FULL LENGTH ARTICLE

Safety and efficacy of transcatheter closure of atrial septal defect type II under transthoracic echocardiographic guidance: A case control study

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Background: **Transcatheter closure of secundum atrial septal defect is routinely performed under general anesthesia and transesophageal echocardiography guidance. If patients have good echo windows, the procedure could be performed under transthoracic echo guidance.**

Aim of study: **To evaluate safety and efficacy of the intervention using fluoroscopy and echo guidance.**

Methods: **In a case control study design, 180 patients underwent atrial septal defect closure between January 2010 and December 2016. In 32 patients, the intervention was performed under fluoroscopy and transthoracic echo guidance. Our study group consisted of 22 out of 32 patients (<13 years old). For the other 10 patients, we could not find a matching pair. The data of the study group were compared with an age, weight, and height matched group (controls), who underwent the procedure under transesophageal echocardiography guidance.**

Results: **The diameter of the atrial septal defect, septal length, and most of the rims were comparable. The superior rim and inferior rims were longer in the study group. The devices chosen for the cases were larger than the control group. Procedure time and fluoroscopy times were shorter in the study group. Success rate was comparable. On follow-up, both groups had almost no or minimal incidence of residual shunt.**

Conclusion: **We conclude that transcatheter closure of atrial septal defect under fluoroscopy and transthoracic echo guidance is safe and successful in selected patients who have single central atrial septal defect with adequate septal lengths and adequate septal rims, with high incidence of complete occlusion rate.**

Keywords: 2D echocardiography, Atrial septal defect, Case control study, Transcatheter closure, Transesophageal echocardiography

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1. Introduction

Atrial septal defect is a common congenital heart disease. Surgical closure of atrial septal defect was first performed in 1953 [1]. Successful transcatheter closure was first reported in 1976 by King et al. [2]. Although surgery is a safe and effective procedure with low morbidity and mortality [3], transcatheter atrial septal defect closure became the technique of choice worldwide [4,5], due to its less traumatic and better cosmetic results [6].

In most centers, percutaneous atrial septal defect closure in children is performed under fluoroscopy and transesophageal echocardiography guidance [7,8] and occasionally by using sizing balloons [9]. Transesophageal echocardiography allows close visualization of the defect rims, enables proper positioning of the device and detects the presence of any residual shunts, venous inflow obstruction, or encroachment on the atrioventricular valves. The main disadvantages of using transesophageal echocardiography are the need for general anesthesia, endotracheal intubation, and the need of a backup bed in the intensive care unit after the procedure. Recently, intracardiac echocardiography is being used for atrial septal defect closure; however, its high cost and the need for a larger sheath made its practice limited for children [10]. Other techniques included percutaneous atrial septal defect closure under transthoracic echocardiography guidance without fluoroscopy [11], or percutaneous atrial septal defect closure, under only fluoroscopy [12]. Most of these studies used sizing balloons during the procedure to select the device size [13].

Our aim was to share our experience of percutaneous atrial septal defect closure in children with transthoracic echocardiography and without using sizing balloons and compare it with age, weight, and height matched patients who underwent this procedure under general anesthesia and transesophageal echocardiography guidance.

2. Materials and Methods

Between January 2010 and December 2016 a total of 180 patients with secundum atrial septal defect underwent percutaneous closure at our institute. All the patients were evaluated in the clinic by transthoracic echocardiography obtaining four standard views: (1) parasternal short axis view; (2) apical four-chamber view; (3) subcostal sagittal; and (4) coronal views. A total of 148 patients were scheduled to undergo transcatheter closure under transesophageal echocardiography and fluoroscopy guidance, which necessitates general anesthesia with endotracheal intubation and mechanical ventilation.

Abbreviations

TTE	transthoracic echocardiography
TEE	transesophageal echocardiography
ASD	atrial septal defect II
2D	two dimensional echocardiogram
3D	three dimensional echocardiogram
TCC	transcatheter closure
Post rim	posterior rim
SVC	superior vena cava
IVC	inferior vena cava
MV	mitral valve
RA	right atrium
LA	left atrium

Due to the occasional unavailability of anesthesia, in those patients with very good echo windows and acceptable rims, 32 patients were selected to undergo transthoracic echocardiography guidance and conscious sedation only.

2.1. Inclusion criteria

Patients with atrial septal defect II with adequate septal rims, central position, and good echo windows (according to echocardiography and color Doppler).

2.2. Exclusion criteria

Patients with other associated congenital heart diseases or incomplete surgical atrial septal defect closure. Patients whose weight was <10 kg, <2 years old, or older than 13 years were excluded.

Usually, when clinically acceptable, only children older than 3 years of age (weighing >15 kg body weight) will be taken for transcatheter closure of atrial septal defect. Thirteen years was the upper limit of age chosen, as the oldest patient in the case group was of this age.

2.3. Data

Data collection was performed using excel spreadsheet. The following parameters were collected: demographic data, echocardiographic size of the atrial septal defect, total septal length, adequacy of rims (inferior, posterior, inferior vena cava, superior vena cava, anterior). Procedure time, fluoroscopy time, success rate, complications, device size, and the difference between the device diameter chosen and the atrial septal defect diameter were collected. The last follow-

up was calculated and existence of residual shunt documented for both groups.

2.4. Patients

In a retrospective case-control chart review study, 32 patients were identified as having undergone transthoracic echocardiography while closing their atrial septal defect II. As we decided on a case-control study design, we could only find a match for 22 out of the 32 patients. Our cases were matched regarding age, weight, and height to 22 patients in whom the atrial septal defect was closed under transesophageal echocardiography guidance.

Hence, a total of 44 children < 13 years of age (22 cases = study group and 22 controls = control group) were included in this study.

The project obtained the approval of the hospital Institutional Review Board.

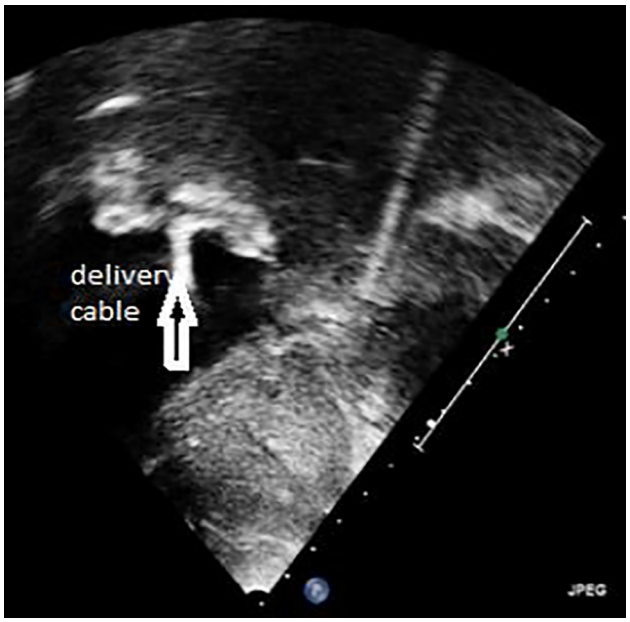

Figure 1. Using transthoracic echo during the procedure, subcostal view showing the Amplatzer device in perfect position with delivery cable before the release of the device

2.5. Procedure

Transthoracic echocardiography was reviewed before the start of the procedure in all 44 patients. In atrial septal defect (study group), the procedure was performed under conscious sedation using midazolam (0.1 mg/kg) and ketamine (1 mg/kg). In patients with inadequate response repeating doses and/or IV fentanyl (0.1 mg/kg) were used according to physician preference. No anesthesiologist or pediatric intensivist were involved during the procedure (see Fig 1).

In the study group, the procedure was guided by fluoroscopy and transthoracic echocardiography. Once the device was in place and felt to be in a good position, periprocedural transthoracic echocardiography using Philips iE 33 xMatrix ultrasound machine (Philipps, Amsterdam, The Netherlands) was selected, that is, four chamber and subcostal coronal views were performed to assure the position of the device and to detect

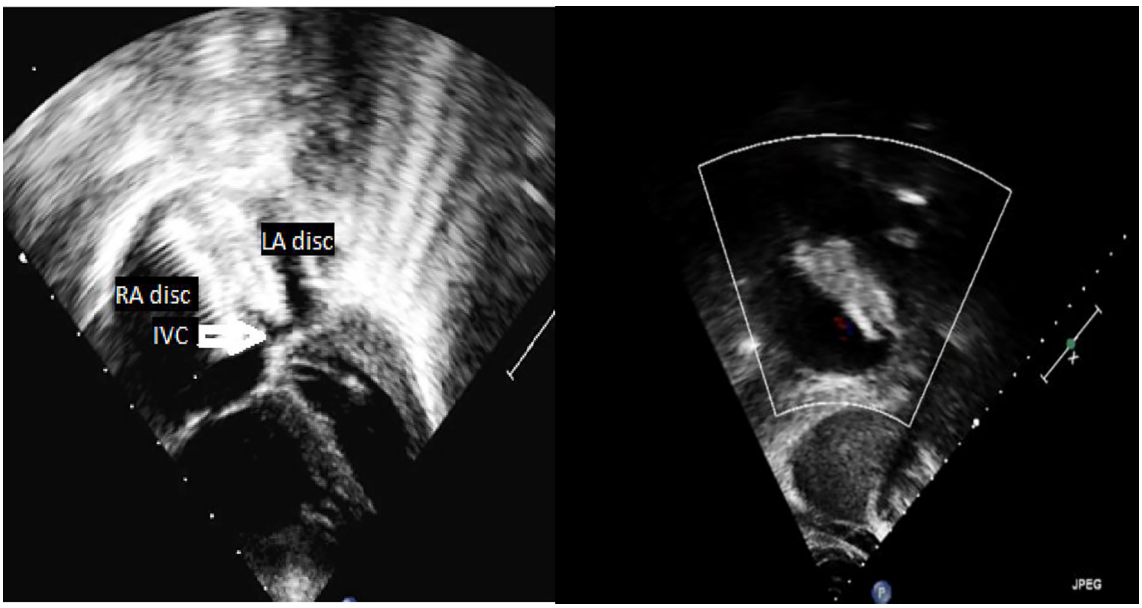

Figure 2. Using transthoracic echo during the procedure; the device in good position after releasing the occluder in 4-chamber and subcostal views.

Table 1. Demographic data (age, weight, height) of the two groups in comparison, showing that both groups are comparable.

	ASD 2D (cases)	ASD TEE (controls)	*p*
Mean age in y ± SD (range)	6.18 ± 2.8 (3–13)	6.27 ± 2.7 (3–13)	$p = 0.430$
Median age in y	5	5	Not significant
Mean weight in kg ± SD (range)	18.9 ± 7.7 (10–45)	19.4 ± 7.3 (12.5–43.5)	$p = 0.405$
Median weight in kg	16	16.65	Not significant
Mean height in cm ± SD (range)	108 ± 21.6 (65–145)	112 ± 13.2 (97–140)	$p = 0.486$
Median height in cm	115	107.5	Not significant

ASD = atrial septal defect; SD = standard deviation; TEE = transesophageal echocardiography.

residual shunting, pulmonary venous return, and function of atrioventricular valves. After a careful push and pull maneuver, the device was released under fluoroscopy observation.

The control group underwent general anesthesia, intubation, and transesophageal echocardiography confirmation of the anatomy preprocedure and transesophageal echocardiography guided atrial septal defect closure using Philips iE 33 xMatrix ultrasound machine. An Amplatzer device (AGA, Minnesota, USA) was implanted according to the usual interventional methods, as described elsewhere [14]. Balloon sizing was not used in either of the two groups. Usually, a device was chosen 2–4 mm larger than the diameter of the atrial septal defect (see Fig 2).

Study group patients were sent to the recovery room until fully awake. Some patients with general anesthesia and transesophageal echocardiography guidance, had to attend the intensive care unit for few hours of observation after extubation. All patients were discharged the next morning after the intervention. Transthoracic echocardiography as well as electrocardiogram were performed in all cases before discharge.

All 44 patients were given a follow-up appointment. Transthoracic echocardiography and electrocardiogram were done in the follow-ups of 1 month, 3 months, and 6 months, and according to clinical status on a yearly basis. At follow-up, their clinical status was documented, any arrhythmias excluded by electrocardiogram and the existence of any residual leak documented by transthoracic echocardiography.

2.6. Statistical analysis

Using JMP Pro 13 (SAS Campus Drive Building, Cary, NC 27513-2414, USA). The data were presented as mean ± standard deviation. To evaluate the difference between groups for numerical numbers the Student *t* test was used. The Chi-square test and Fisher's exact test were used for categorical data comparison. Statistical significance was defined as $p < 0.05$.

3. Results

3.1. Demographics (selection of cases and controls)

The 44 selected patients were divided in two groups (22, study group and 22, control group). In the study group, nine (40.9%) were females and 13 (59.1%) were males. In the control group, 12 (54.5%) were females and 10 (55.5%) were males. The remaining demographics for comparison are listed in Table 1. The mean of age, weight, and height of both groups were comparable (see Table 1).

3.2. Echo findings in comparison

The mean atrial septal defect diameter in the study group was 15.6 ± 6.3 (14–28) mm, not different from the control (transesophageal echocardiography) group, where the mean atrial septal defect diameter was 15.3 ± 3.9 (12–30) mm.

The mean size of the implanted device diameter in the study group was 20.4 ± 5.4 (10–28) mm comparable to the mean size of the implanted device in the control group of 18.3 ± 4.4 (12–30) mm.

The calculated difference between the device diameter and maximum atrial septal defect diameter between both groups, which represent the upsizing of the device, was significantly larger in the study group; ($p = 0.0208$); (study group: 4.8 ± 2.1 mm), (control group: 2.6 ± 1.9 mm) (see Table 2).

3.3. Procedure

As there was one embolization of the device in the study group, the success rate was 95.5%, compared with 100% in the control group. The device could not be retrieved, and the patient was sent for surgical closure of the atrial septal defect. In this patient during surgery, it was found that the inferior vena cava rim was deficient.

Fluoroscopy time as well as procedure time in the study group was significantly shorter than for the control group (see Table 3).

All other patients in both groups could be sent home 1 day after the intervention.

Table 2. Echocardiographic measurements in comparison between both groups. Data includes ASD diameter, septal length, the five different rims measured, the mean device diameter, and the mean difference between the chosen device size minus the ASD diameter. The difference of the device diameter minus ASD diameter was highly significant (p = 0.0208), longer in the study group than in the control (TEE) group. The significant categories are underscored and are presented in bold.

	Study group (cases)	Control group (controls)	*p* significance
Defect diameter (mm) ± SD (range)	15.6 ± 6.3 (14–28)	15.3 ± 3.9 (12–30)	0.8195
Total septal length (mm) ± SD (range)	36 ± 5.1 (30–52)	33 ± 4.5 (16–38)	**0.0422**
Device diameter (mm) ± SD (range)	20.4 ± 5.4 (10–28)	18.3 ± 4.4 (12–30)	0.1540
Device/defect difference ± SD (range)	4.8 ± 2.1 (1–10)	2.6 ± 1.9 (0–7)	**0.0208**
Post rims (mm) ± SD (range)	6.8 ± 2.8 (5.5–8.1)	5.0 ± 1.8 (4.2–5.8)	**0.0185**
AV rims (mm) ± SD (range)	6.3 ± 2.4 (0– 9)	4.7 ± 1.8 (1–14)	**0.0109**
SVC rims (mm) ± SD (range)	6.1 ± 1.6 (4–11)	6.3 ± 3.2 (3–13)	0.8126
IVC rims (mm) ± SD (range)	5.4 ± 1.9 (0–8)	4.4 ± 3.0 (0–14)	0.1189
Aortic rims (mm) ± SD (range)	6.3 ± 1.7 (3–9)	6.0 ± 1.7 (3–10)	0.6648

ASD = atrial septal defect; AV = atrioventricular valve rim; IVC = inferior vena cava; Post rim = posterior rim; SD = standard deviation; SVC = superior vena cava.
There is no statistical difference between both groups in regard to the mean ASD size and the mean device size chosen. However, it should be noted that in the study group, there is a trend towards choosing larger devices compared with the other group. The septal length in the study group was significantly longer than in the control (TEE) group. Hence the device/defect difference was significantly larger in the study group. In regard to the rims, in the study group, the posterior rim as well as the inferior rim (towards the MV) were significantly longer. In the statistically significant different factors, the *p* value was underscored, for better reading.

Table 3. Procedure data between both groups in comparison. The fluoroscopy time as well as the procedure time are significantly shorter in the study group. Success rate and complication rate were comparable. There is a trend for the study group to have a shorter follow-up time. In the statistically significant different factors, the p value was underscored and are presented in bold, for better reading.

	Study group (cases)	Control group (controls)	*p* significance
Fluoroscopy time (min) ± SD (range)	6.6 ± 4.0 (2.3–80.4)	11.6 ± 5.8 (3.2–27)	**0.0023**
Procedure time (min) ± SD (range)	35 ± 10.8 (16–230)	66 ± 31.5 (13–120)	**0.0002**
Success rate	95.5%	100%	Not significant
Complications	Embolization of device in 1 case	None	
FU in y mean ± SD (range)	2.1 ± 1.97 (0.08–6.3)	3.2 ± 2.3 (0.73–10.5)	0.0975

FU = Follow up; SD = standard deviation.

3.4. Follow-up

In the first follow-up of the patients, there were minimal leaks through the device in nine patients from each group. The mean follow-up for both groups was comparable (2.1 years for the study group and 3.2 years for the control group). Regardless of the duration at the last follow-up, there were minimal leaks in five patients in the study group and three patients in the control group. The difference was not significant. The device was in a good position in both groups. None had arrhythmias. No change in the mitral and tricuspid valve status was noticed.

4. Discussion

Transcatheter closure of atrial septal defect in children is routinely performed under general anesthesia and transesophageal echocardiography guidance [7,15]. Transesophageal echocardiography allows close visualization of the defect rims, enables proper positioning of the device,

and determining any residual shunts, venous inflow obstruction, or encroachment on the atrioventricular valves. The main disadvantages of using transesophageal echocardiography are the need for general anesthesia, endotracheal intubation, prolonging procedure time, need of backup bed in intensive care unit, and a relatively long stay in the hospital.

In a case control study design manner, we compared safety and efficacy of transcatheter percutaneous atrial septal defect closure in children performed solely under guidance of fluoroscopy with periprocedural transthoracic echocardiography with an age and weight matched group who underwent transcatheter closure under general anesthesia and transesophageal echocardiography guidance.

Transcatheter closure of atrial septal defect utilizing only transthoracic echo was favorable. The success rate was comparable. The procedure and fluoroscopy time was significantly shorter in the study group. Furthermore, safety and midterm outcome in regard to residual leak was comparable.

It is worthwhile mentioning that in the study group, the mean atrial septal defect size was similar to the control group. Although for the study group, the mean diameter of the device chosen was statistically not different from the control group, but in the study group, the devices were generally larger than for the control group. This could probably be explained by the fact, that in the study group, the septal length of interatrial septum was significantly longer than in the control group, which encouraged us to use larger devices for safety reasons. Expectedly, also in the study group the mean device/defect difference was significantly larger than in the other group.

In regard to the atrial septal defect rims measured, apart from two rims (superior rim and inferior rim), the other rims were comparable in the two groups.

The superior and inferior rim were significantly larger in the study group than in the control group. This underlined that our selection for patients to undergo atrial septal defect closure without transesophageal echocardiography and without sizing balloon was adequate.

There were some issues to consider during the procedure; to obtain good echocardiographic views and due to space limits and infection control issues, only apical four chamber view and subcostal sagittal and coronal views were obtained and seemed to be more than enough. Other authors emphasized the importance of three-dimensional imaging, for better visualization of the atrial septal defect under transthoracic echocardiography guidance [13]. Furthermore, to protect the echo person from radiation hazards, fluoroscopy and echocardiography could not be done simultaneously, as is possible when transesophageal echocardiography is utilized.

Other studies utilizing this technique of percutaneous atrial septal defect closure under transthoracic echocardiography guidance were mostly done in adults. Additionally, in most of these studies, sizing balloons were used during the procedure to select the correct size of the device for closure [13]. Erdem et al. [13] compared transcatheter closure of atrial septal defects in children and adults under transthoracic echocardiography in 206 patients and compared the results with 131 patients who underwent intervention under transesophageal echocardiography guidance. Both groups were not matched [13]. Praz et al. [12] described the safety and feasibility as well as long-term results of atrial septal defect closure under fluoroscopy guidance only in adults while they used transesophageal echocardiography and general anesthesia in children. Bartakian et al. [16] also suggested that in selected pediatric patients, use of transthoracic echocardiography and fluoroscopy is safe and efficacious for atrial septal defect device closure. In all three studies, balloon sizing was done before selecting the device size.

In our patients, although with a smaller number of patients, our groups were matched with regard to age, weight, and height. Additionally, we did not utilize a sizing balloon. We selected our devices only on transthoracic echocardiographic imaging.

Pan et al. [11] mentioned in their study that transcatheter closure of atrial septal defect can be performed solely under transthoracic echocardiography without transesophageal echocardiography or fluoroscopy. However, for the patients with poor echo windows, transthoracic echocardiography could not give clear visualization of the catheter to guide the placement of the device and transesophageal echocardiography was used in those cases [11]. To avoid this, we used limited fluoroscopy and there were no complications because of good visualization of the catheter.

Unlike the other studies, we also compared the measurements of the atrial septal defect as well as the different rims of the septum, to understand whether these rims matter in choosing our patients for this less invasive procedure.

Hanslik et al. [9] performed their atrial septal defect cases under deep sedation using propofol while we used midazolam and ketamine and in all cases and we did not face any sedation problem. We could show in a previous study [17] that conscious sedation given by the pediatric cardiologist in absence of anesthesiologist is safe.

4.1. Limitations of the study

Aside from the retrospective nature of our study, one of the major limitations is the relatively small number of patients in this cohort. Additionally, case-control studies are sometimes less valued for being retrospective. Also, the selection of age, weight, and height matched cases and controls could be difficult to conduct. In our study we had to reduce the original 32 patients with only transthoracic echocardiography guidance to 22 patients to find the matching control group, which led to the smaller sample size for both cases and controls. Therefore, these numbers might be even less representative for the ''community'' of transthoracic echocardiography atrial septal defect closure. We believe having a case-control study design is still more valuable than a case series.

We conclude that transthoracic echo guided for atrial septal defect II without balloon sizing is safe and successful in selected patients who have good echocardiographic windows, single central atrial septal defect II with good septal lengths, and good septal rims. It is less cumbersome for the patients, has no need for intubation, no anesthesia, and no transesophageal echocardiography. Procedure and fluoroscopy time are significantly shorter than atrial septal defect closure under transesophageal echocardiography guidance. There is no need for intensive care unit stays and hence it is more cost effective. It has the same high incidence of complete occlusion rate as patients under transesophageal echocardiography guidance.

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