

Imaging for ASD and PFO Closure

The requirements and future direction of imaging for percutaneous atrial septal defect and patent foramen ovale closure procedures.

BY JOHN F. RHODES, JR, MD

Percutaneous atrial septal defect (ASD) and patent foramen ovale (PFO) closure procedures are now the most common congenital intervention performed in the cardiac catheterization laboratory. Although this procedure has used ultrasound imaging guidance since the early 1990s,¹ the frequency of ultrasound imaging in the cardiac catheterization laboratory has increased greatly during the past decade. Simultaneously, with the emergence of new imaging modalities,² many congenital interventional cardiologists, rather than their noninvasive colleagues are performing the imaging as part of the atrial septal device closure procedure.

BACKGROUND

Atrial septal shunt is a common problem in congenital heart disease; 20% to 25% of the population has a PFO,³ and 30% to 40% of patients with a congenital heart problem have an ASD.⁴ Since the first reports of transcatheter device closure for ASD and PFO, further development of transcatheter techniques and improved atrial septal occlusion device design have resulted in this procedure becoming the treatment of choice for this patient population.⁵ In addition, imaging requirements during these procedures has changed due to the ongoing evolution toward better imaging for patients with congenital heart disease.

IMAGING REQUIREMENTS

Fluoroscopy as a Second Imaging Modality or Alone

The majority of patients with congenital heart disease who enter the cardiac catheterization laboratory will have fluoroscopic imaging as one tool to guide the interventional procedure. Although the standard has been to use a combination of fluoroscopy and echocardiographic imaging, there is no agreement that the congenital invasive cardiologists use a biplane laboratory or a single-plane labora-

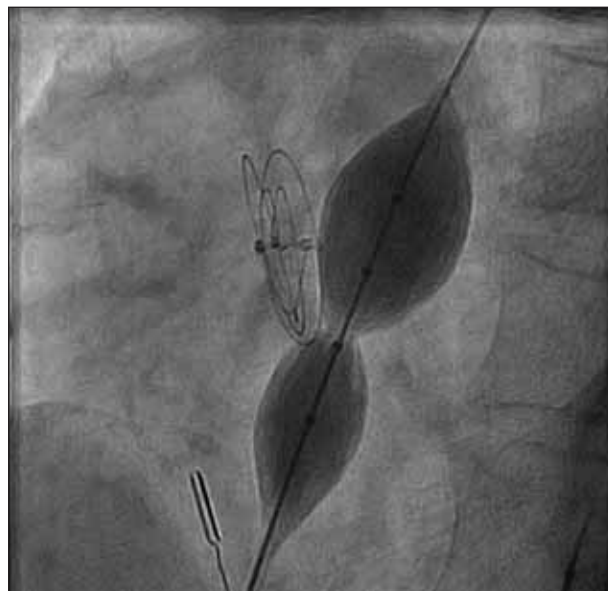


Figure 1. Fluoroscopy imaging of the Helex septal occluder device (W. L. Gore & Associates, Flagstaff, AZ), a sizing balloon in a second defect, and the intracardiac echocardiography probe along the right atrial wall.

tory for atrial septal interventions (Figure 1). Although there is no requirement for biplane capabilities when using a single-plane laboratory, the invasive cardiologist will usually have to maneuver the camera from the anteroposterior view to the left anterior oblique view to assess the device and outline the septum appropriately. In addition, the use of fluoroscopy is of greater value with the Helex septal occluder as compared to the Amplatzer septal occluder (AGA Medical Corporation, Plymouth, MN). This is inherent in the device design and the need to confirm the position of the lock loop with the Helex device.

Fluoroscopy alone can be performed for some ASD and PFO device closure procedures. With this single-imaging technique, the congenital cardiologist can use angiography to outline the septal anatomy and determine which device to implant. Although the advantages of this technique are decreased cost and procedural duration, there may be an increase in adverse events, such as device malposition and residual leak. Consequently, although most congenital invasive cardiologists may consider this technique for small shunts, the majority of septal closure procedures require a combination of imaging modalities.

2D Transesophageal Echocardiography With Fluoroscopy

Transesophageal echocardiography (TEE) has been the mainstay for guidance (along with fluoroscopy) during atrial septal interventions during the past few decades.⁶ The TEE imaging modality (Figure 2) has advantages related to the cost of the probe, multiplane imaging capabilities, and avoidance of an additional large venous sheath. On the other hand, TEE has disadvantages, including patients requiring a general anesthetic, the cost and time utilization for having an anesthesiologist and a second cardiologist involved for the duration of the procedure, and patient discomfort during the procedure, resulting in more sedation medication. In addition, the duration, as well as the turnaround time between procedures, affects the efficiency of the catheterization laboratory. Despite these issues, many congenital intervention programs continue to use the combination of TEE and fluoroscopy as their imaging modalities to guide ASD and PFO device closure procedures. It remains to be determined whether the trend will be away from TEE as the ultrasound imaging component when the cost of newer technology and the comfort of the invasive cardiologist interpreting the echocardiographic images improves.

2D Transesophageal Echocardiography Without Fluoroscopy

Transcatheter closure of ASD and PFO under TEE guidance without fluoroscopy has been previously described. In 2000, Ewert and colleagues reported 22 patients that underwent attempted percutaneous atrial septal device closure with TEE alone.⁷ They were able to perform the intervention in 19 patients without fluoroscopy and in three patients in whom fluoroscopy was required. Although they demonstrated that the procedure could be safely performed under TEE guidance without fluoroscopy, the patients required a general anesthetic and significantly higher doses of sedation secondary to a longer duration of TEE. Consequently, this imaging option exists for select patients but is not considered by the majority of congenital

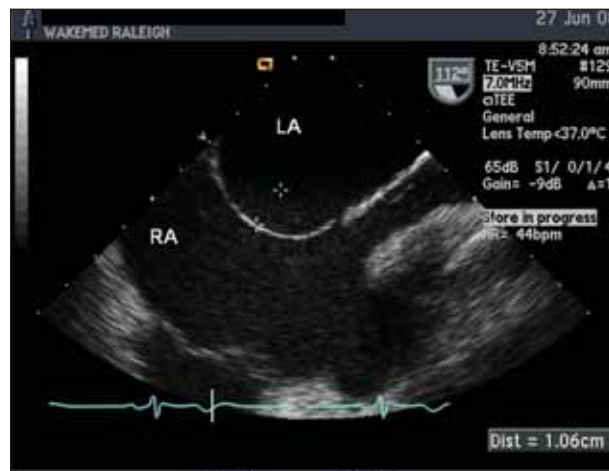


Figure 2. TEE demonstrating excellent image quality of the left atrium (LA), right atrium (RA), interatrial septum, and superior vena cava.

invasive cardiologists as the imaging option of choice for this patient population.

2D Intracardiac Echocardiography With Fluoroscopy

Intracardiac echocardiography (ICE) uses an echocardiogram with an intracardiac ultrasound catheter that can be maneuvered in the cardiac chambers in a manner analogous to a TEE probe in the esophagus. The ICE catheter provides a 2D pie-shaped image oriented perpendicular to the long axis of the catheter, rather than images of only the surrounding vessel wall, as seen with intravascular ultrasound. The first ICE catheter used during electrophysiology procedures was a 9-F, 9-MHz, single-plane probe with a mechanically rotating single crystal and radial cross-sectional imaging at 10° oblique. Unfortunately, the radial imaging plane was a cross-sectional image with limited tissue penetration to only 4 cm. The next-generation catheter was a 10-F, 7.5-MHz, single-plane phased-array linear-arc probe. This system improved on some of the limitations in penetration, but a detailed image of all of the cardiac anatomy remained inadequate. Subsequently, the Acuson AcuNav 10-F (and later 8-F), multifrequency, single-plane diagnostic ultrasound catheters (Siemens Healthcare, Malvern, PA) were developed with a 90-cm insertion length with tissue penetration to approximately 12 cm. This probe is maneuvered within the cardiovascular system using a four-way tip deflection control knob. It provides a 2D image and also has pulsed wave, continuous wave, color-flow mapping, and tissue Doppler capabilities. In addition, this ICE probe has multiple frequency capabilities ranging from 5.5 to 10 MHz. Therefore, invasive cardiologists can select a lower frequency to allow more tissue penetration with



Figure 3. Intracardiac echocardiography (ICE) from the right atrium demonstrating the compliant sizing balloon and the stop-flow defect diameter.

less image resolution, or a higher frequency to give less tissue penetration but with improved image resolution. The 5.5-MHz frequency often allows enough tissue penetration from the right atrium to visualize the left ventricle, left atrial appendage, or pulmonary veins. The 10-MHz frequency remains limited in tissue penetration but significantly improves the image detail of the atrial septum from the right atrium.

Procedures utilizing ICE are mainly performed with the patient under moderate sedation, and a standard 9- or 11-F sheath is placed in the femoral vein. Although placement of the two venous sheaths can be in the same or opposite femoral vein, it has been our practice (for the past 6 years) to place both sheaths in the right femoral vein (11 F x 2), with no adverse events. Subsequently, the ICE probe is advanced through the sheath (with the operators' fingers close to the tip to avoid damaging the transducer) and then carefully, under fluoroscopic guidance, to the right atrium. Slight deflection of the probe tip may be necessary to enable smooth advancement of the probe along the iliofemoral junction (rightward deflection) and past the hepatic veins (leftward deflection). The orientation of the image plane is controlled through variable deflection of the catheter tip by the control knobs. The catheter tip flexes approximately 160° in the direction of deflection. To visualize the atrial septum or the compliant sizing balloon, the probe is advanced to the high right atrium and deflected to the lateral right atrial wall (large control knob slightly toward the operator) (Figure 3). The probe is then locked in position (turn locking mechanism away from the operator), and fine movements of the probe are performed with the middle smaller control knob away from the operator to move toward the superior

vena cava, and toward the operator to move toward the aorta. Continual manipulation is performed in a superior and inferior direction, or clockwise and counterclockwise rotation, resulting in a change in the image plane to enable all of the atrial septum to be visualized. If the image remains suboptimal, either the "tricuspid valve view" or the "long axis image of the ascending aorta view" can often be used as a "home view" to start the rotation.⁸

Although ICE can be performed safely with careful manipulation, the reported procedural adverse event rate is 1% to 3%.^{9,10} Adverse events include arrhythmia, allergic reaction from latex exposure to the sterile sleeve used to cover the handle and connecting cable, groin hematoma, and pericardial effusion. In addition, there are reports of retroperitoneal bleeding and venous perforation. Therefore, safety may be improved by advancing the probe under fluoroscopic guidance with the two articulation knobs in the neutral position and the lock released. Also, there is the option to use a longer venous sheath for the ICE probe, which eliminates movement through the iliofemoral system.

Despite these potential adverse events, the important advantages include the probe's proximity to intracardiac structures (especially the inferior atrial septum), the absence of any air or tissue interference with the catheter in the right atrium, and its maneuverability to achieve almost any orthogonal view. These strengths make it an ideal adjunct imaging tool for the invasive cardiologist in the congenital catheterization laboratory because it permits more accurate assessment of the congenital heart defect and real-time guidance of intervention in combination with fluoroscopy. Limitations remain, however, including the absence of multiplane views when compared to TEE, the inability to image the left atrial disc as well as TEE, 3D capabilities are not in real time, the current probe cost, and the probe size limiting manipulation as well as resulting in the need of an additional 9- to 11-F sheath. Despite these limitations, it is generally agreed that ICE is on the cutting edge of an evolving paradigm in which multiple imaging tools can improve the safety and overall outcome of atrial septal device closure.¹¹

2D Intracardiac Echocardiography Without Fluoroscopy

ICE has been used in select patients, such as during pregnancy, to perform percutaneous atrial septal closure without fluoroscopy. Schrale and colleagues reported on three patients who experienced a neurological event during or immediately preceding pregnancy.¹² Due to evidence of recurrent events or relative contraindication to anticoagulation, they proceeded to percutaneous device

closure during the second trimester. Successful closure was achieved with the Helix septal occluder device in all three patients. There were no procedural adverse events, and all three pregnancies were successful, with the patients remaining free of further neurologic events.

FUTURE DIRECTIONS

Real-Time Magnetic Resonance Imaging With or Without Fluoroscopy

Although a combination of fluoroscopy and echocardiography is the standard method for guidance during percutaneous atrial septal device closure, there are disadvantages, including poor soft tissue visualization and exposure to radiation. Razavi and colleagues describe multiple diagnostic and two interventional cardiac catheterization procedures guided by magnetic resonance imaging (MRI) with some fluoroscopy support.¹³ They combined MRI and radiographic imaging facilities and showed that interventional cardiac catheterization guided by MRI allowed better soft tissue visualization, provided more pertinent physiological information, and resulted in lower radiation exposure than fluoroscopically guided procedures. In addition, Buecker and colleagues tested the feasibility of applying MRI guidance for percutaneous closure of PFO in seven piglets without fluoroscopic assistance.¹⁴ They used a specially designed prototype of a nonmagnetic atrial septal closure device introduced via the femoral vein, and deployment of the device was depicted by real-time MRI. They also reported that the initial misplacement of the device in two cases was easily detected and corrected. Therefore, in this animal model, they demonstrated that real-time MRI guidance of atrial septal closure without the use of fluoroscopy is feasible. Consequently, MRI guidance may evolve into a viable method for diagnostic and interventional cardiac catheterization in patients with congenital heart disease.

Real-Time 3D Transesophageal Echocardiography With Fluoroscopy

Balzer and colleagues recently published their experience with the use of real-time 3D TEE for guiding percutaneous atrial septal device closure.¹⁵ Their series included 25 patients undergoing device placement guided by fluoroscopy and real-time 3D TEE. The addition of real-time 3D TEE allowed safe device deployment with no adverse events in all patients, as well as a significant reduction in fluoroscopy time.

CONCLUSION

Ultrasound imaging technology has advanced significantly during the last few decades. The application of

current ultrasound imaging modalities has augmented the capabilities of invasive cardiologists performing percutaneous ASD and PFO closure procedures. The invasive cardiologist, rather than an echocardiographer, now more often performs the imaging, and so this physician must be appropriately skilled in the manipulation of the imaging catheter as well as the interpretation of the images generated.

ICE is clearly emerging as an important aid to the invasive cardiologist for septal closure device implantation and guidance during interventional procedures. In the majority of percutaneous atrial septal interventions, ICE eliminates the need for TEE and general endotracheal anesthesia. Despite the current limitations of cost and probe size, the eventual development of smaller catheters and multiplane, as well as real-time 3D imaging capabilities, may facilitate the use of ICE for imaging during percutaneous ASD and PFO device closure. ■

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