Floret PDA Occluder after implantation and release

3. Results

The present study was undertaken between September 2017 and August 2019. During this two-year period, 30 transcatheter device closures were attempted. Of these 30 procedures, 13 were for ASD closure, 15 for PDA occlusion and remaining 2 were off-label uses of Ductal Occluder, one for the closure of Prosthetic Mitral Valve Paravalvular leak and another for Right coronary artery aneurysm. 13 patients of ASD and 15 patients of PDA were included in the study for Transcatheter device closure. The median age of the patients with ASD was 18 years (range 4 – 52 years) while that with PDA was 8 years (range 1.5 – 50 years). Majority of the patients selected for transcatheter device closure were female with 84.6% patients of ASD and 73.3% patients of PDA being female. Only 15.4% patients of ASD and 26.7% patients of PDA were males.

The mean ASD diameter as determined by transesophageal echocardiography was 18.8 ± 6.3 mm (range 10 – 30 mm) while that of PDA as measured by transthoracic echocardiography was 6 ± 3.6 mm (range 2 – 14 mm). The mean diameter of the septal occluder device was 20.9 ± 6.5 mm (range 14 – 34 mm). Cocoon Septal Occluder was deployed in 3 cases of ASD while HeartR and Floret ASD Occluder were implanted in 3 and 5 cases of ASD respectively. Cocoon Ductal Occluder was deployed in 6 cases of PDA while HeartR, Cera and Floret PDA Occluder were implanted in 4,1, and 4 cases of PDA respectively. All patients with implanted occluder device were followed-up at regular intervals. Mean duration of follow-up of the patients with implanted septal occluder device was 10 ± 7.5 months (range 2 – 23 months) and that for implanted ductal occluder device was 13.9 ± 7.5 months (range 2 – 24 months). *Table 1* depicts the demographic profile and various characteristics of the defect and transcatheter device employed for the respective closure of the defect in the studied population.

Table 1: Demographic, Defect and Device characteristics

Characteristics	ASD	PDA
Number of patients	13	15
Age in years (Median with Range)	18 (4 – 52)	8 (1.5 – 50)
Males	2 (15.4%)	4 (26.7%)
Females	11 (84.6%)	11 (73.3%)
Defect size in mm (Mean ± SD)	18.8 ± 6.3	6 ± 3.6
Deployed Device size in mm (Mean ± SD)	20.9 ± 6.5	-
Devices employed		
Cocoon (Vascular Innovations)	3	6
HeartR or Cera (LifeTech Scientific)	3	5
Floret (Meril Life Sciences)	5	4
Duration of follow-up in months (Mean ± SD)	10 ± 7.5	13.9 ± 7.5

Results of the transcatheter device closure of ASD and PDA are tabulated in *Table 2*. The success rate of deployment was 84.6% for the transcatheter device closure of ASD while ASD could not be closed only in one case due to the floppy and deficient IVC rim. Also, in another case, procedure was abandoned due to inadvertent rupture of Left atrial appendage leading to cardiac tamponade and patient was subsequently referred for ASD patch closure which was eventually successful. The success rate of implantation for transcatheter device closure of PDA was 100%. Immediate closure rate was 90.9% and 86.7% with septal and ductal occluder respectively with only 1 case (8.3%) in ASD closure cohort and 2 cases (13.3%) in PDA closure cohort with minor residual shunt were observed post procedure. However, all cases of ASD and PDA implanted with device were found to be completely closed at 1 month of follow-up without any residual shunt. No cases with anaesthesia and allergic dye reactions were observed in the studied population. Device migration and embolization was observed in none of the cases. There was only 1 case of transcatheter ASD closure where supraventricular tachycardia occurred transiently during the procedure and subsided spontaneously without any consequence, however, no case of tachyarrythmia was noted during transcatheter PDA device closure. No case of conduction disturbance was observed in any of the patients of ASD and PDA closure. Inadvertent air embolism occurred in 1 case each during ASD (7.7%) and PDA (6.7%) closure which was managed

conservatively with high flow oxygen without any adverse consequence. No cases of migraine and stroke were noted in any of the procedures. No death occurred during or following any procedure.

Local site complications were infrequent with only 1 patient (7.7%) in case of ASD closure and 2 patients (13.3%) in case of PDA closure suffered minor groin hematoma. No cases of pseudoaneurysm and arteriovenous fistula were observed following anyof the procedures.

Device related complications like, Nickel allergy, thrombosis of device, endocarditis, hemolysis, erosion and valvular regurgitationwere not observed in any case, neither following ASD closure, nor after PDA closure. Also, no case of device related obstruction following PDA closure leading to Left pulmonary artery (LPA) stenosis and Coarctation of Aorta was noted.

Table 2: Results of Transcatheter device closure of ASD and PDA

Results	ASD	PDA
Success rate	84.60%	100%
Immediate closure rate	90.90%	86.70%
Closure rate at 1 month follow-up	100%	100%
General complications		
Anaesthesia reactions	0	0
Allergic dye reactions	0	0
Residual shunt	1 (9.1%)	2 (13.3%)
Device migration and embolization	0	0
Device withdrawn	1 (8.3%)	0
Rhythm disturbance	1 (7.7%)	0
Stroke	0	0
Migraine	0	0
Air embolism	1 (7.7%)	1 (6.7%)
Pericardial effusion/ Cardiac Tamponade	1 (7.7%)	0
Death	0	0
Local site complications		
Groin Hematoma	1 (7.7%)	2 (13.3%)
Pseudoaneurysm	0	0
Arterio-venous fistula	0	0
Device related complications		
Nickel allergy	0	0
Thrombosis	0	0
Endocarditis	0	0
Hemolysis	0	0
Erosion	0	0
Valvular regurgitation	0	0
Left Pulmonary artery stenosis	-	0
Coarctation of Aorta	-	0

4. Discussion

With rising awareness about congenital heart defects among population, more and more patients are being subjected to undergo various imaging procedures like echocardiography with even subtle clinical clue thereby resulting in increased number of patients being diagnosed with various congenital heart defects at an early age.

It provides a good opportunity to address these defects at an early age when they can be treated thereby preventing major morbidity and mortality inherent to inoperable lesions if diagnosed at a later stage. Atrial septal defects and Patent

ductus arteriosus account together 15 -20 % of all the congenital cardiac defects. Many of these defects are amenable for transcatheter closure if diagnosed at an early stage before development of irreversible obliterative pulmonary vascular disease.[4] These past 4 decades have witnessed the rapid development of transcatheter techniques and various advancements and modifications in device design for closure of these defects since the initial reports of transcatheter device closure of ASD by Mills and King and that of PDA by Rashkind dating back to 1976 and 1979 respectively. [8,9] Transcatheter ASD closure is indicated in patients with hemodynamically significant ostium secundum ASD as evidenced by right sided heart volume overload, right sided heart failure or elevated right sided heart pressures along with suitable septal rims surrounding the defect. Various other indications for ASD closure are stroke or recurrent transient ischemic attack resulting due to paradoxical emboli or cyanosis with transient right-to-left shunt across ASD. Moreover, patients with small ostium secundum ASD can be considered for transcatheter closure who are at risk of thromboembolic events as in hyper coagulable states or with chronic indwelling intravenous cathteters. Transcatheter closure is contraindicated if there is hemodynamically insignificant small ostium secundum ASD or patients of ASD with advanced pulmonary vascular obliterative disease. It should not be performed in other anatomic subtypes of ASD including ostium primum, sinus venosus ASD and unroofed coronary sinus defects.[10]Patients with deficient (defined as size < 5mm) SVC, IVC, coronary sinus, posterioror atrioventricular valve rims should not undergo transcatheter closure. [11] Transcatheter PDA occlusion is indicated in every audible PDA with suitable anatomy and patient size to prevent endocarditis / endarteritis development and eliminate pulmonary overcirculation and subsequent development of obliterative pulmonary vascular disease. It is contraindicated in cases of severe irreversible pulmonary hypertension.[8] Closure of silent PDA is controversial as there are only few case reports of endocarditis in the silent ductus.[12]

With the wide availability of transcatheter devices nowadays, percutaneous closure of the defects has become the treatment of choice whenever the conditions are favourable thereby emphasizing that patient selection is a crucial first step to achieve desirable results.[10]

28 patients were selected for the transcatheter defect closure with 13 patients of ASD and 15 patients of PDA during the study period after thorough clinical and imaging workup. Median age of the patients with ASD was 18 years while that of patients with PDA was 8 years. The youngest patient selected for the ASD device closure was 4 years old girl while that for the PDA device closure was 1.5 years old girl. The eldest patient that underwent ASD and PDA device closure was a 52 years old woman and a 50 years old man respectively (Table - 1). As expected, there was higher female preponderance of patients undergoing transcatheter device closure as both ASD and PDA are more common in females with a female to male ratio of 2:1.[1-3] Interestingly, 84.6% cases of ASD and 73.3% case of PDA were females who underwent transcatheter defect closure (Table - 1). The mean size of ASD was 18.8 ± 6.3 mm as determined by transesophageal echocardiography, smallest being 10 mm

and the largest defect closed measured 30 mm. The mean size of PDA as measured by transthoracic echocardiography was 6 ± 3.6 mm, smallest being 2 mm and the largest defect closed measured 14 mm (Table - 1). The mean diameter of the septal occluder was 20.9 ± 6.5 mm, smallest being 14 mm and the largest device deployed was of 34 mm. The smallest ductal occluder implanted measured 4/6 mm while the largest device deployed was of 16/18 mm (Table - 1). All patients were followed-up at regular intervals to study the outcome in detail and look for development of complications if any with mean follow-up duration of 10 ± 7.5 months ranging from 2 to 23 months for ASD device closure while that for PDA device closure was 13.9 ± 7.5 months ranging from 2 to 24 months (Table - 1).

Three different brands of occluders were employed for the transcatheter closure of the defect, namely, Cocoon (Vascular Innovations Co., Nonthaburi, Thailand), HeartR and Cera (LifeTech Scientific Co., Shenzhen, China), and Floret (Meril Life Sciences Pvt. Ltd., Gujarat, India)septal and ductal occluders as per the availability made by the institution according to their procurement rules (Table - 1). The basic design of the ASD closure devices employed were similar to Amplatzer septal occluder (ASO) with two atrial discs connected by a waist which straddles the defect. Also, PDA occluders employed in the present study were similar to Amplatzer Ductal Occluder type I (ADO I) which is a cone shaped device that tapers from a larger rimmed edge or cap.[13]

Outcomes following transcatheter ASD device closure

Since the introduction of ASO in 1997 by Masura et al, it has been the most commonly used and most extensively studied device.[14] Very few systematic studies have been performed with other devices employed in the present study and this data is even more scarcer in Indian population. The success rate for the transcatheter implantation of ASD closure device was 84.6% in the present study (Table - 2) which is in close concordance with the recent study done among 27 ASD patients in Romania by Mahmoud et al who reported the success rate of 88.9%.[4] However, majority of the studies have reported much higher ASD closure device implantation success rate ranging from 94 - 99%.[15-23]

The immediate post procedure closure rate for transcatheter ASD device closure was 90.9% but was 100% at 1 month follow-up suggesting that all implanted ASD closure devices had a good stability with no persistent residual shunt in the present study(Table - 2). The findings are in accordance with the other studies, most reporting closure rate without any residual shunt in excess of 90%.[4,15,18-20,22,23]

Every procedure has its own inherent risk and so is the transcatheter ASD device closure. Amplatzer pivotal trial reported minor complications in 6.1% cases including cardiac dysrhythmia requiring minor treatment, thrombus formation, allergic reaction, migraine, transient ischemic attack and minor residual leak.[24] Many other studies report similar rates of minor complications, suggesting that these complications are infrequently encountered.[4,15,18-20,22,23,25] There was no case of anaesthesia and allergic reactions observed in the present study (Table - 2). There was only 1

case of transient supra ventricular tachycardia noted during procedure in the present study which reverted back to sinus rhythm spontaneously (Table - 2). Conduction blocks were not observed in any case in the present study. It has been estimated that post procedure atrial arrhythmia do occur in 2 - 4 % of cases due to foreign body reaction, while only occasional reports of conduction block are present in the literature, sometimes requiring even permanent pacemaker implantation.[25,26] No case of migraine and possible transient ischemic attack was observed in the present study (Table - 2). Most of the studies report this as a very rare event except for a study done by Sadiq Masood et al who reported incidence of migraine in 3.9% of their study cohort.[18] Residual shunt, although mild was noted in only 1 patient post procedure but it disappeared at 1 month follow-up in the present study (Table - 2). Residual leaks are classified according to the Boutin classification as mild (1 - 2 mm), moderate (2 - 4 mm) and large (> 4 mm).[27] With device endothelialization, mild - moderate leaks may improve or disappear.[25] Similar proportion of residual leaks have been reported in other studies as well.[4,18-20,22,23] In the present study, only in one case the device withdrawal was necessary due to floppy and marginally deficient IVC rim (Table - 2). This complication, although rare can be avoided to some extent by meticulous screening before selecting patient for the transcatheter device closure, however, few other studies too have reported this unforeseeable circumstance leading to device withdrawal.[4,15,23]

Complications inherent to cardiac catheterisation are infrequent and include air embolism, infections and local site complications, like ,hematoma, pseudoaneurysm and arteriovenous fistula.[4,10,15,21,26] One case of air embolism and one case of minor groin hematoma was noted in the present study (Table - 2).

The major complication rate as reported in the Amplatzer pivotal trial was 1.6% including device embolization, cardiac dysrhythmia requiring major treatment and stroke.[24] No case of device migration and its subsequent embolisation was noted in the present study (Table - 2). However, many studies report device embolisation as one of the most commonly encountered major complication ranging from 0.1 - 2%.[10,18-20,22-25,28-30] Interestingly, Fischer et al reported a case of delayed cerebral embolisation after 5 years of successful implantation of Amplatzer septal occluder, most probably due to device embolisation.[15] One case of inadvertent left atrial appendage rupture occurred in the present study leading to cardiac tamponade (Table - 2). Patient was managed by emergent pericardiocentesis followed by referral for surgery which was eventually successful. Cardiac perforation is a life threatening complication caused by wire and catheter maneuvering. Many studies report pericardial effusion, cardiac tamponade and cardiac perforation to be an infrequent occurrence in their study cohort ranging from 0.1 - 1.5%.[18,22,25,31,32] No patient suffered stroke during or post procedure in the present study (Table - 2). Fortunately, stroke too is a rare complication reported in the literature.[24,28] The Manufacturer and User Facility Device Experience (MAUDE)/ Food and Drug Administration (FDA) have reported mortality to be a very rare event with ASO, occurring in less than 0.1%.[30] No

deaths occurred in the present study as in most of the other studies (Table - 2).[4,15-25]

There were no device related complications, viz., nickel allergy, erosion, hemolysis, thrombosis, valvular regurgitation and endocarditis observed during the follow-up in any case (Table - 2). Nickel allergy is estimated to be 10% in the general population.[4,33.] However, with the advancement and modification of device designs, like, platinum coating over nitinol wires that prevent nickel release into the circulation after device implantation, this complication has become extinct.[28] Erosions associated with transcatheter ASD device closure implantation have been reported as one of the most common life-threatening complication. It has been estimated that erosions occur at a frequency of 0.1-0.3%, however true incidence is difficult to determine owing to unknown number of device implants.[13] However, with more than 240,000 device implantation of ASO, life-threatening cardiac erosions have been very rare with a reported frequency of 0.1%.[26] Few other studies in the literature too report this complication as an extremely rare event.[22,25] Zahid Amin and coworkers reviewed the registry of complications associated with ASO and made certain recommendations to prevent the future risk of cardiac erosion. They identified the patients who were at higher risk for erosions as those needing ASO greater than 1.5 times the unstretched diameter of the ASD, those with deficient aortic rims, and those in whom the device splayed around the aorta. Stop flow method of balloon sizing and only gentle to and fro motion after device implantation were recommended to prevent this dreaded complication.[13,32] However, majority of the members of the Congenital Cardiovascular Interventional Study Consortium (CCISC) were of the opinion that a device in which the discs were in close approximation to each other and touched the aorta without any splaying were at the highest risk for cardiac erosion.[34] Executive summary of FDA advisory panel while addressing the issue of cardiac erosion listed 95 documented and 8 suspected erosions. They reported that almost half of the erosions occurred within first 7 days, 61% within 30 days and 87% within the first year. They found the associated mortality rate to be 8.4%. Regular and long term followup is thus recommended to identify this dreaded complication and intervene then in timely manner to decrease the morbidity and mortality resulting thereof.[13] Due to routine usage of Aspirin, thrombus formation is extremely rare with Turner et al reporting it to be around 0.1%.[25] Infective endocarditis is also quite rare due to fairly strict observance of prophylaxis protocol when required for 6 months post procedure, however, Masood Sadiq and coworkers do report this complication to have occurred in their study cohort with the frequency of 0.5%.[18] Valvular regurgitation is also extremely rare with frequency of less than 1%.[18,25] Hemolysis following transcatheter ASD device closure is a rarely reported complication but can occur due to residual shunt associated with tricuspid regurgitation impinging on the inferior edge of the implanted device.[35]

Outcomes following transcatheter PDA device closure

ADO was introduced in 1998 by Masura et al to overcome many deficiencies of the coil occlusion techniques for percutaneous PDA closure and since then this device has been used most commonly in various centres globally.[36] PDA occlusion is a pretty straightforward procedure as compared to ASD closure with only rare reported complications.[10] The success rate of the transcatheter implantation of PDA occluder was 100% in the present study (Table - 2). Pivotal multicenter USA ADO device trial reported successful implantation rate of 99%.[37] Many studies too report similar success rate in excess of 97%.[4,38-43] The immediate post procedure closure rate for transcatheter PDA occlusion was 86.7% but was 100% at 1 month follow-up in the present study(Table - 2) which is in close concordance with the findings of the pivotal ADO device trial reporting 89% closure rate at day 1 which increased to 99.7% at 1 year follow-up.[37] Immediate post procedure closure rate varies widely between studies but during follow-up this closure rate reaches upto 97% in most of the studies.[4,38,39,41,44] With growing experience regarding utilization of transcatheter PDA occlusion, complications have been minimised as compared to initial reports. No case of allergic and anaesthetic reactions were noted in the present study (Table - 2). No cardiac dysrhythmia and transient ischemic attack was observed in the present study (Table - 2). Arrhythmias result most commonly due to catheter manipulation and is usually benign and very infrequent, occurring in less than 1% of cases.[42] Residual shunts, although mild were noted in 2 cases in the immediate post procedure period, of which one disappeared at the 7th day follow-up while other disappeared at the 1 month follow-up. Most studies in the literature too report higher closure rate with subsequent disappearance of majority of the residual leaks by one year.[38,39,41,44] Careful and meticulous imaging by transthoracic echocardiography can guide proper size selection of the PDA occluder thereby mitigating this problem. Also, no device was needed to be withdrawn in the present study (Table - 2). This complication, although rare has been reported variedly in the literature occurring due to variety of reasons, mainly device instability, device encroaching great arteries leading to their obstruction or rarely due to device embolization.[4,40-42]

Complications related to cardiac catheterization are usually rare and minor. Only one case of air embolism was observed in the present study, which was managed conservatively with high flow oxygen without any consequence (Table - 2). As far as local site complications are concerned, only two cases of minor groin hematoma were recorded in the present study which resolved with manual compression (Table - 2). Many of these minor complications have been reported in other studies as well, although infrequent without any consequence.[4,39,42,43]

The complication rate reported in the pivotal ADO trial was 2.3% with a single death unrelated to the device implantation and one case of device embolization, thereby suggesting that ADO has a good efficacy and safety.[37] No device embolization, pericardial effusion or cardiac tamponade and death occurred in the present study (Table - 2). Device embolization is one of the most common and feared major complication of the transcatheter PDA occlusion being reported to occur in less than 2% of cases in many studies, especially occurring in low volume centres with early experience.[37,38,40-43] It has been widely held that device embolization can result due to improper size

selection of the device, large distensible PDA or improper fixation at he PDA, however, embolized device can be retrieved majority of the times with the help of snare.[41] Death is an extremely rare occurrence but Bilkis et al reported a single death due to device embolization.[38]

Device related complications like, nickel allergy, hemolysis, valvular regurgitation, endocarditis, erosion, LPA stenosis, coarctation of aorta are very rare and infrequently reported events. No device related complications were observed in the present study (Table - 2). Endocarditis is a rare complication but can be minimized with observance of proper dental hygiene and giving antibiotic prophylaxis whenever indicated for six months following procedure. LPA stensosis and Coarctation of aorta result due to protrusion and encroachment of implanted PDA occluder towards Left pulmonary artery and descending aorta respectively.[43] The multicenter ADO trial observed two cases of partial LPA stenosis but no case of significant aortic obstruction.[37] Many studies do report insignificant mild narrowing of aorta suggested by flow acceleration in echocardiography but without any hemodynamic sequelae.[37,39,41,43] However, few series have reported significant aortic obstruction following ductal occluder implantation requiring removal.[4,45] Hemolysis following transcatheter PDA closure has been reported in literature as a rare event resulting due to persistent residual shunt with significant gradient thereby highlighting the importance of elimination of residual flow. All these device related complications occur more commonly in patients of younger age, lower body weight and with larger PDA.[46] Careful patient selection followed by proper sizing of the duct in order to select appropriate size of the device can help minimise these complications.

5. Limitations of the Study

The data presented in the study should be interpreted in the light of certain limitations. The study being a monocentric experience on a small number of cases, the results cannot be extrapolated to the whole population. As children younger than 2 years with ASD and infants younger than 6 months with PDA were excluded from the study cohort, age bias could not be adjusted both for technical success and complications since these procedures are technically challenging and are associated with more complications in these younger patients. The follow-up period was short in the present study ranging from 2 - 24 months and could miss certain rare late complications. Also, the learning curve for transcatheter techniques of ASD and PDA closure was not determined in the present study thereby underscoring the importance of the fact that complications are more common in low volume centres with early experience. Larger prospective studies including infants and lower body weight children with longer term follow-up could addresss these shortcomings.

6. Conclusion

Transcatheter techniques for closure of congenital heart defects have improved rapidly during the past two decades and with the currently available devices, both ASD and PDA closure can be achieved successfully in majority of cases.

Complications do occur but are usually very rare and are mild, especially in younger patients with lower body weight. Thorough clinical examination and imaging is extremely necessary to determine accurate defect size in order to select appropriate device for closure. It can't be overemphasized that careful patient selection along with meticulous imaging can prevent most of the complications encountered during these procedures. The experience with the three set of brands employed in the present study, viz. Cocoon, HeartR and Floret show a good implantation rate for both ASD and PDA. No device related complications were observed in the present study with any of the devices implanted thereby suggesting that all these three brands are both safe and efficacious for transcatheter closure of the defects. Longer term follow-up studies including more number of patients with wide age range are needed to exactly elucidate the difference if any between these devices as shorter and intermediate term follow-up data from the present study reveals encouraging results with these devices along with almost similar performance in the study cohort. Ofnote, with growing number of brands and ever improving design, head to head trials are a need of an hour to determine the accurate efficacy and safety of the devices being employed for the transcatheter closure of the congenital heart defects.

7. Disclosure

None.

8. Conflict of Interest

All authors have none to declare.

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