Editorial

Intracardiac Echocardiography: Current Status, Clinical Benefits, and Future Perspectives

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Intracardiac echocardiography (ICE) is an ultrasound imaging technique capable of providing real-time, high-quality visualization of cardiac structures and their adjacent tissues through a catheter with a transducer inserted directly into the heart chambers, typically via transfemoral venous access. By allowing direct and precise visualization of intracardiac anatomy, ICE has been increasingly used to guide structural interventions and catheter ablations for cardiac arrhythmias, as well as to enable immediate detection of intraoperative complications.[1]

Initial clinical investigations began in the 1960s, focusing on the assessment of atrial septal defects. Since then, ICE has evolved significantly.[2] The introduction of the phased-array transducer, the addition of color Doppler functionality, and advancements in manipulation systems have enabled its widespread clinical application. The latest version of phased-array ICE features a position sensor at the catheter tip, allowing real-time integration with three-dimensional electroanatomic mapping systems used in complex ablations. The ability to precisely maneuver the catheter, combined with its versatile positioning, makes ICE a valuable tool for anatomic navigation and real-time monitoring during complex interventions.[3]

Initially, ICE was used to guide the percutaneous closure of atrial septal defects, serving as an alternative to transesophageal echocardiography (TEE), with comparable imaging quality and better tolerability.[1] Currently, ICE is the preferred imaging modality in various electrophysiology procedures, as it eliminates the need for general anesthesia and allows the operator to manage the imaging, optimizing time and resources.[4]

In electrophysiology, ICE has become an essential tool. In atrial fibrillation ablation, ICE safely guides transseptal puncture and provides real-time visualization of the left atrium, pulmonary veins, atrial appendage, and adjacent structures, such as the esophagus and pulmonary arteries, allowing precise delineation of the ablation area and preventing thermal complications. In atrial tachyarrhythmia ablations, such as atypical atrial flutter, ICE helps identify complex anatomical structures and reentry pathways, guiding catheter positioning around scars or critical zones.[5]

In ventricular arrhythmias, ICE has been increasingly used. In the ablation of extrasystoles or tachycardias originating from the right ventricular outflow tract, ICE enables precise anatomical positioning between the outflow tract and adjacent structures. For arrhythmias originating from the left ventricular outflow tract and the left ventricular summit, ICE assists in guiding transseptal or retroaortic approaches, improving procedure efficacy and safety. Its role is even more crucial in coronary cusp arrhythmias, as it provides clear visualization of catheter contact with the cusp, Valsalva sinus, and coronary artery ostium. In cases of arrhythmias originating from the papillary muscles, ICE is particularly valuable, as it allows direct visualization of these mobile structures and continuous catheter contact with the target, which is challenging using electroanatomic mapping alone, enabling more effective procedures. In scar-related ventricular tachycardia, ICE complements electroanatomic mapping by identifying areas of myocardial thinning, aneurysms, and akinetic walls, as well as fibrotic regions associated with the arrhythmogenic substrate, while also monitoring real-time catheter stability during ablation.[6]

Another highlight is the use of ICE in the closure of left atrial appendage. In addition to transseptal puncture, ICE provides visualization of the appendage anatomy, diameter assessment, and guidance for device deployment, while reducing the use of iodinated contrast and fluoroscopy. In many centers, ICE has replaced TEE in this scenario, allowing the procedure to be performed under conscious sedation. This approach is particularly useful when combining atrial fibrillation ablation with LAA closure.[7]

ICE has been gaining ground in interventional cardiology, especially with the development of 3D ICE, serving as a valuable complement and even an alternative to TEE in certain cases. In adults, its application stands out in the percutaneous closure of atrial septal defects and patent foramen ovale, where image quality is superior, and the procedure can be performed under conscious sedation.Initial results are promising for transcatheter mitral valve repair, and more recently, ICE has been studied for percutaneous tricuspid valve procedures and paravalvular leak closure. In transcatheter aortic valve implantation, fluoroscopy remains the standard imaging method, but in more complex cases, 3D ICE can add value and serve as an alternative to TEE.[8]

In percutaneous treatment of congenital heart diseases, ICE has been explored in structural interventions beyond atrial septal defect closure, including ventricular septal defect interventions, patent ductus arteriosus procedures, and pulmonary valve disease treatments. Its use reduces radiation

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exposure and minimizes the need for prolonged general anesthesia, providing significant benefits for pediatric and adult patients with congenital heart disease.[1,9]

ICE is a safe alternative for identifying thrombi in the left atrial appendage, significantly enhancing procedural safety by reducing complications such as cardiac tamponade, thrombosis, and pulmonary vein stenosis.[10] Performing ablations with minimal or even no radiation exposure is now a reality, making it especially relevant for young patients and pregnant women, while also significantly reducing occupational risks for the medical team.[1,10,11]

Additionally, the implementation of ICE in daily practice is feasible after a short learning curve, allowing for rapid adoption without compromising procedure safety or efficacy.[12]

Despite advancements, cost remains a barrier to the widespread dissemination of ICE, primarily due to the high price of disposable catheters. However, considering reduced procedure time, fewer complications, and decreased need for general anesthesia, the total cost of the procedure may be comparable to that of TEE.[1,13]

Emerging technologies, such as real-time three-dimensional ICE, are already being applied and promise to further enhance the precision of interventions.[8] The miniaturization of catheters, improvement in image resolution, and integration with artificial intelligence algorithms for automatic segmentation and structure identification are expected soon.[1,9]

ICE represents one of the major innovations in cardiovascular imaging for contemporary interventional practice. Its growing use is driven by its ability to combine image quality, safety, and efficiency, making it a fundamental tool for high-complexity procedures in electrophysiology and structural cardiology, with a positive impact on procedural safety and efficacy.

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