Intracardiac Echocardiography

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INTRACARDIAC ECHOCARDIOGRAPHY (ICE) is used during interventional cardiology and electrophysiology procedures to guide catheter placement, monitor for complications, and assess effectiveness of various interventions. As ICE becomes the standard of care for many procedures, it is imperative that anesthesiologists understand the strengths and limitations of this technology. ICE has evolved since its inception in the 1960s from elementary imaging to complex catheters capable of three-dimensional and Doppler imaging. The goal of this review is to introduce the anesthesiologist to common ICE views and to demonstrate the perioperative utility of this emerging diagnostic tool.

Echocardiography has improved the success rate of several cardiac interventional procedures, most notably device closure of atrial septal defects and patent foramen ovales.[1] Transesophageal echocardiography (TEE) frequently is used to guide device deployment; however, these procedures may last for several hours and may necessitate general endotracheal anesthesia for prolonged TEE usage. As the complexity of procedures being undertaken in the catheterization laboratory continues to escalate, ICE has become central to the success and safety of these procedures. ICE offers the advantage of being able to continuously obtain images with the patient under mild-to-moderate sedation and provides all the two-dimensional, three-dimensional, and Doppler capabilities available with TEE. And while fluoroscopy has been the mainstay of interventional procedures, intracardiac imaging has gained popularity due to the radiation risk fluoroscopy poses to patient and provider. With improvements in ICE technology, some cardiologists advocate performing ablation procedures without any use of fluoroscopy to minimize such exposure.[2] In addition, intracardiac imaging allows minimized use of intravenous contrast agents, thus decreasing nephrotoxicity in this vulnerable patient population. The case example below highlights the utility of this imaging modality.

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CASE REPORT

A 65-year-old female was scheduled for a diagnostic electrophysiology study and tachyarrhythmia ablation for symptomatic supraventricular tachycardia. She was managed medically with metoprolol, 25 mg twice a day, with continued episodes, including chest pain and shortness of breath. A recent dobutamine stress echocardiogram was normal. Her prior resting echocardiogram was notable for normal biventricular systolic function, impaired relaxation, mild tricuspid regurgitation, and mild mitral regurgitation. Her past medical history included mild chronic obstructive pulmonary disease. Preoperative complete blood count, coagulation panel, and electrolytes were within normal limits.

During the case, intravenous sedation was administered, including midazolam, 2 mg, and a propofol infusion of 100 µg/kg/min. The sheaths and catheters were inserted into the femoral veins under local anesthesia and positioned under fluoroscopy. Programmed stimulation then was performed at the right atrium, coronary sinus, and right ventricle, and radiofrequency ablation of the aberrant pathway was performed. At the end of the study, the patient was noted to be hypotensive. Intracardiac echocardiogram was performed immediately, and a significant pericardial effusion was identified (Fig 1, Video clip 1).

Pericardiocentesis was performed using fluoroscopy and a standard J-wire and pigtail. The J-wire was advanced around the lateral heart border, and the pigtail was advanced into the pericardium; 400 mL of bloody fluid were drained initially (Fig 2, Video clip 2).

Over 3 hours of observation with gentle negative pressure suction on the drains, a total of 1100 mL of bloody output were recorded for the entire case. Intracardiac echo confirmed resolution of the pericardial effusion. The patient was hemodynamically stable and was transported to the recovery room (Fig 3, Video clip 3).

Insertion Technique and Catheters

The insertion technique for ICE includes central venous access obtained via the femoral or jugular vein, preferably with ultrasound guidance. Historically, the femoral vein has been used for ICE insertion because the proceduralists are inserting other catheters from that location. Alternatively, placing the ICE catheter from the superior vena cava offers the advantage of avoiding echocardiographic artifacts created when the ICE catheter is inserted into the same location as the mapping and ablation catheters.

There are several catheters available for clinical imaging that display 90-degree imaging. The ViewFlex Xtra catheter (St. Jude Medical, St. Paul, MN) is a 9-French phased-array transducer that includes color Doppler capabilities. The operator is able to flex the catheter in 4 directions (left, right, anterior, and posterior), allowing for 120-degree tip deflection with one hand, which allows for easy maneuverability between the views described below. The penetration depth is approximately 20 cm. The AcuNav catheter (Biosense Webster, Diamond Bar, CA) is a phased-array transducer that comes in 8-French and 10-French sizes. It has two-dimensional and color Doppler capabilities with imaging frequencies of 5 to 10 MHz and a penetration depth of approximately 15 cm. Four-way steering allows for 160-degree tip deflection. The Soundstar catheter (Biosense Webster, Diamond Bar, CA) is another phased-array

Fig 1. Home view of right ventricle showing moderate pericardial effusion.

transducer with 4-way flexion that also has three-dimensional capabilities.

Standard Views

TEE exams are guided by the standard 28 views described by the American Society of Echocardiography, but there is no analogous standard exam for ICE.[3] The images obtained depend on the type of interventional procedure and the specific anatomic structure being evaluated. Several of the common views are described below.

Understanding the orientation of an echocardiography image is essential for appropriate interpretation. Most anesthesiologists are familiar with TEE orientation. The probe is in the esophagus; therefore, the chamber closest to the transducer is the left atrium when the probe is in the middle portion of the esophagus. For cardiothoracic or intensive care physicians, transthoracic imaging (TTE) has gained popularity. In this setting, TTE displays anterior structures closest to the transducer. For ICE imaging, the catheter is placed in the right atrium; therefore, the right atrium is displayed closest to the transducer.

Once the ICE catheter has been introduced into the vascular sheath, it is advanced into the right atrium; this serves as the home view. From this position, the tricuspid valve, right ventricular inflow and outflow, and pulmonic valve may be examined in two dimensions and with Doppler. A short-axis view of the aortic valve can be seen in this view as well, with small amounts of manipulation. This view is analogous to

Fig 2. Pericardial drain placed into the pericardium.

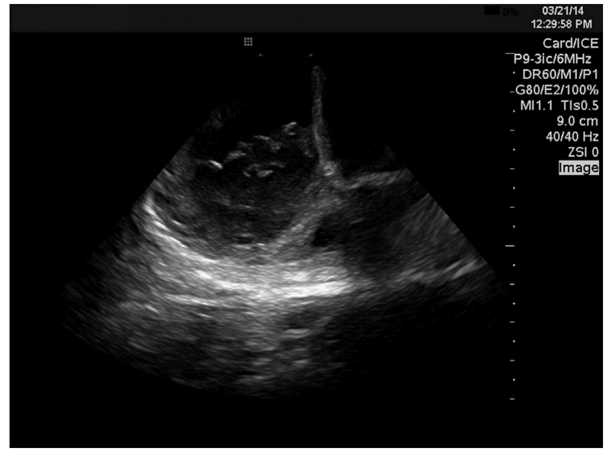

Fig 3. Home view showing no residual effusion after pigtail catheter placement.

the TEE midesophageal right ventricular inflow-outflow view used to examine tricuspid valve anatomy, right ventricular free wall movement, and pulmonic valve anatomy (Video clip 4).

From the home view, the catheter can be manipulated to point toward the inter-atrial septum; this is called the septal view. The coronary sinus and the pulmonary veins also can be seen from this view depending on the penetrating frequency.[4] Both atria are visualized but unlike TEE, in ICE the right atrium is closest to the transducer, so it is seen at the top of the image in the near field; meanwhile, the left atrium, which is farther from the transducer, is seen at the bottom of the image in the far field (Video clip 5).

Left-sided heart structures can be visualized with phased-array ICE transducers, because they have better penetration. The usual penetration depth of ICE imaging is about 8-10 centimeters. From the home view, clockwise rotation of the catheter directs the transducer toward the left heart. In this view, the left atrium, mitral valve, left atrial appendage, and left ventricle can be seen in the long axis. This view is analogous to the TEE midesophageal two-chamber view seen at approximately 90 degrees. With continued rotation, the left-sided pulmonary veins can be seen entering the left atrium.[5] This is analogous to leftward rotation of the TEE probe from the midesophageal two-chamber view to visualize the left-sided pulmonary veins. One unique advantage of ICE over TEE is that with continued rotation, the left atrium and its relationship to the esophagus can be seen in addition to the relationship between the pulmonary veins and the esophagus. These images and the corresponding anatomic relationship between the left atrium and esophagus cannot be obtained with TEE. (Video clip 6)

Clinical Utility

ICE may be used effectively to monitor for complications during electrophysiology and interventional cardiology procedures. As shown by the case example, cardiac perforation resulting in tamponade may occur during any interventional or electrophysiology procedure. While the incidence is small, on average 0.3% of cases, the number of electrophysiology and interventional cardiology cases is growing rapidly.[6] Early detection of pericardial effusions allows for heparin reversal and may help prevent the development of tamponade physiology. Intervention with pericardiocentesis and drain placement may be needed, and ICE can monitor for reaccumulation of fluid. In the case example, the patient was only under light, intravenous sedation and, thus, was not a suitable candidate for transesophageal echocardiographic imaging. ICE allowed for prompt diagnosis and management and thus may have helped prevent sternotomy and open repair.