Transesophageal Echocardiographic Monitoring for Transcatheter Closure of Atrial Septal Defect

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Background and purpose: Transcatheter closure of atrial septal defect (ASD) is generally performed under fluoroscopy alone. Recently, we have used transesophageal echocardiography (TEE) monitoring as an aid in performing this procedure. The purpose of this study was to evaluate the efficacy and complications associated with this use of TEE.

Methods: Transcatheter closure of ASD was accomplished under TEE guidance simultaneously with fluoroscopic imaging in 11 patients aged 3 to 33 years (weight, 15.4–62.9 kg). TEE was successfully performed in all patients after endotracheal general anesthesia. The ASDs were reexamined before catheterization. The appropriate placement of the occluder device was evaluated.

Results: Seven cases were uneventful with successful ASD occluder implantation, but one failed because of a large ASD (24.7 mm). In three cases, transcatheter closure was aborted after TEE examination, one with a large ASD (27.05 mm), one with an ASD that was too small, and one with multiple fenestrated ASDs.

Conclusions: Routine TEE monitoring for transcatheter closure of ASDs is effective for evaluation of ASD before implantation of an occluder, to ensure the proper seating of the occluder after the defect occlusion is complete.

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Key words:
atrial septal defect
atrial septal occluder
transesophageal echocardiography

In the past 20 years, transcatheter therapy for many different types of congenital heart defects has been well described [1–10]. The secundum type of atrial septal defect (ASD) is the most amenable to the transcatheter closure technique. The first experimental closure of ASD was performed more than 20 years ago. Many types of device have been developed and undergone clinical trials since then. The Amplatzer® Septal Occluder (AGA Medical Corporation, Golden Valley, MN, USA) is a novel device constructed of Nitinol mesh. It has polyester–Dacron disks in both the left atrial and right atrial components of the occluder, as well as in the central 'waist' that connects the two atrial discs. Correct placement of this device relies on fluoroscopic imaging.

The relatively recent development of transesophageal echocardiography (TEE) imaging transducers interfaced with steerable endoscopes has altered the nature of echocardiography. These "semi-invasive" studies provide high-quality tomographic images of the heart and great vessels, unaffected by superimposed lung tissue and body habitus [11]. The use of TEE during cardiac surgery has been well described for patients whose precordial echocardiographic studies are inadequate for diagnostic purposes, in both intensive care unit and outpatient settings [11].

This report describes the combined application of TEE and fluoroscopic imaging in the performance of transcatheter closure of ostium secundum ASD. The efficacy and safety of the use of TEE for ASD closure were also examined.

Methods

Patients

Between 27 April and 15 June 1999, 11 patients, aged 3 to 33 years (median, 9 yr) and ranging in weight from

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15.4 to 62.9 kg (median, 25.1 kg), underwent attempted transcatheter closure of ASDs at National Taiwan University Hospital (Table). These procedures were performed under a protocol for human investigation approved by our institutional review board, using an investigational device being evaluated under the approval of the US Food and Drug Administration (investigational device exemption [IDE]-approved).

Patients underwent TEE monitoring and fluoroscopic guidance simultaneously during placement of the atrial defect occluder device. The procedure was performed with patients under general anesthesia, as required by the study protocol.

Patients were prepared in standard fashion for cardiac catheterization and transcatheter atrial defect closure. Patients fasted overnight and were not premedicated. Anesthesia induction was performed with intravenous thiopental (5 mg/kg), fentanyl (2 μg/kg), and atropine (0.01 mg/kg). Muscle relaxation was accomplished with intravenous atracurium (0.5 mg/kg). The trachea was subsequently intubated with an endotracheal tube appropriate for the patient's age and size, and the presence of an air leak around the endotracheal tube of less than 20 cm H_2O positive airway pressure was confirmed in children. Anesthesia was maintained for the duration of the catheterization procedure with intravenous propofol infusion (150 $\mu g \cdot kg^{-1} \cdot min^{-1}$) and oxygen; supplemental atracurium was infused when required.

Transesophageal echocardiography

TEE was performed with a commercially available GE Vingmed Ultrasound AS echocardiography machine (Horten, Norway) interfaced with a 5-MHz multiplane TEE probe, mounted on an endoscope. The probe has a transverse diameter of 15.7 mm, and is mounted on a shaft measuring 10 mm in diameter. The tip of the endoscope has 90° forward mobility and approximately 40° reverse and lateral mobility. This transducer provides a 90° sector for echocardiographic imaging and also provides for color-flow and pulsed-Doppler flow analyses.

After the patients were anesthetized and intubated, the lubricated TEE probe was introduced with the patient in the supine position, the head in the midline position, and the neck slightly flexed. Under direct laryngoscopic visualization, the probe was passed gently into the esophagus. The patient's head was kept in a neutral position, and the absence of change in the air leak around the endotracheal tube was confirmed. To minimize the possibility of laryngeal or other injury, the probe was left in place for a maximum of 30 minutes, which was more than adequate to obtain the necessary imaging data before, during, and after placement of the ASD occluder.

Comprehensive TEE examinations were performed, using a sequence of transducer positions and tomographic sections, as described by investigators at the Mayo Clinic [11]. Transducer positioning was selected to provide optimum imaging of the interatrial septum, which is best examined in multiple short-axis and four-chamber imaging planes. The size and site of the ASD was reviewed, and the distance from the rim of the defect to the mitral valve, right pulmonary veins, and coronary sinus was estimated. A rim of more than 5 mm in each direction was required for the implantation.

TEE monitoring and guidance of ASD closure involved identification and localization of atrial defects

Table. Findings at precatheterization precordial echocardiography, cardiac catheterization, and transesophageal echocardiography (TEE) in patients with atrial septal defect (ASD)

Patient No.	Age (yr)	Weight (kg)	Precordial echo* (ASD size, mm)	TEE (ASD size, mm)	Stretched ASD diameter (mm)	Occluder size (mm)	Clinical result
1	6.7	25.1	10.5	1	ND	ND	ND
2	3.5	17.2	9.5	15	15.15	16	Implanted/closed
3	6.1	19.1	10.3	16	22.7	22	Implanted/small Residual L–R shunt
4	3.5	15.4	5.7–8.3	8	ND	8	Implanted/closed
5	7.7	20.1	8–10	12 x 18	15	16	Implanted/closed
6	10.4	62.9	9	8–9	8.5	9	Implanted/closed
7	9.6	23.0	10.8–12.5	12 x 13	12.8	15	Implanted/closed
8	31.1	57.6	15	17 x 13	13.9	22	Implanted/closed
9	33.3	57.0	18.5	24.7	ND	30	Failed
10	27.5	47.4	13.5	9	27.05	ND	ND
11	23.7	50.0	12.5–14.2	Multiple fenestrated ASDs	ND	ND	ND

*Size was measured in subcostal four-chamber view. ND = not done; L–R = left to right.

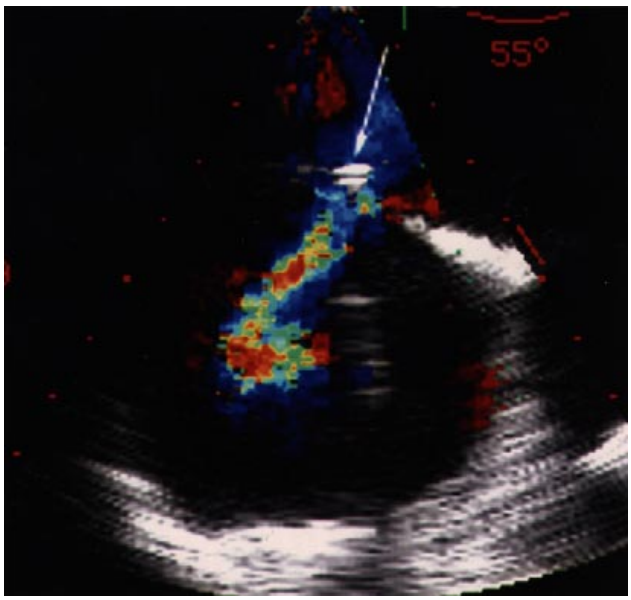

Fig. 1. *Short-axis transesophageal image of the atrial septum, showing a marker catheter (arrow) crossing the atrial septal defect.*

as well as careful measurement of the defect diameter, to assist in the placement of the marker catheter across the ASD (Fig. 1). TEE was also used to detect the number of atrial defects (Fig. 2), and to facilitate balloon sizing of the defect (Fig. 3). During placement of the occluder device, TEE provided visualization of the defect and its margins, and was used to ascertain that the disks of the device were properly aligned and well seated on both sides of the interatrial septum (Figs. 4 and 5). Transcatheter closure was not performed if there were multiple ASDs, or if the ASD diameter was larger than 24 mm on TEE assessment, or if the residual septum (rim toward the aorta) was smaller than 5 mm.

After release of the properly placed occluder device, TEE was used to visualize the anatomically closed defect, and color-flow mapping was used to evaluate the presence and location of any residual left-to-right interatrial shunting.

Results

All 11 patients had uncomplicated ostium secundum ASDs with left-to-right shunts and underwent attempted transcatheter closure of ASD. Seven had successful implantation of occluder devices, and all of the defects were closed with the transcatheter technique (Table). In one patient (patient 9), transcatheter ASD closure failed because the defect diameter was too large (24.7 mm) to place the device. Multiple fenestrated ASDs were found after TEE examination (Fig. 2) in patient 11, so the transcatheter procedure was canceled. In patient 1, TEE examination showed that the defect was so small that transcatheter closure was not necessary. Transcatheter closure in patient 10 was cancelled because the ASD was too large (27.05 mm).

The Table summarizes the findings at precatheterization precordial echocardiography, cardiac cathe-

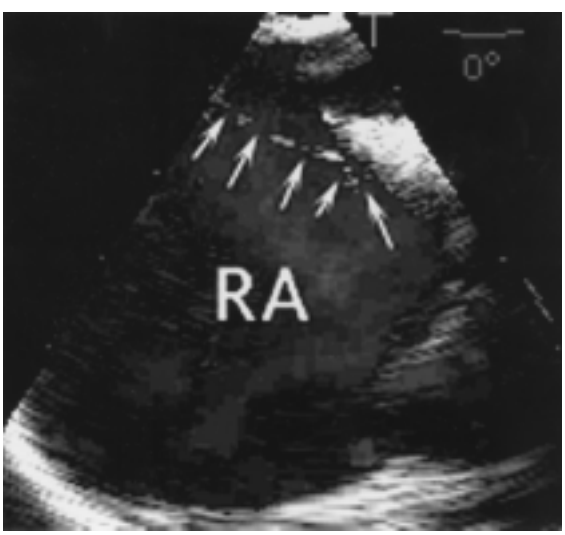

Fig. 2. *Short-axis transesophageal scan of the atrial septum, demonstrating multiple atrial septal defects (arrows), with shunt flow from the left atrium to the right atrium (RA).*

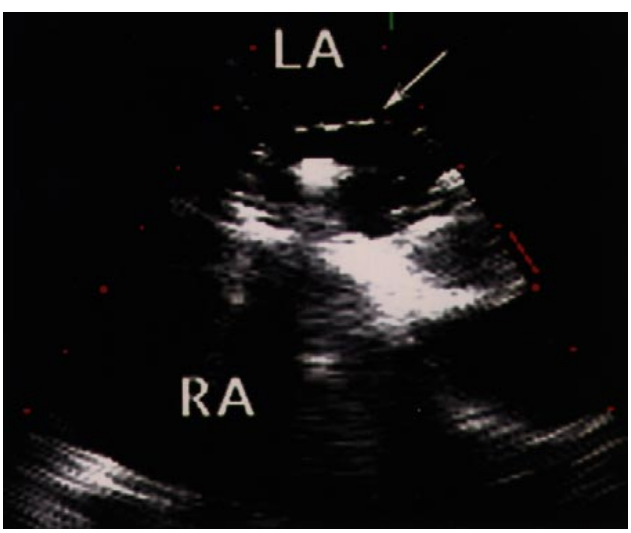

Fig. 3. *Transesophageal echocardiographic image of the sizing balloon crossing the atrial septal defect (arrow). The sizing balloon is pulled through the atrial septal defect to measure the "stretched diameter" of the defect. LA = left atrium ; RA = right atrium.*

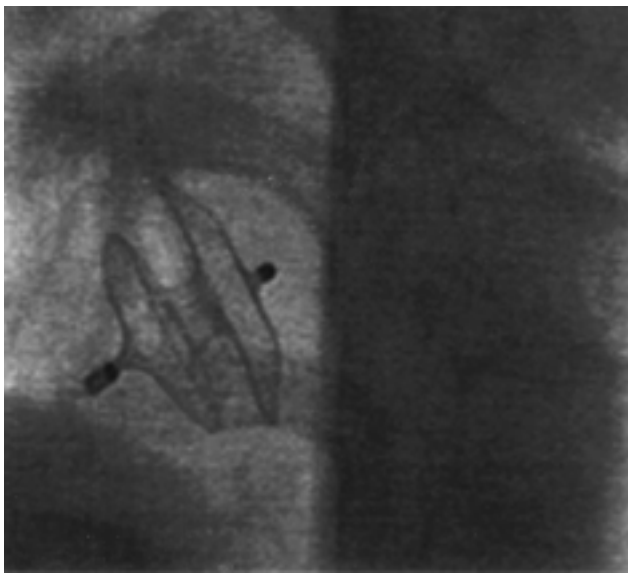

Fig. 4. *A fluoroscopic image of the Amplatzer® Septal Occluder.*

terization, and TEE. The stretched diameter of the defect varied from –7.3 to 120.4% larger than that estimated using precordial echocardiography, and was –19.2 to 41.9% larger than that estimated using TEE.

Discussion

This study demonstrated that the addition of TEE monitoring to fluoroscopic imaging during transcatheter closure of ASDs enhances the ability of the operator to visualize the defect. By providing direct visualization of the atrial septum surrounding the defect, TEE offers important information to allow safer and more effective application of this nonsurgical technique.

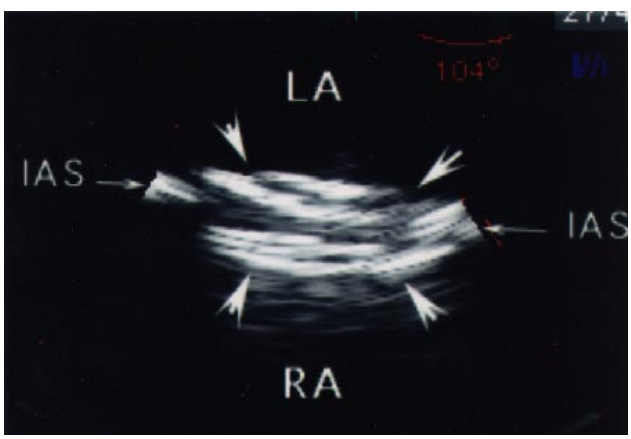

Fig. 5. *The corresponding transesophageal echocardiographic image after device release in Fig. 4. The atrial septal defect (IAS) is completely occluded by the Amplatzer® Septal Occluder, without residual shunt. LA = left atrium; RA = right atrium.*

Fluoroscopic monitoring is required to adequately guide the venoarterial wire through the inferior caval vein into the cardiac chambers, and to control the course of the wire during the implantation procedure. Fluoroscopy also allows hemodynamic study, but necessitates exposure of the patient to the potentially harmful effects of contrast medium and radiation. Echocardiographic monitoring may reduce the need for radiation exposure during the implantation procedure. Therefore, TEE is superior to fluoroscopic monitoring for continuous observation during the implantation procedure. Two-dimensional imaging allows measurement of the septum and ASD diameters, the rim around the circumference, and the thickness of the septum before considering an implantation procedure, and enables detection of correct placement of each disk of the occluder at the correct atrial site. Residual shunts may be detected and located. At the end of the implantation procedure, the open ostia of the pulmonary and caval veins as well as the unaffected mobility of the atrioventricular valves may be documented using two-dimensional TEE imaging before removal of the venoarterial wire. Careful observation of this procedure with TEE is mandatory because of possible displacement of the device into the mitral valve. Complications of the procedure such as mobilization or embolization of the device may be seen immediately.

In the past 17 years, when TEE has been in common clinical use, major complications have been infrequently reported [11]. The major concern is esophageal perforation, of which there has been one reported episode in an adult; the estimated overall incidence of this complication in adult flexible esophagoscopy is 0.02 to 0.05% [11–13]. Vocal cord paralysis secondary to recurrent nerve compression may be avoided by maintaining an air leak and limiting the dwell time of the TEE probe in the esophagus [11, 14]. In this study, none of the patients developed complications associated with transcatheter closure of ASD using TEE. In addition, during 1998 and 1999, no complications occurred in more than 1,000 examinations using intraoperative TEE during cardiac surgery at this hospital. While strict guidelines regarding the maximal safe endoscope size for any given child do not exist, the consensus appears to be that an outer diameter of less than 9 mm can be used in children less than 2 years of age (provided the tracheal airway is secured), and that larger endoscopes (10–12 mm outer diameter, the size used in the present study) may be used in older children, keeping in mind that tracheal compression may occur

in children at the younger end of these age ranges for any given endoscope size [13, 15, 16].

In this study, closure of the defect was canceled in two of three patients (patients 1 and 10) as a result of changed diagnosis after TEE examination prior to catheterization; precordial echocardiography overestimated the defect size in one of these patients (No. 1). Multiple fenestrated ASDs were found only on precatheterization TEE examination in the third patient (No. 11). In another patient (No. 9), although the defect size was too large (24.7 mm) as shown by TEE, transcatheter closure was attempted but failed. Because the atrial septum lies in the posterior aspect of the heart, the echo window from TEE provides better visualization in the transverse and long-axis views. The actual size of the occluder correlated well with precatheterization TEE measurement. However, precordial echocardiographic measurement often overestimated or underestimated the atrial defect size (Table). The stretched diameters of the defects in patients 3 and 10 were larger than those estimated using TEE; this discrepancy occurred because stretching of the pathologic thin atrial septum by the balloon sizer enlarged or tore the septum, necessitating open surgical repair. These findings confirm that TEE can provide important information concerning placement of the occluder device that is unavailable using alternative imaging techniques.

In conclusion, this study has demonstrated that TEE provides valuable information that makes the transcatheter procedure of ASD occlusion easier, safer, and more effective than with fluoroscopic guidance alone.

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