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Role of Intracardiac Echocardiography (ICE) in Transcatheter Occlusion of Atrial Septal Defects

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1. Introduction

Nowadays transcatheter closure of atrial septal defects (ASDs) is a reality in the vast majority of countries; this procedure can be done safely and effectively in skilled hands and with the appropriate devices. Accurate and precise knowledge of the anatomy of the secundum atrial septal defect and the nearby structures is essential for the effectiveness and safe performance of ASD closure. Improvements in ultrasound technology over the last several decades have been particularly useful for guidance during this particular invasive procedure.

Transesophageal echocardiography (TEE) has been the conventional imaging method for guidance in transcatheter closure of ASDs in children and adults; TEE has been shown to be safe and effective for closure of ASDs but in the majority of cases it has to be done under general anesthesia with subsequent increase in the procedure time, increased risks of anesthesia and patient discomfort after the procedure.

Intracardiac echocardiogram (ICE) was developed to provide accurate and precise knowledge of the anatomy of the intracardiac structures. ICE was first used in 1980s for the visualization of the coronary arteries and then it was also used as a guiding tool during radiofrequency ablation and to assist transeptal puncture techniques in difficult cases. It was our group who reported for the first time in 2001 on the use of ICE to guide device closure of ASDs and patent foramen ovale.

Since then, multiple improvements in the ICE catheter have been developed and now it is well recognized imaging tool for guidance of several interventional cardiac and electrophysiological procedures.

Unlike TEE, ICE doesn't require general anesthesia, it provides accurate real time images and the procedure can be done faster with successful results.

2. History

During the 1950s and 1960s, the first ultrasound tipped catheters were introduced because of the advancement in percutaneous procedures in the medical field, the need for close

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assessment of the organs to be studied as well as the need for guidance of procedures under real time image. The first ultrasound tipped catheters were created to obtain organ dimensions and organ distances. No Doppler velocities or cross sectional images were obtained

In 1956, Cieszynsky et al. used the first ultrasound tip catheter in dogs; he found it to be useful without injury to the system being observed. In the mid-1960s, Kossofs et al used the first ICE in measuring the thickness of the ventricular septum and ventricular wall by M-mode with surprising precision, but the catheter lacked mobility when it was inside the heart. In 1969, a mechanically rotating 4-element probe was developed by Eggleton et al and during the same time the first two dimensional real time ultrasound tip catheter was developed by Bom et al.

In 1974 Reid introduced the Doppler system by measuring Doppler velocities of femoral and coronary artery in dogs and in 1975 Gichard et al developed a new concept of catheter in which the shaft was more flexible with the ability to rotate inside the heart.

In the mid-1980s, percutaneous transluminal coronary angioplasty was adopted in many centers as the procedure of choice for coronary artery disease. This advancement in the field of cardiac catheterization created the need for development of an ideal device for intracardiac echo. The goal was to create a catheter with a flexible shaft, predictable orientation inside the heart with lower frequency transducers, superior imaging depth as well as enhanced tissue penetration.

Pandian et al in 1990 used the ICE catheter for the first time in humans in detecting iliofemoral artery obstructing disease with the ability to distinguish diseased arteries from normal vessels. Subsequently he used ICE in guidance of PTCA with encouraging results.

ICE was introduced to the field of congenital structural heart disease when Valdez-Cruz et al in 1991 described successful results of percutaneous closure of atrial septal defect (ASD) under ICE guidance in piglets. Since then, the utility of ICE has expanded. Electrophysiology studies demanded more accurate assessments during and after ablation studies. The first ablation procedure described under ICE guidance was by Seward et al in 1996 in dogs; it was found to have more accurate assessment of the size of the ablation injury, enhanced visual detection of intramyocardial hematoma and thrombus formation which were not well seen by fluoroscopy or even by TEE.

In the subsequent years as we mentioned above, ICE has had a tremendous advancement in technology and it has been described to be useful in the guidance of most cardiac interventional procedures such as ASD/PFO/VSD device closure, balloon valvuloplasty, aortic coarctation angioplasty/stent placement or other central vascular stenosis, transeptal puncture, percutaneous pulmonary and aortic valve placement, left atrial appendage closure and many others.

3. ICE catheters

Over the past several years, improvements in technology have allowed the development of intracardiac transducers of lower frequency as well as Doppler imaging capability with improved depth penetration and better image resolution.

At present, there are five different transducer technologies for real-time intracardiac ultrasonic imaging

1. The *ultraICE* mechanical single-element system (Boston Scientific Corp, San Jose, CA, USA)
2. The *AcuNav* system from Siemens from Biosense-Webster
3. The *Clear ICE* system from St Jude Medical
4. The *SoundStar Catheter* system from Biosense-Webster
5. The *ViewMate Z* Intracardiac Ultrasound System and *ViewFlex Plus* ICE Catheter from St Jude Medical.

The UltraICE system (Boston Scientific Corp, San Jose, CA, USA) is a 9 MHz single element transducer incorporated in a 9F catheter. The catheter is not steerable and it lacks Doppler capabilities. This system provides cross-sectional images in a 360° radial plane with only 5 cms radial field depth which provides near-field clarity but poor tissue penetration; hence the left sided structures are not possible to obtained when the ultrasound catheter is in the Right heart. It has been used in guidance of coronary artery interventional procedures because of the catheter's capability of producing near - field images. Three-dimensional reconstruction of the anatomy can be obtained as well.

The ClearICE device (St. Jude Medical, Inc) has a 64-element phased-array transducer with a highly steerable catheter and bidirectional steering up to 140°. It works with the Vivid system (GE Healthcare Technologies, Wauwatosa, WI). It has two sets of electrodes for integration of 3D localization with NavX. Apart from grayscale and tissue Doppler; it also allows for synchronization mapping and 2D speckle tracking.

The SoundStar Catheter system (Biosense-Webster) has the same characteristics like AcuNav catheter but with CARTO magnetic sensor in the tip.

The ViewFlex Plus catheter (St. Jude Medical, Inc.) uses the ViewMate Z ultrasound system (EPMedSystems, Inc., Berlin, NJ). It has a 64-element phased-array transducer with a frequency of 4.5 to 8.5 MHz, and an imaging depth of 12 cm. it has a steerable catheter via two-way articulation; it can be rotated axially and steered in anterior and posterior directions up to 120° with enhanced tip stability. It also allows a two-way flex color Doppler and grayscale. This catheter has the ability to quickly produce exceptional images in a compact, cart-based system.

Currently AcuNav catheter (Biosense Webster, Inc, Diamond Bar, CA, USA) (FIGURE 1) is the most popular ICE catheter used for guidance of percutaneous closure of an ASD. The catheter size decreased from 11F to 8 F in diameter in the last years and now requires only an 8 Fr introducer with subsequent fewer traumas to the vessel entered. The catheter consists of a miniaturized 64-element phased-array transducer with color, tissue and spectral Doppler capabilities; the frequency of the transducer varies from 5.5 to 10 MHz and it provides a 90° sector image with excellent tissue penetration up to 16 cm for the 8F catheter, allowing visualization of left-sided structures from the right heart. The catheter is somewhat stiff but with a brilliant four-way articulation that provides excellent maneuverability inside the heart; the handle has a locking knob that allows the catheter tip to be fixed in a desired position. This is an important feature of this catheter. It works with Sequoia, Cypress, or Aspen imaging systems, all of which are manufactured by Siemens Medical Solutions USA, Inc. (Malvern, PA). It can be introduced by a femoral or internal jugular approach; The 8 F catheter is 90-110 cms long and careful advancement from the groin to the heart under continuous fluoroscopic guidance is recommended, unless a long sheath (>30 cms) is used in the femoral vein.



Fig. 1. AcuNav Catheter; the control handle has three knobs: one to move the tip in posterior/anterior directions, one to move the tip in right/left directions, and the last knob is a locking one that will fix the tip in the desired orientation.

4. ICE catheter insertion techniques

The catheter can be introduced by femoral or internal jugular approach; however the femoral vein approach is the most popular among most of the interventionalists because it is closer to the table, allowing easier manipulation of the control handle. The 8 F AcuNav catheter is 90-110 cms long and careful advancement from the groin to the heart under continuous fluoroscopic guidance is recommended because of its rigidity (stiffness) and possible advancement of the catheter into side branches with potential vessel injury before reaching the right atrium (RA); it is recommended to use a long 8 french sheath (30 cms) in either femoral vein in order to avoid vascular complications or possibly entanglement below the level of the IVC. This approach offers easy accessibility and allows fairly free movement of the catheter inside the heart. In adult patients, the catheter can be introduced in the same vein used for the device delivery (FIGURE 2). For patients with weight below 35 kg, access in the opposite femoral vein is recommended (FIGURE 2).

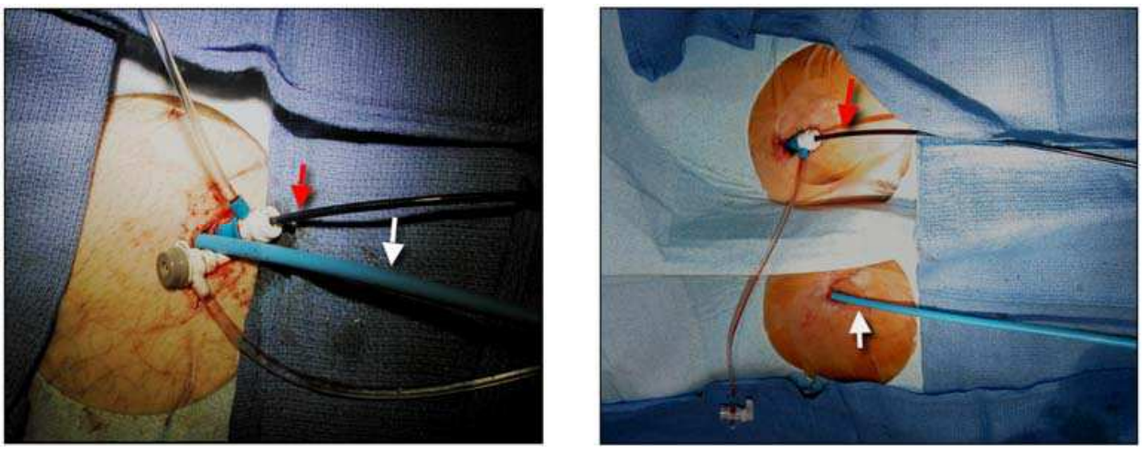


Fig. 2. ICE catheter insertion; Left: Adult patient with ICE catheter (red arrow) and delivery sheath (white arrow) in same femoral vein. Right: Pediatric patient with ICE catheter (red arrow) and delivery sheath (white arrow) in opposite veins.

The superior vena cava (SVC) is another option to achieve access to the RA. This approach can be accomplished either from the right internal jugular vein or the left subclavian vein into the RA.

5. ICE guidance protocol for ASD closure

The ICE catheter is introduced in the usual fashion and advanced from the inferior vena cava (IVC) into the RA. We start the ICE protocol obtaining first the home view, septal view, long axis view and short axis view in combination with fluoroscopic image (FIGURE 3).

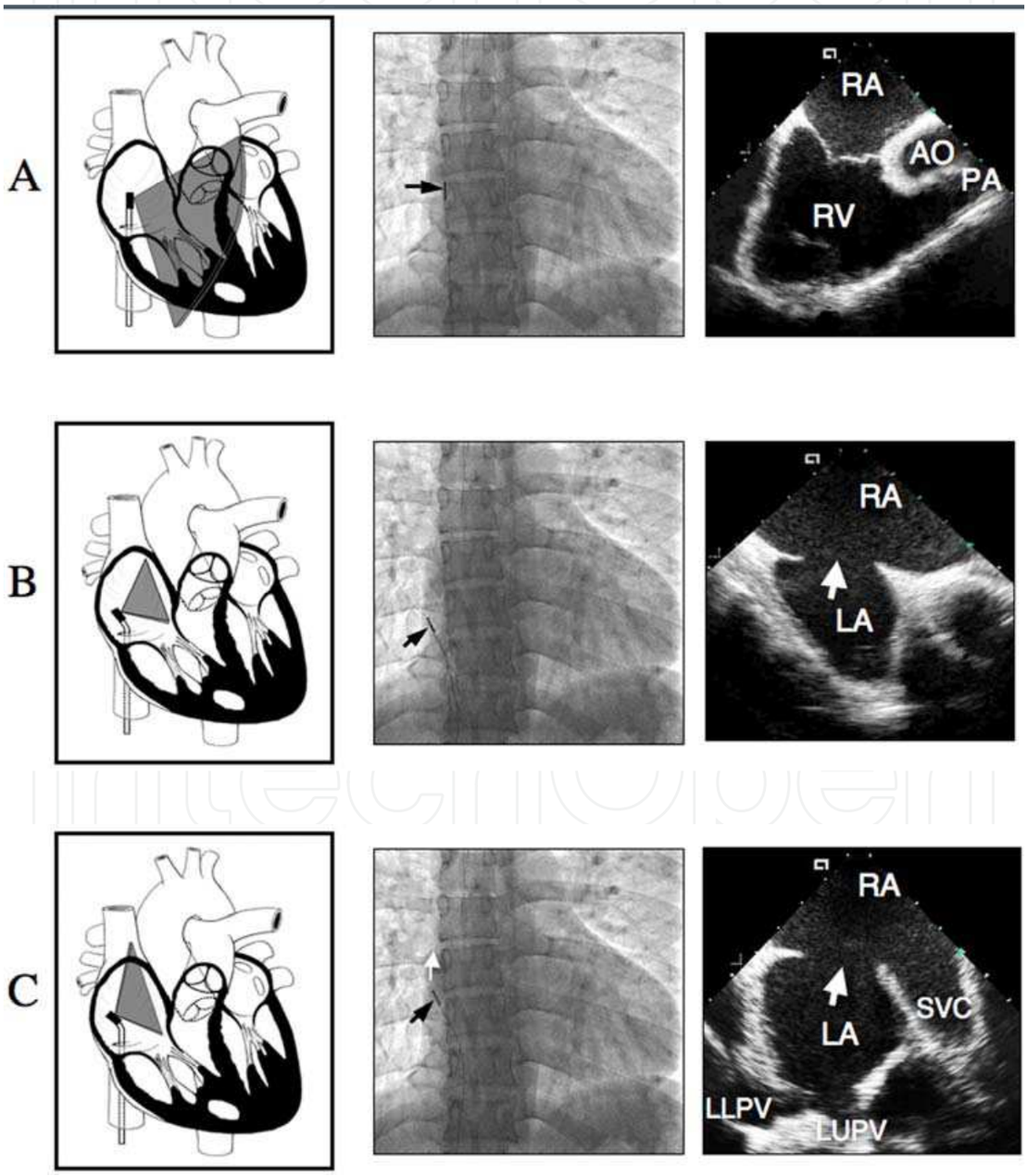




Fig. 3. Fluoroscopy and ICE assesment of an ASD; (A) Home view. Left, heart diagram with the position of the ICE catheter in the neutral 'home view' position. The shaded area represents structures seen in this view. Middle, A-P Fluoroscopic image of the ICE catheter positioned in the mid RA (arrow) and parallel to the spine. Right, ICE 2-D image in the neutral home view position. The tricuspid valve, right atrium (RA), right ventricle (RV), RV outflow tract, pulmonary artery (PA) and aorta in short axis are well seen in this position.
(B) Septal view. Left, heart diagram with the position of the ICE catheter in the posterior flexed position looking at the atrial septum 'septal view'. The shaded area represents structures seen in this view. Middle, Fluoroscopic A-P image of the ICE catheter (arrow) in the RA pointing to the right side of the heart and the transducer flexed posterior looking at the septum. Right, ICE 2-D image septal view position. The right atrium (RA), left atrium (LA) and the atrial septal defect are well seen (arrow) in this position.
(C) Long-axis 'caval view'. Left, heart diagram with the position of the ICE catheter in the posterior flexed position with a more superior advancement looking at the atrial septum and the superior vena cava. The shaded area represents structures seen in this view. Middle, A-P Fluoroscopic image of the ICE catheter (black arrow) demonstrating catheter pointing posteriorly to the septum and positioned higher than the septal view closer to the SVC (white arrow). Right, ICE 2-D image in the long axis view position. The atrial septal defect (arrow), right atrium (RA), left atrium (LA), left upper, left lower pulmonary veins (LUPV, LLPV), and the superior vena cava (SVC) are all well seen.
(D) Short-axis view. Left, heart diagram with the position of the ICE catheter in the flexed position but now positioned near the tricuspid valve and below the aortic valve. The shaded area represents structures seen in this view. Middle, Fluoroscopic A-P image of the ICE catheter pointing to the right side of the spine, next to the tricuspid valve and just below the aortic valve. Right, ICE 2-D image in the short-axis view. The atrial septal defect (arrow), the left atria (LA), right atria (RA) and the aortic valve are all well seen in this view.

5.1 Standard views

5.1.1 Home view

This view can be obtained by advancing the ICE catheter to the mid right atrium. Catheter is parallel to the spine with the transducer portion facing the tricuspid valve. Subtle counter clockwise movements in the knob of the catheter can be done to obtain the home view image. When you are in home view you should see the right atrium, the tricuspid valve, the right ventricle, right ventricular inflow and outflow and a portion of the aortic valve in short axis view. The anterior portion of the septum can be occasionally visualized as well. (FIGURE 4).

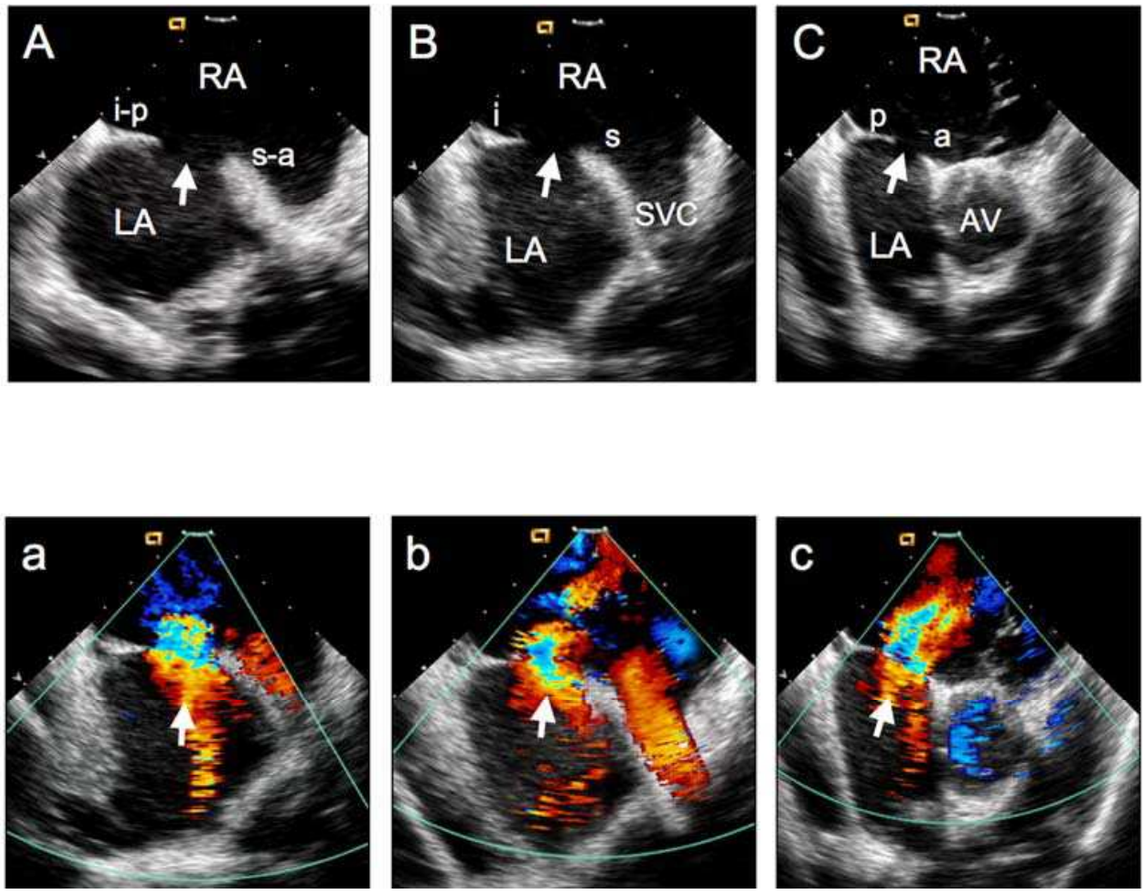


Fig. 4. Septal View: Left A) ICE 2-D image demonstrating a large ASD (arrow), right atrium (RA), left atrium (LA), the superior anterior rim (s-a) and the inferior posterior rim (i-p) a) ICE color image demonstrating a large ASD (arrow) with left to right shunt. Long axis view: Center B) ICE 2-D image demonstrating large ASD (arrow), superior vena cava (SVC) right atrium (RA), left atrium (LA), superior rim (s) and inferior rim (i). b) ICE color image showing a large ASD (arrow) with left to right shunt and SVC drainage to RA. Short Axis View: Right C) ICE 2-D image demonstrating a large ASD (arrow), right atrium (RA), left atrium (LA), aortic valve (AV), anterior rim (a) and posterior rim (p). c) ICE color image showing a large atrial septal defect with left to right shunt.

5.1.2 Septal view

After the home view image is obtained, slight movements of the anterior-posterior knob posteriorly and the right-left knob rightward will make the transducer face the atrial septum. In this view you can see the entire length of the atrial septum. The image closer to the ICE catheter (superior) is the RA and distal to the image (inferior) is the left atrium.

Occasionally you can see the pulmonary venous return to the left atrium and the coronary sinus as well. Once you lock the catheter you can make fine movements in the knob or rotate the entire catheter to get the image that suits better guidance of the procedure. (FIGURE 4)

5.1.3 Long axis view

This view can be obtained after having the catheter in the septal view, followed by slight superior advancement of the ICE catheter in the RA towards the SVC. The catheter can either face the atrial septum, the SVC or both; it depends on the position of the catheter. Advancing the flexed catheter in the direction of the SVC can profile much better the SVC and the respective posterior superior rim. Withdrawal of the flexed catheter towards the IVC will profile the inferior part of the atrial septum and the posterior inferior rim as well. This view is good for measurements of an atrial septal defect as well. The right and left pulmonary venous drainage can be seen just rotating the catheter clockwise or counterclockwise as well as with flexion/anteflexion. (FIGURE 4).

5.1.4 Short axis view

The catheter is still flexed in its locked position; to obtain the image, the entire catheter should be moved from the sheath hub in a clockwise manner in order to place it inferior to the aortic valve and near the tricuspid valve; this is followed by slight adjustments in the posterior anterior knob with less posterior flexion and more leftward rotation on the right/left knob. Fluoroscopy image shows the position of the catheter. This view is the opposite of the short axis view that can be obtained using TEE with the near field image being the right atrium and the far field image being the left atrium. The superior anterior rim and inferoposterior rim can be obtained as well (FIGURE 4).

5.2 ICE guidance during and after device deployment

5.2.1 The defect is crossed with a wire; this image is crucial in complex atrial septal defects or fenestrated ASD's to confirm that the largest defect is being crossed by the wire. Subsequently the delivery sheath is advanced and placed in one of the left pulmonary veins (Figure 5)

5.2.2 Balloon sizing is also of significant importance in large or complex defects for further delineation of the atrial septal defect (FIGURE 6) and to measure the "stop-flow diameter" of the defect.

5.2.3 The device is advanced and the left disk deployed in the left atrium and positioned in a way that is oriented with the atrial septum. The left disk is slowly pulled back to the atrial septum. The device position is constantly evaluated by ICE, making sure its position in relation to the left side of the atrium is maintained. When the device makes contact with the defect; it is important well seated; it makes good well seated; makes good contact with all available rims and the left disk doesn't protrude to the RA . this is followed by deployment of the right atrial disk in the right atrium. Deployment of the device is always done under fluoroscopic and ICE guidance for successful results (FIGURE 7A-7B)

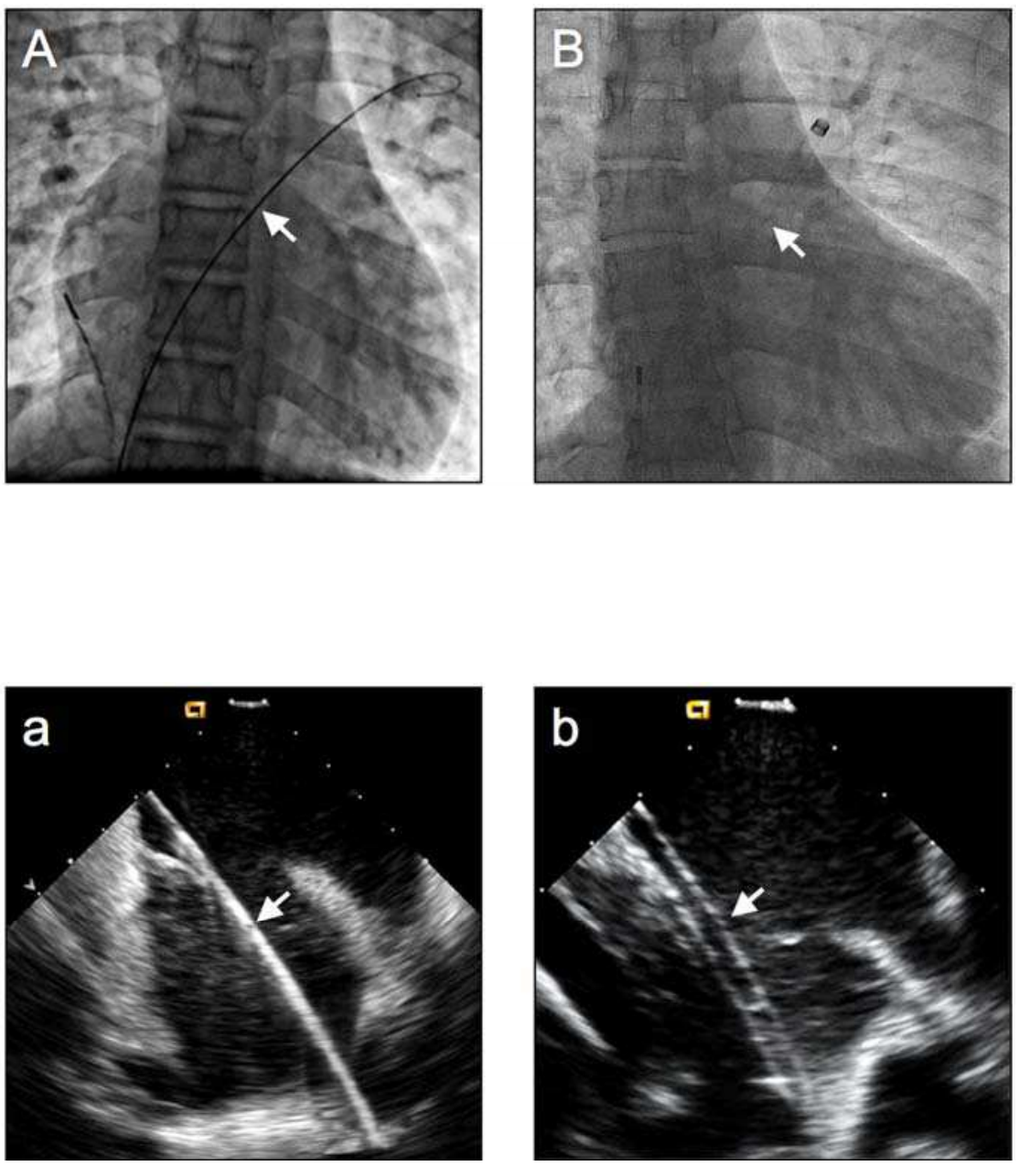


Fig. 5. Wire and delivery sheath assessment. Left A) A-P fluoroscopic image of the wire (arrow) crossing the ASD and positioned in the left upper pulmonary septal view demonstrating the wire (arrow) crossing the large ASD and the tip located in the left upper pulmonary vein. Right B) fluoroscopic image showing sheath (arrow) crossing the ASD and positioned in the left upper pulmonary vein. b) ICE septal view demonstrating the sheath (arrow) crossing the ASD and positioned in the left upper pulmonary vein.

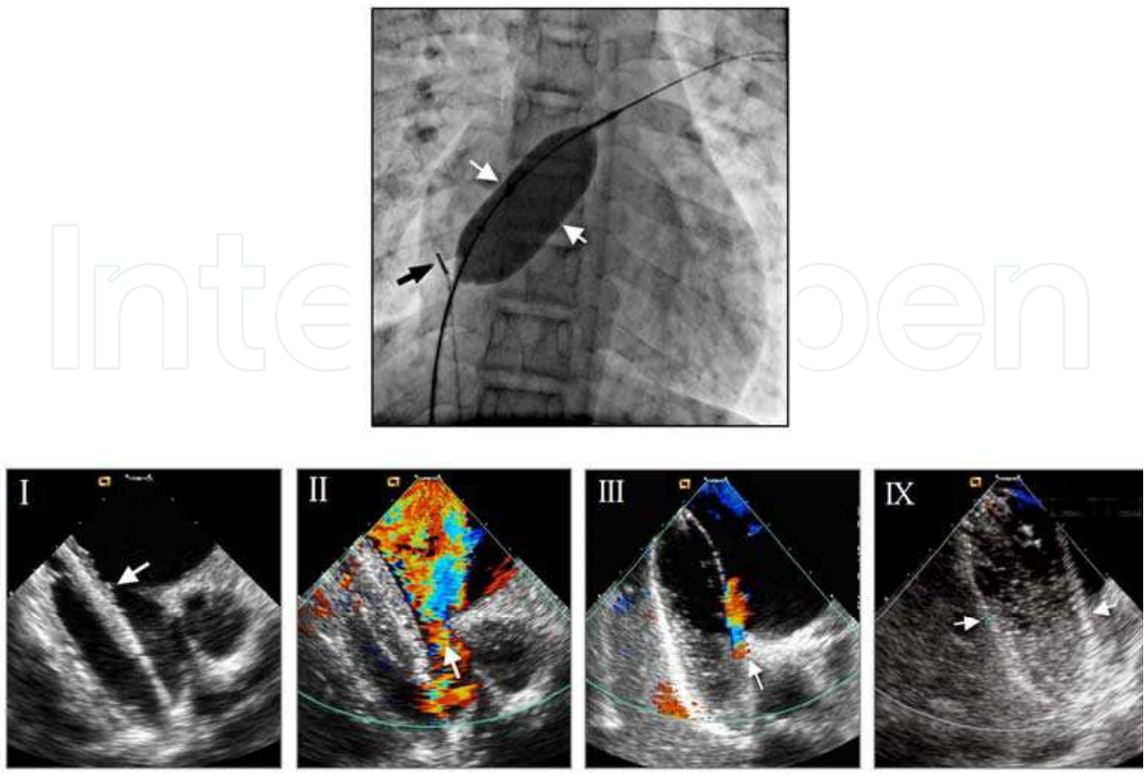


Fig. 6. Balloon "Stop-flow" diameter assessment; . I) Balloon sizing deflated (arrow) crossing the ASD. II) Balloon inflated with evidence of residual shunt (arrow). III) Balloon inflated again with evidence of very mild residual shunt (arrow). IV) Balloon stop flow diameter (white arrows) achieved without evidence of residual shunt. Image in top demonstrating an A-P fluoroscopic image of the stop flow balloon sizing diameter (white arrows), ICE catheter (black arrow) positioned in the septal view during balloon inflation.

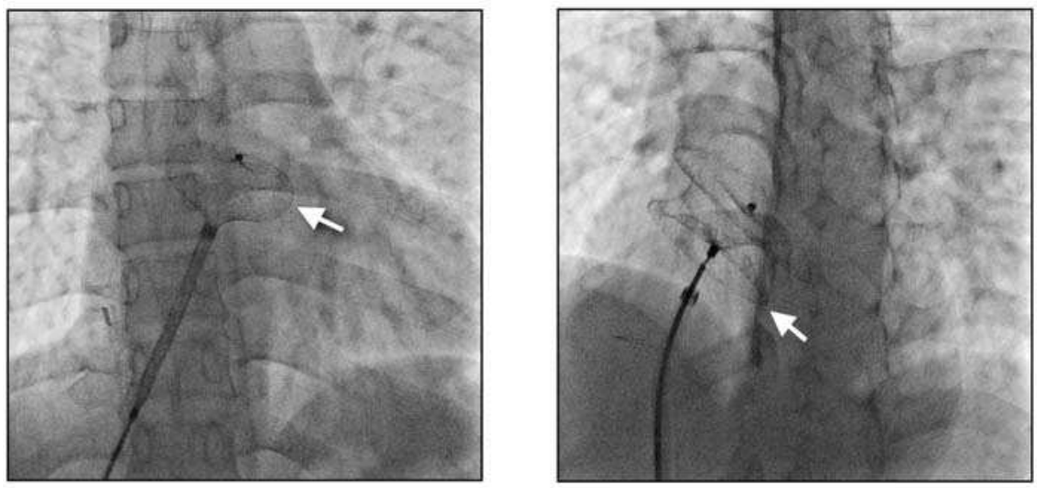


Fig. 7A. Left and right atrial Disks Deployment. Left) Fluoroscopic image of the left atrial disk (arrow) deployed in the LA. Right) A-P Fluoroscopic image in the hepatoclavicular view demonstrating the right atrial disk (arrow) deployed in the RA.

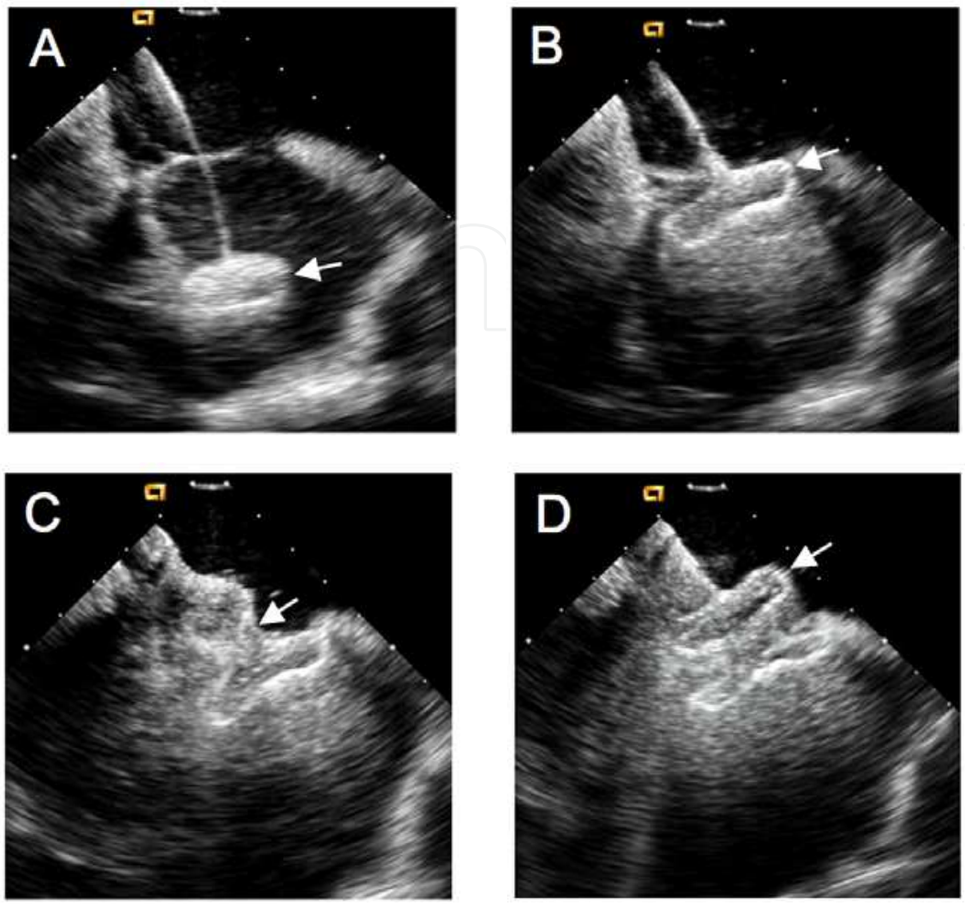


Fig. 7B. A) ICE image in short axis view demonstrating the left atrial disk (arrow) deployed in left atrium in alignment with the ASD. B) Continuous ICE assessment in septal view of the left disk while is pulled back to the left side of superior and inferior posterior rims. C) ICE image in septal view demonstrating the waist of the device (arrow) before complete deployment of right disk D) ICE image in septal view demonstrating the deployment of right atrial disk (arrow).

5.2.4 After right disk is deployed, subsequent assessment of the position and stability of the device is done. Long axis view view and short axis view are the best views for assessment of the device position prior to its release. Assessment of device stability, residual shunt , SVC and IVC is important before releasing the device. Again fluoroscopic image correlation with ICE images is essential for assessment of device position and stability before releasing the device (FIGURE 8A-8B).

5.2.5 After releasing the device, further assessment for device stability is performed with fluoroscopy and ICE; Evaluation of nearby structures and assessment of any residual shunt is done again in short axis, septal and long axis views (FIGURE 9A-9B).

It is very important to remember that before pulling out the ICE catheter from the sheath, it must be unlocked before withdrawal to the IVC.

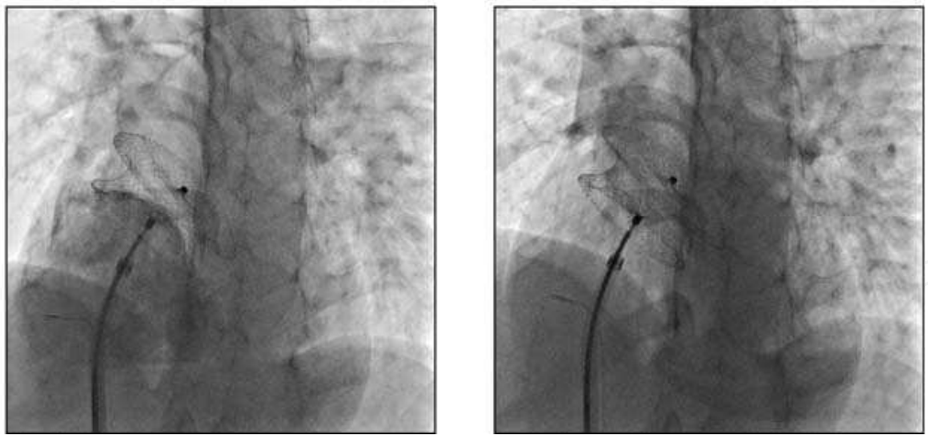


Fig. 8A. Fluoroscopic pre-release assessment of device. A) Fluoroscopic image in the hepatoclavicular view with injection of contrast confirming appropriate position of the right atrial disk in the atrial septum. B) Fluoroscopic image in the hepatoclavicular view with contrast on levophase confirming appropriate position of the left atrial disk in the atrial septum.

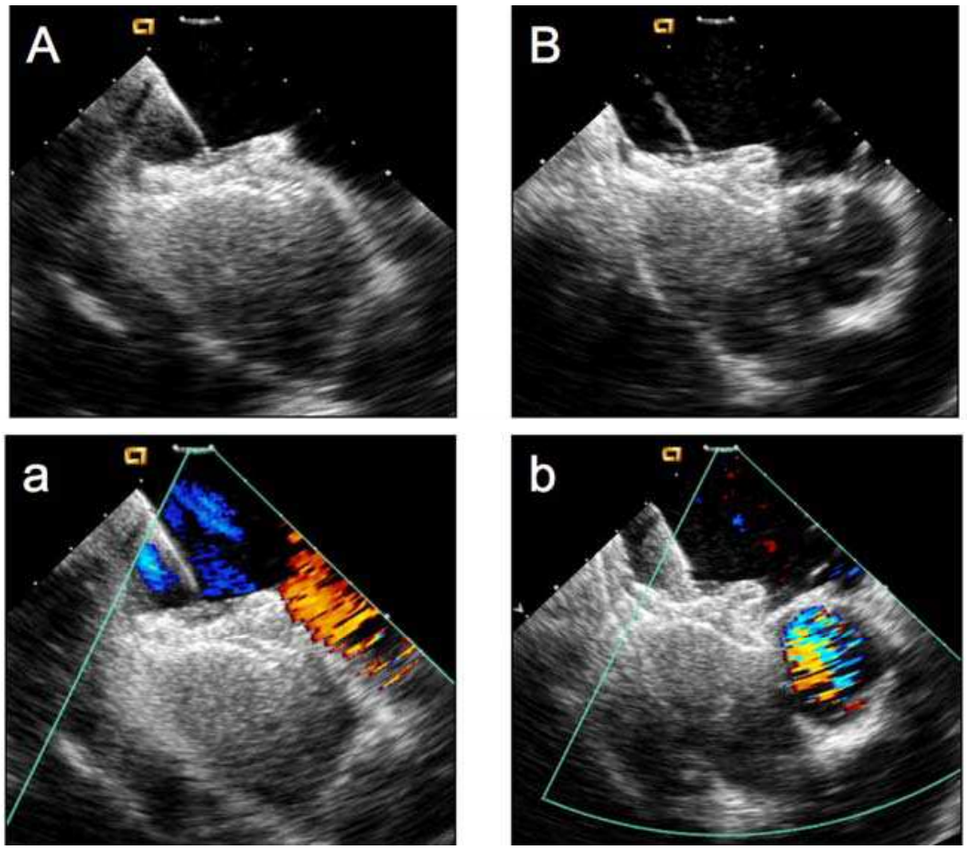


Fig. 8B. ICE pre-release assessment of device. A) ICE 2-D image in long axis view demonstrating the device well seated.a) ICE with color in long axis view demonstrating normal SVC flow and no residual shunt; delivery system still attached to the device. B) ICE 2-D image in short axis view demonstrating the device well seated. b)ICE with color in short axis view demonstrating no residual shunt.

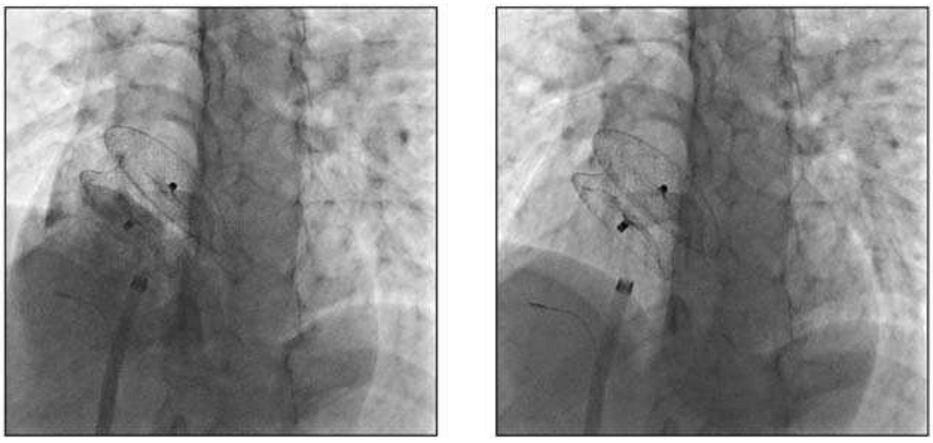


Fig. 9A. Fluoroscopic final assessment: Left) Fluoroscopic image in the hepatoclavicular view confirming device not attached to the delivery system and after contrast Injection, right atrial disk appeared to be in good position. Right) Fluoroscopic image with injection of contrast on levophase confirmed appropriate positioned of the left atrial disk after being released from the delivery system.

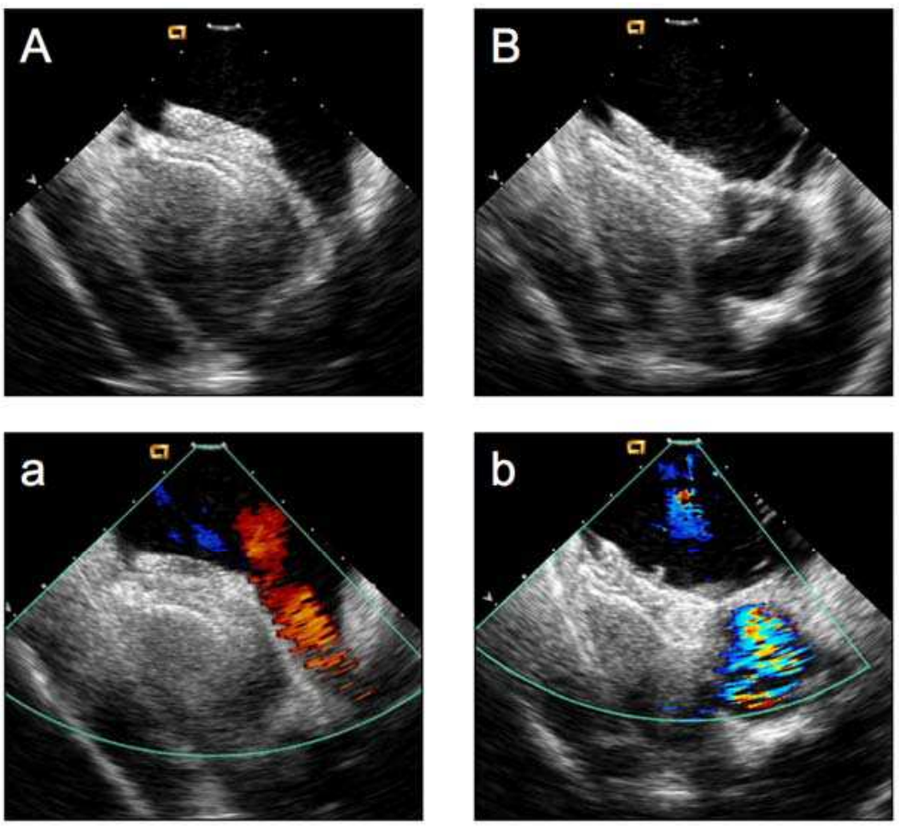


Fig. 9B. ICE final assessment post release of device: A) ICE 2-D image in long axis view demonstrating the device well seated. a) ICE with color in long axis view demonstrating normal SVC flow and no residual shunt. B) ICE 2-D image in short axis view demonstrating the device well seated. b) ICE with color in short axis view demonstrating no residual shunt.

6. Advantages and limitations of ICE

Transthoracic Echocardiogram (TTE) has been used for guidance of percutaneous closure of ASDs. However the pictures sometimes are not accurate to evaluate the size of the defect and it is difficult for evaluation of the rims, therefore risking stability of the device. Further, due to it being close to the working area of the intervention, there is risk to compromise sterility of the procedure. The advantages are that it can be done under conscious sedation and it is cheaper than ICE and TEE.

The use of TEE is well known for guidance of percutaneous closure of ASDs. It provides excellent intracardiac resolution and has 3D capabilities. However, it requires sedation and possible endotracheal intubation, it is uncomfortable for patients, and may raise the cost of the procedure due to professional and procedural fees.

ICE has been used in the last decade for guidance of percutaneous closure of ASDs and is lately gaining more acceptance in the interventional community. It provides excellent real time cardiac resolution as good as or even superior to TEE without exposing patients to the risks of deep sedation or endotracheal intubation. Several studies have shown decrease in fluoroscopy time, interventional procedure time, and catheterization laboratory time when compared with TEE and subsequent decrease in radiation exposure and procedure cost.

ICE has the advantage of having an accurate evaluation of all ASDs as compared to TEE which sometimes can miss an inferior-posterior atrial septal defect (FIGURE 10A, 10B, 10C). It is also important in the evaluation of fenestrated ASDs by determining the larger defect and this allows accurate evaluation of the larger defect while it is being crossed by a wire and during balloon sizing (FIGURE 11).

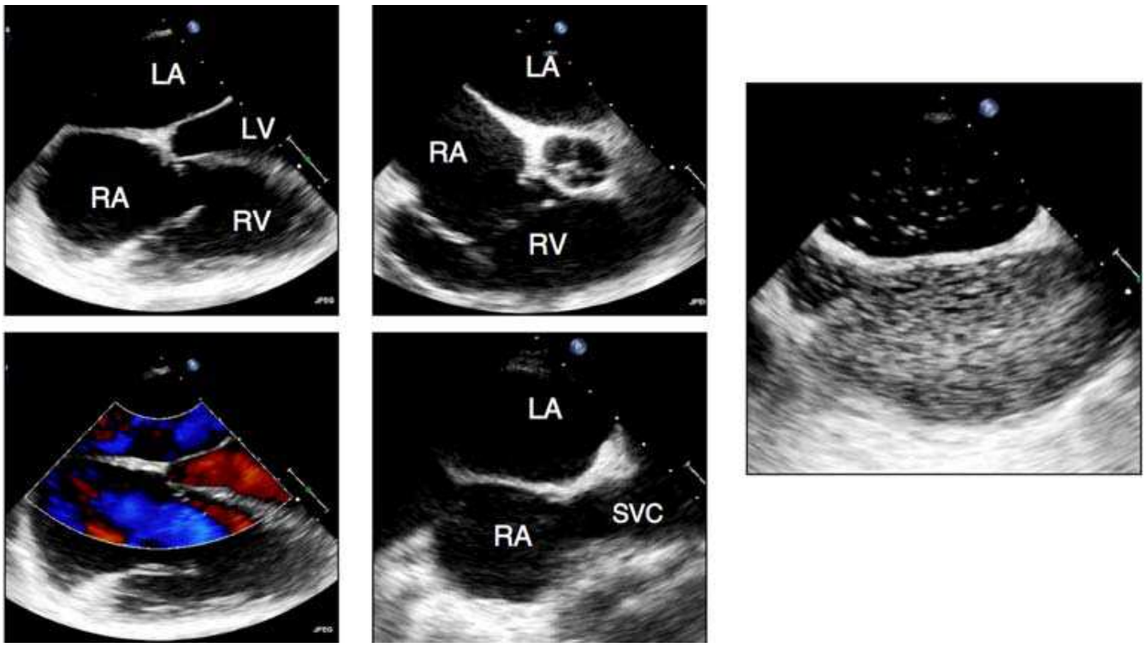


Fig. 10A. Inferior posterior ASD missed with TEE. TEE in four chamber, short axis and long axis view demonstrating intact atrial septum by 2-D and by color. Figure to the right demonstrating positive bubble study when injected in the right atrium. Right Atrium RA, Left Atrium LA, Right Ventricle RV, Left Ventricle LV, Superior vena Cava SVC.

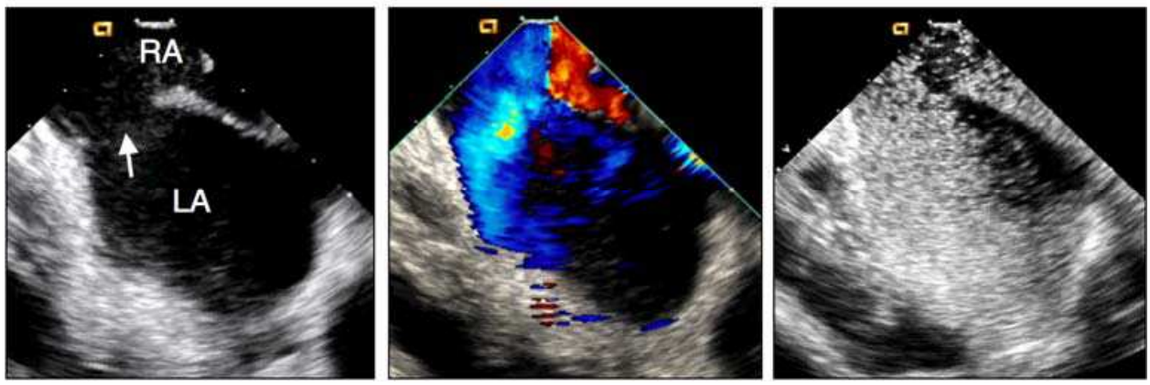


Fig. 10B. Inferior posterior ASD detected with ICE. Modified septal view showed small inferior posterior atrial septal defect (arrow) and confirmed with bubbles from the RA to the LA. Right atrium RA, Left atrium LA.

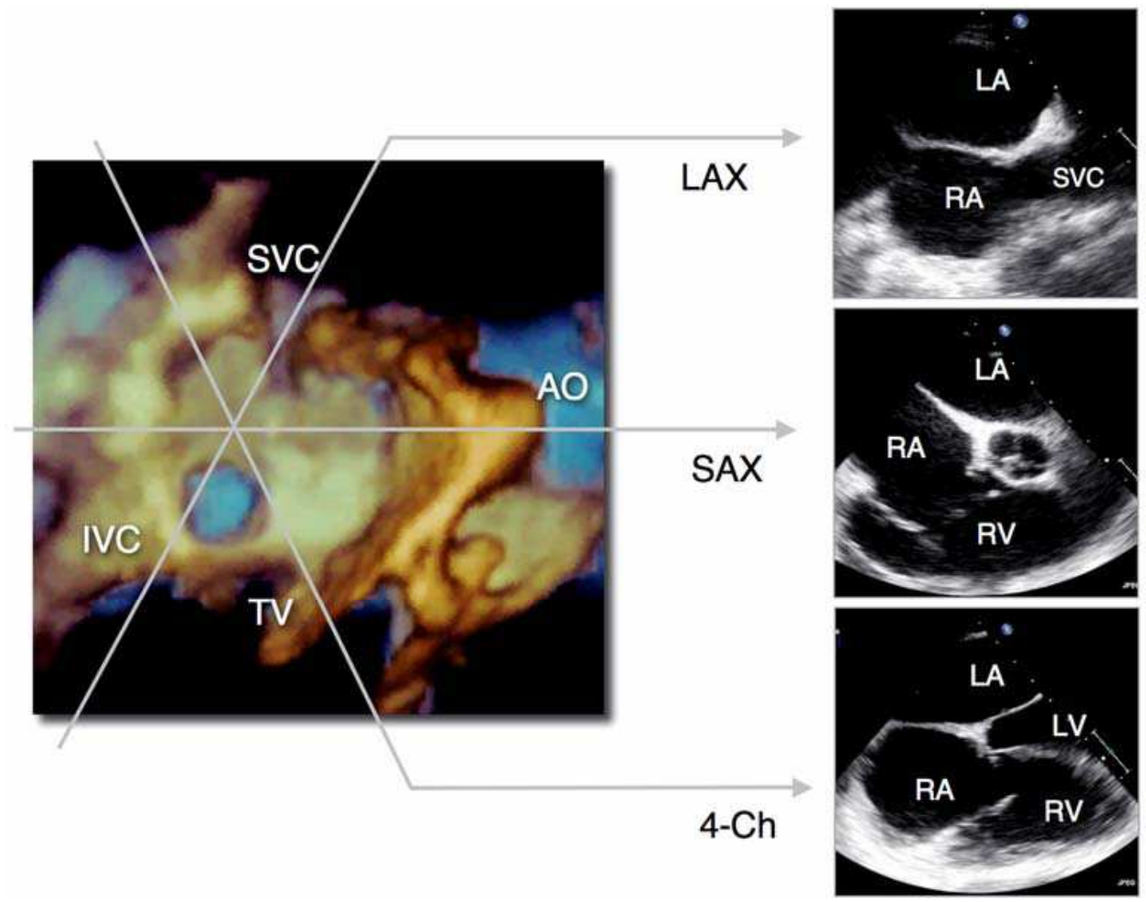


Fig. 10C. TEE 3-D. Left) TEE detected small inferior posterior defect by 3D; Right) Demonstrating different cuts while performing standard TEE 2-D views and how an inferior posterior atrial defect can be missed if 3-D image is not performed.

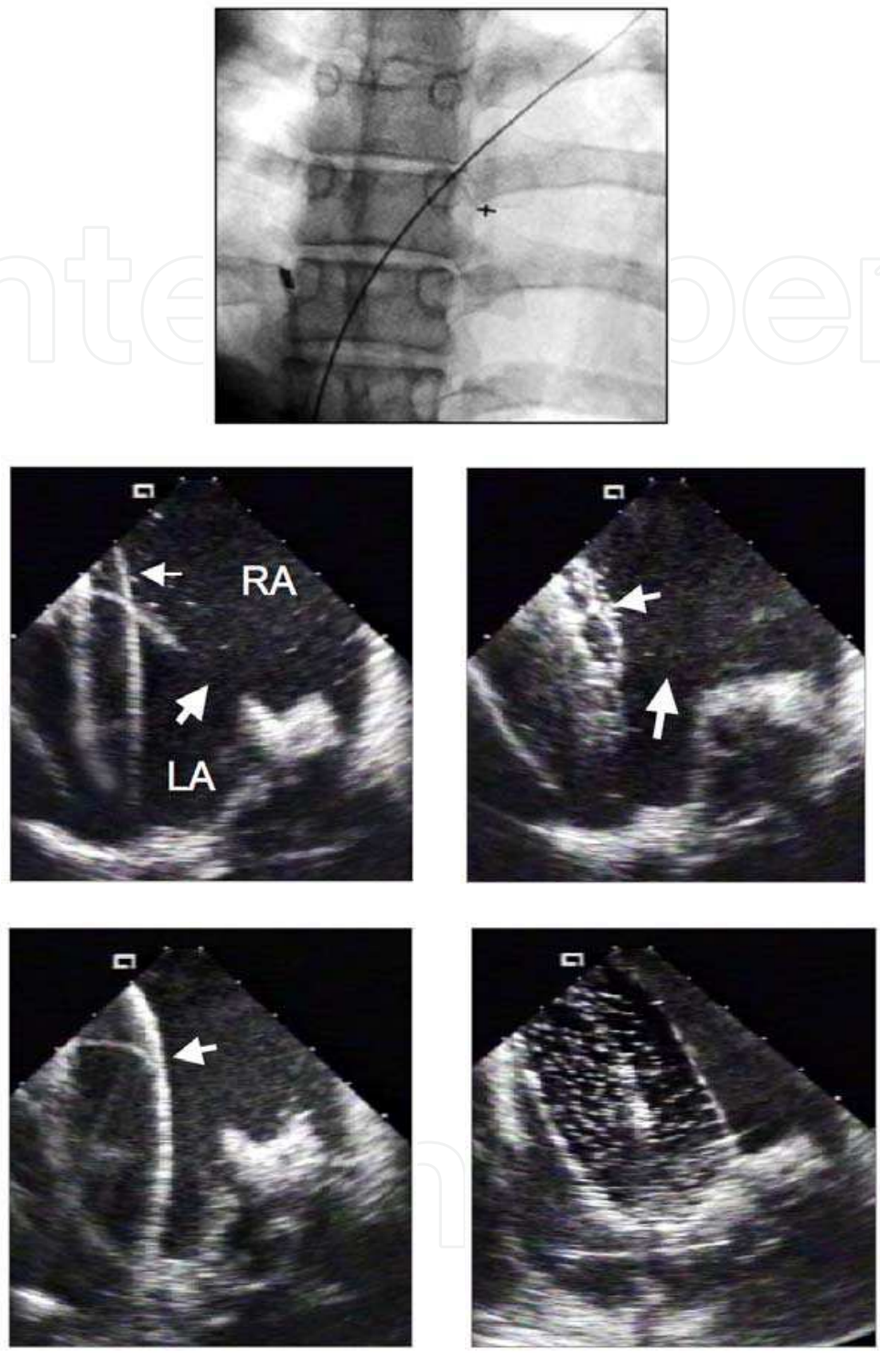


Fig. 11. Fenestrated ASD assessment. ICE images to the left demonstrating fenestrated ASD crossed by a wire (arrow). Larger atrial septal defect (arrow) not crossed by the wire. Subsequent balloon partially inflated with waist (arrow), confirming smaller atrial septal defect crossed by the wire. ICE images to the bottom demonstrating correct position of the wire crossing larger defect with successful balloon stop flow diameter. Fluoroscopic image in the top demonstrating wire crossing atrial septal defect and positioned in the left upper pulmonary vein.

The limitations of ICE include its large shaft size (8 French), and cost. In addition, there is no real time three-dimensional (3D) available in the market yet.

7. Complications related to ICE catheter

At the present time only vascular complications have been reported in the literature. There are some potential complications that may result from ICE and these are the same as the ones being reported during right heart catheterization. Transient arrhythmias can result from direct contact of the probe to the wall of the chamber. The arrhythmia should disappear after adjusting the position of the catheter. Thrombus formation around the catheter can also happen during any intracardiac procedure but can be prevented with adequate anticoagulation and decreasing the time of the ICE catheter inside the body. Other potential complications such as pericardial tamponade, pulmonary embolism, and bleeding/infection from the puncture site are infrequent but can occur as well.

8. Conclusion

ICE has shown to be helpful in guiding cardiac catheter interventions, especially EP studies and transcatheter closure of ASDs.

The use of ICE is becoming more popular for guidance of interventional procedures, especially for ASD closure (evaluation of the defect and rims and live guidance during device deployment). It has also been found to be extremely helpful during guidance of closure of complex atrial septal defects.

Currently ICE systems are easily available in the market; the skills in maneuvering the catheter and interpreting the images are not difficult to learn. The real time structural and hemodynamic information are comparable or even better than TEE with an accurate and safe procedural guidance for transcatheter closure of ASDs. The capabilities of identifying complications immediately during the procedure are exceptional.

So far to our knowledge there are no major complication reported and the only minor complications that can be encountered are related to the site of access and during advancement of the catheter. Although the risk potential seems to be low, it is mandatory that the ICE catheter is handled with caution, since it is not wire-guided.

Because the ICE catheter is inserted through the femoral vein, similar to other cardiac catheters; it allows the interventionist to perform procedures without general anesthesia, shortening procedure time, and reducing fluoro exposure with subsequent reduction of radiation exposure and costs in personnel and equipment. There is no need of an extra skilled person for the TEE, and, as such, fewer physicians are required to be present for the procedure. This results in a shorter turnaround time in the cardiac catheterization laboratory.

In the future, the development of smaller and softer catheters will decrease the incidence of vascular complications. It may also be possible for the ICE catheter to be used in all pediatric age groups. Three-dimensional/four dimensional real time images are not so far away from being developed and an extraordinary understanding of the intracardiac anatomy during

any intracardiac procedure will be achieved. Advancement of guidewires, catheters and devices through the ICE catheter can potentially be available as well.

Along with fluoroscopy it is likely that ICE will improve the safety and outcome of percutaneous closure of ASDs. With all its inherent advantages, ICE may soon replace TEE as a guiding tool not only in adults but also in adolescents and children

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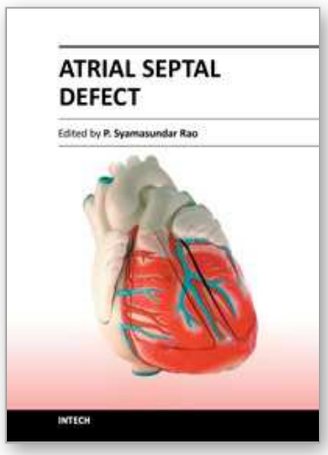
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Atrial Septal Defect

Edited by Dr. P. Syamasundar Rao

ISBN 978-953-51-0531-2

Hard cover, 184 pages

Publisher InTech

Published online 25, April, 2012

Published in print edition April, 2012

Atrial Septal Defects (ASDs) are relatively common both in children and adults. Recent reports of increase in the prevalence of ASD may be related use of color Doppler echocardiography. The etiology of the ASD is largely unknown. While the majority of the book addresses closure of ASDs, one chapter in particular focuses on creating atrial defects in the fetus with hypoplastic left heart syndrome. This book, I hope, will give the needed knowledge to the physician caring for infants, children, adults and elderly with ASD which may help them provide best possible care for their patients.

How to reference

In order to correctly reference this scholarly work, feel free to copy and paste the following:

Ismael Gonzalez, Qi-Ling Cao and Ziyad M. Hijazi (2012). Role of Intracardiac Echocardiography (ICE) in Transcatheter Occlusion of Atrial Septal Defects, Atrial Septal Defect, Dr. P. Syamasundar Rao (Ed.), ISBN: 978-953-51-0531-2, InTech, Available from: http://www.intechopen.com/books/atrial-septal-defect/role-of-intracardiac-echocardiography-in-transcatheter-occlusion-of-atrial-septal-defects

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