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Reliability of Transthoracic Echocardiography to Guide Transcatheter Closure of Atrial Septal Defects

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Abstract: Introduction: Transthoracic echocardiography (TTE) is used for the pre-interventional assessment of atrial septal defects (ASDs). However, the efficacy of TTE for guiding transcatheter closure of ASD still has not been widely assessed. The aim of this study was to evaluate the efficacy, and reliability of TTE in pre selecting ASDs for transcatheter closure using the Occlutech Figulla ASD occluder. Patients & methods: This was a prospective study carried out between April 1, 2019 and February 1, 2020. Forty-nine patients were referred for transcatheter closure of their ASDs at mean age of 22±18 years and mean weight of 36±17 kg. TTE was used to measure the largest ASD diameter in different views. The device diameter used for closure was chosen based on the largest diameter obtained by TTE plus 3-5 mm if ASD < 20 mm, and 5-6 mm if ASD > 20 mm. Results: The patients divided into two groups according to the size of ASD, group A when the size of the defect was < 20 mm, and group B when the size of the defect was > 20 mm. The average size of the defects for group A 16±4 mm, and 28±6mm for group B. the average size of the devices used was 19±5mm, and 33±7 mm for group A and B respectively. Transcatheter closure of ASD was successful in 41 patients (83.6%), and failed in 8 patients (16.4%). In 7 out of the 8 failed cases, the closure was achieved successfully using transesophageal echocardiography (TEE) guidance and one patient, was referred for surgical closure due to an acute complication due to large pericardial effusion and tamponade that resulted from injury to the left atrial appendage. The successful rate for selection of the appropriate ASD device was 83.6%. Conclusion: this study demonstrated that TTE is satisfactory & reliable in selecting the appropriate ASD device size & in guiding transcatheter closure of ASD.

Keywords: Atrial Septal Defect, Transthoracic Echocardiography, Transesophageal Echocardiography, Transcatheter Closure of ASD

1. Introduction

Transcatheter closure of atrial septal defect (ASD), initially described by King and Mills in 1976 [1], is now an accepted alternative to surgical closure. It offers safer and as effective alternative to the traditional surgical closure [2, 3].

In addition to fluoroscopy, traditionally, transesophageal echocardiography (TEE) [4, 5] or intracardiac echocardiography (ICE) [6] have been used as imaging modalities during the closure procedure. However, both methods are relatively inconvenient, with TEE usually requiring general anesthesia and with ICE the need for another puncture site and potential increase in cost.

TEE allows accurate measurement of the defect diameter and visualization of the rims, guides proper positioning of the device and assessment of residual shunts or obstruction to venous inflow and any encroachment on neighboring structures [4, 5]. However, the use of TEE is associated with longer procedural times and may be associated with complications.

There is limited data about the use and reliability of TTE

in guiding device closure of ASD [7, 8].

Therefore, our goal was to share our experience and report on the reliability and effectiveness of this modality (TTE) in closing ASDs using Occlutech Figulla ASD occlude.

2. Patients & Methods

This was a prospective study conducted in our center from April 2019 to February 2020. Forty-nine patients with secundum type ASD were referred to the catheterization laboratory for transcatheter closure of their ASDs. There were 30 females and 19 males with an age 22±18 years, and the body weight ranged from 15-92 Kg (mean 37kg).

Inclusion criteria were the presence of a significant atrial level shunt with right ventricle volume overload as determined by TTE and deemed suitable for catheter closure. While the exclusion criteria included patients less than 3 years of age; patients less than 12 kg in weight and total atrial septal length of less than the left disc diameter of the chosen occluder as measured by apical four chambers view using TTE.

Before the procedure, the anatomy of the defect was evaluated by TTE using Vivid-9 machine (GE Healthcare, USA) in all patients.

The ASD position and size were assessed from standard apical, parasternal and subcostal views. The defect was measured in each of these views without and with color Doppler, and maximum diameter was determined and atrial septal rims were measured.

From subcostal sagittal views, the postero-superior, antero-inferior and postero-inferior rims were measured as the distance from the defect to the openings of the superior and inferior vena cava respectively.

From subcostal coronal view, the posterior rim was measured as the distance from the defect to the posterior atrial wall.

The anterior-inferior rim was measured as the distance from the defect to the anterior edge of the mitral valve. In the apical four-chamber view, the entire septum was measured. From the parasternal short axis view, the anterior-superior rim was measured the distance from the defect to the aortic root.

As most atrial septal defects are oval in shape, the largest diameter may be detected in different cross sectional views in different patients, and thus the largest ASD diameter in a given patient was chosen as the reference ASD diameter for selecting the optimal size of device.

Any concomitant cardiovascular abnormality was searched for and if deemed appropriate for catheter intervention, the procedure was done concomitantly, otherwise, surgical repair was recommended.

After obtaining informed consent, patients were sent to the catheterization laboratory for the interventional procedure.

The procedures were done under deep sedation using ketamin and/or midazolam [doses used for ketamin 1.5 mg/kg, and midazolam 50 mic/kg] for those patients younger than 18 years while for patients older, only local anesthesia was used.

The femoral artery was cannulated for monitoring of systemic pressure. The vascular access was obtained through the right femoral vein.

After complete right heart catheterization, an extra stiff guide wire 0.035" was advanced through the end-hole catheter crossing the defect to be fixed in the left upper pulmonary vein, meanwhile, intravenous heparin bolus 100 unit/kg was administered, then in 11 patients ASD balloon stretched diameter was determined using appropriate sizing balloon catheters (AGA Medical corporation, Plymouth, MN, USA).

The occlutech figulla ASD occluders (occlutech AB, Helsiborg) were used for closure of ASDs in this study.

Device size selection depended on ASD size, position and whether the ASD rims were sufficient (more than 5mm). The device size chosen as the following:

For patients with ASD < 20 mm, device size selection=largest diameter of ASD + (3 - 5 mm).

For patients with ASD > 20 mm, device size selection=largest diameter of ASD + (5 to 6 mm).

The closure steps were done in a way similar to the technique described by Hijazi [9].

During the ASD closure, fluoroscopy was used to guide the catheter tip positioning and monitor device deployment and release.

TTE was done during several steps of the procedure using Sonosite echocardiographic machine. The TTE was used to confirm correct left atrial disc position and whether the device was deployed correctly. Then the aortic, mitral, IVC, SVC flows and the presence of any residual shunt were investigated by different views.

Push and pull test "Minnesota wiggle" to assess device stability was used by pushing and pulling the cable gently under TTE. If the device was stable, it was released from the cable.

Dilator assistant method was used in one patient with large ASD and deficient antero-superior rim [10].

Devices: we used figulla (occlutech GmbH, jana Germany) ASD occluder device in all patients.

Patients received aspirin [100 mg] one day before and continued for 6 months after closure.

Statistical analysis:

Descriptive statistics such as mean, median, standard deviation and frequency were calculated for each demographic and clinical characteristic whenever appropriate.

3. Results

The procedure was successful in 41 patients (83.6%), and failed in 8 patients (16.4%). In 7/8 patients, guidance was switched to TEE because of their rim deficiency, while 1 patient referred for surgery immediately after TTE because of complication due to large pericardial effusion and tamponade that resulted from injury to the left atrial appendage. The ASD devices were deployed 60 times (mean 1.46 times per patient) in the successful cases.

The ASDs were classified according to their anatomic characteristics (table 1): 35 patients had (centrally located defect "good rims"), 7 (deficient anterosuperior rims), 4 (deficient posteroinferior rim), 2 (multiple defects), & 1 (multi-fenestrated defect with aneurysm).

The total patients (49) were divided into 2 groups (table 2) according to the size of ASD: group A (29 patients with ASD size <20 mm) and group B (20 patients with ASD ≥20 mm).

In group A, the transcatheter closure of ASD under TTE guidance was successful in all patients with one ASD device, without complications or residual shunts including (27 patients with centrally located defect, 2 patients with deficient anterosuperior rim). In 27 cases the left disc was opened in the left atrium, one case in the left upper pulmonary vein, and in one case in the right upper pulmonary vein. The device was deployed 38 times (1 time in 20 patients & 2 times in 9 patients) with an average of 1.31 per patient. The median time of fluoroscopy was 7.8, ranged from 5.5 to 16 min [tables 2, 3, 4].

In group B, the transcatheter closure of ASD under TTE guidance was successful in 12 patients including (8 patients with centrally located defects, 4 patients with deficient anterosuperior rims). In successful cases the left disc was opened in the left atrium in 7 patients, in the left upper pulmonary vein in 2 patients, and the last 2 in the right upper pulmonary vein. The dilator technique [10] was used in 1 patient. The devices were deployed 21 times: 4 patients (1 time), 7 patients (2 times) & 1 patient (3 times). The median time of fluoroscopy was 26 min, ranged from 14 to 63 min [Tables 2, 3, 4].

In group B, 7 patients failed the attempt at transcatheter closure under TTE guidance. Therefore, the guidance was switched to TEE. Failure was due to deficient posteroinferior rim in 4 patients, multiple defects in 2 patients and multiple defects with aneurysm in one case. Two patients of 7 (patients who underwent the procedure under TEE) were referred for surgical closure due to residual shunt (Tables 3, 5).

In group B, 1 patient who underwent transcatheter closure under TTE guidance was referred for surgery due to large pericardial effusion and tamponade that resulted from injury to the left atrial appendage using the Dilator technique (see below for more details).

Table 1. *Anatomic characteristics of ASDs.*

Group	Centrally located defect	Deficient anterosuperior rims	Deficient posteroinferior rims	Multiple defects±aneurysm
A	27 patients	2 patients	0	0
B	8 patients	5 patients	4 patients	3 patients

Table 2. *Classification of ASD according to size, successful rate & selection of guiding tool.*

Group	Total No. of patients (49)	ASD Size	TTE use	successful rate of TTE use 83.6%	TEE use
A	29	<20 mm	29 patients	100%	0
B	20	≥20 mm	12 patients	60%	7 patients

Table 3. *The average ASD Size, Average Device size, fluoroscopy time & successful Selection Rate of ASD device.*

Group	Average ASD Size	Average Device Size	Fluoroscopy time	Successful Device Selection
A	16 mm (Min.11.5mm-Max.19mm)	20.6 mm (Min.15mm-Max.24mm)	5.5-16 min. (mean 7.8 min.)	28 patients 96.50%
B	26.2 mm (Min.21mm-Max.34mm)	32 mm (min.26mm-Max.40mm)	14-63 min. (mean 26 min.)	11 patients 91.60%

Table 4. *Site of release of LA disc & using of assisted method.*

Group	Left atrium	Upper left pulmonary vein	Upper right pulmonary vein	Dilator method use
A	27 patients	1 patient	1 patient	0
B (successful cases)	7 patients	2 patients	2 patients	1 patient

Table 5. *Age, Body Weight and Causes of TTE Switch to TEE.*

No.	Age (Years)	Sex	Body Weight (Kg)	Causes to Use TEE
1	6	Male	20	Deficient posteroinferior rim
2	8	female	25.5	Multiple Defects
3	9.5	female	27	Deficient posteroinferior rim
4	12	female	31	Multiple Defects With aneurysm
5	15	male	36	Multiple Defects
6	16	male	45	Deficient posteroinferior rim
7	42	female	71	Deficient posteroinferior rim

Six of 7 patients who had deficient anterosuperior rims were closed successfully under TTE guidance.

All patients with deficient posteroinferior rims failed transcatheter closure attempt under TTE guidance.

The dilator assisted technique under TTE monitoring was used in 2 cases with deficient anterosuperior rim. In one case, the attempt was successful and in 1 patient the procedure was complicated by development of pericardial tamponade and the patient was referred for surgical closure.

The successful rate for selection of the appropriate ASD device in group A was 96.5% (28 patients) and the successful rate for selection of ASD in group B was 91.6% (11 patients).

So, the ASD diameter measured by TTE correlated well with ASD device size. The diameter for the ASD and ASD device size were as follows: group A: 16±4 mm, 19±5 mm. Group B: 28±6mm, 33±7 mm. In general, the ASD device size was about 3.5-6 mm larger than ASD diameter measured by TTE (table 3).

The only complication encountered in our study was the case of left atrial appendage perforation (mentioned above).

4. Discussion

Over 35 years ago by King and Mills, transcatheter ASD closure has evolved with considerable advances in device technology and imaging tools to guide the procedure.

In many centers, 2D TEE monitoring under general anesthesia is the gold standard method for guidance of ASD closure. Recently intracardiac echocardiography and three-dimensional TEE have gained acceptance as alternative imaging modalities for closure [11, 12].

The main disadvantages of TEE include: the need for general anesthesia with/out endotracheal intubation and prolonged procedure times [13, 14].

On the other hand, ICE eliminates the need for general anesthesia, however, it is still an expensive modality for many centers and it requires an additional vascular access.

TTE not only reduces the procedure time but also is more cost effective.

The quality of images obtained by TTE is less optimal than those obtained by TEE. However, the quality is influenced by factors such as the weight of patient, obesity, thoracic deformity and presence or absence of lung disease.

During the study period, the overall success rate of closure using TTE as an imaging modality was 83.6% with 100% success in patient with ASD size less than 20mm. Therefore, we believe that TTE is a reliable tool to guide transcatheter closure of ASD and our results were comparable to those reported by Wang G [15] and Simkova [16], where they reported success rates of 88.3% and 87.8% respectively.

The most common causes of failure of TTE guidance of transcatheter closure and the need to switch to TEE in this study were deficient postero-inferior rims and presence of multiple defects. These findings were also influenced outcome as reported by others [17, 18].

Therefore, we believe that all patients with sufficient septal rims and good acoustic windows and some selected patients who may have been considered as having complex ASDs, the procedure can be done safely and effectively under TTE guidance.

In this study we found that an ASD with deficient antero-superior rim can be closed successfully in most patients and this finding is consistent with findings reported by Fu Huang et al [19] who found no statistical difference in closing ASDs with or without antero-superior rims.

At present, we use TTE for the pre-interventional examination of ASDs in all patients. We used multiple views to obtain the largest ASD diameter and used this diameter as the reference for selection of the device size. The overall success rate in selection of ASD device size was 95%. Again, these results are comparable to those reported by Tan et al [20]. Further, the stretched ASD diameter (measured by sizing balloon) correlated well with TTE measurements obtained in the subcostal views (long and short axis). The stretched diameter can be estimated as following formula: (1.09*TEE obtained diameter in mm + 3.9). The difference between the measured and predicted values was within 2mm.

In conclusion, we believe TTE is a very useful imaging modality and it can accurately estimate the stretched diameter, which in turn could be used for selection of device size for occlusion of the ASD.

5. Conclusion

In this study, we conclude that the use of TTE in assessment of ASD prior to closure, and as guidance in addition to fluoroscope for transcatheter closure of ASD is reliable, and safe, and time consuming.

Data Availability Statement

All data generated or analyzed during this study are available on request.

Conflict of Interests

No conflict of interests.

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