Clinical Update

Use of Intracardiac Echocardiography in the Electrophysiology Laboratory

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Abstract

The intracardiac echocardiography (ICE) offers a detailed visualization of the cardiac structures, in association with hemodynamic information, allowing the precise and real-time positioning of the catheters, decreasing the time of exposure to fluoroscopy and the monitoring of acute complications during the electrophysiological procedure (i.e., formation of thrombi, pericardial effusion, cardiac tamponade), Consequently, its use has progressively increased, mainly in the ablation of atrial fibrillation and ventricular arrhythmias. It has shown to be very useful in the ablation of atrial fibrillation by providing anatomic data on the left atrium and pulmonary veins, helping in transseptal punctures, locating the ostium and antrum of the pulmonary veins, monitoring tissue injury during radiofrequency (RF) use, preventing esophageal injury by monitoring the injuries caused by RF on the left atrial posterior wall and assessing the pulmonary vein flow.

Introduction

The intracardiac echocardiography (ICE) is a method that allows the detailed visualization of cardiac structures, associated with hemodynamic information. Consequently, its use has progressively increased in several interventionist cardiology procedures, among them: transseptal puncture, closing of atrial septal defect[1], detection of intracardiac thrombus, balloon valvuloplasty[2], diagnosis/biopsy of intracardiac mass and electrophysiological procedures, such as ablation of atrial fibrillation (AF)[3], atrial flutter and ventricular tachycardia[4] and occlusion of the left atrial appendage[5].

The ICE is performed by percutaneous venous approach, usually through a 10 to 11 French vascular introducer in the femoral vein, which is positioned in the right cavities. The 2nd generation or 64-element systems (Acunav™, Siemens Medical Solutions, USA and ViewMate™, EPMedSystems, USA) operate at a ufrequency of 5 to 10 MHz and allow the visualization of two-dimensional images, M-mode and color-Doppler images. The catheters are multidirectional and can be handled at two planes (anteroposterior and right-left). These systems offer a penetration of 12 cm in depth, allowing the visualization of structures on the left side of the heart, when positioned on the right side. Through rotational movements (clockwise and anticlockwisecounterclockwise) and deflections, one can obtain images of several cardiac structures. More rarely, the positioning of the catheter in the right ventricular cavity or within the coronary sinus can also be useful in the visualization (Figure 1).

At the laboratory of electrophysiology laboratory, the use of the ICE has been progressively increasing in practice, as it presents important advantages, such as decreased time of exposure to fluoroscopy, allowing a more accurate and updated information on the positioning of the catheters and their association with the anatomical structures[6], as well as enabling the monitoring of acute complications during the procedure (thrombus formation, cardiac tamponade, gas embolism etc) (Table 1).

The ICE can be used to detect the presence of thrombi before or during interventions on the left side of the heart. Additionally, it detects the presence of spontaneous contrast (Figure 2) and decreased left atrial appendage filling velocity $\leq$ 20 cm/s, factors that are associated with an increased risk of thromboembolic events[7].

The images recorded by the ICE located in the right atrium allow an accurate visualization of the interatrial septum (IAS), facilitating the transseptal puncture directing it posteriorly, thus facilitating access to the pulmonary veis and the left atrial posterior wall and its directioning (i.e., posterior for better access to the pulmonary veins) and increasing the safety of the intervention, with a consequent lower rate of complications (i.e., aortic puncture, pericardial puncture or tamponade, systemic arterial embolism and vena cava puncture) (Figure 3).

The precise location of important endocardial structures and their association with the catheters is essential for a successful ablation. The ICE facilitates the understanding of the cardiac anatomy, being superior to the simple fluoroscopic method (Table 2). Zanchetta et al[6] demonstrated an excellent accuracy of the images of intracardiac structures provided by the ICE, when compared to those obtained through cardiac magnetic resonance imaging.

The ICE also allows the monitoring of the contact of the catheters with the tissue and the formation of radiofrequency lesions. There is a good correlation between the ultrasonographic image and the pathology of lesion, as

Keywords

Echocardiography/utilization; monitoring; echocardiography, Doppler.

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Manuscript received July 22, 2009; revised manuscript received September 20, 2009; accepted October 26, 2009.

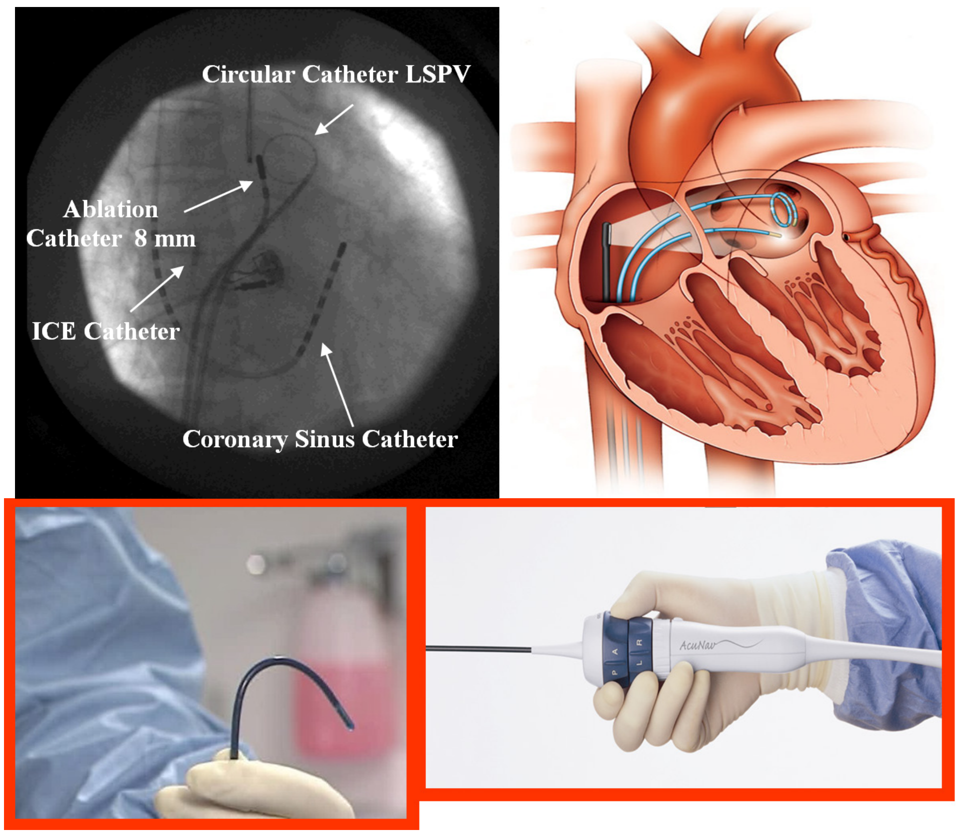

Figure 1 - Positioning of the intracardiac echocardiography (ICE) probe in the right atrium through fluoroscopy (to the left). Schematic visualization (to the right). ICE probe handling (below).

Table 1 - **Use of the intracardiac echocardiography in cardiac arrhythmias**

Detect intracardiac thrombus
Help in transseptal puncture
Identify endocardial structures
Locate catheters with accuracy
Monitor and quantify radiofrequency ablation lesions
Monitor complications during the procedure (formation of thrombus, embolism, tamponade, vein stenosis)
Evaluate the atrial mechanical function

seen in a canine model[8]. The ICE demonstrates edema and/or increased echogenicity at the site of ablation[9-11].

The electrophysiological procedures carried out under ICE visualization are safer and allow the immediate identification of complications that are inherent to the procedure, such as the early detection of cardiac perforation, pericardial effusion or tamponade (Figure 4).

The formation of thrombi and the occurrence of embolic events are feared complications, mainly during procedures carried out on the left side of the heart. The ICE allows the early identification of this complication, facilitating the prompt decision-making to prevent systemic embolism[12,13] (Figure 5).

ICE nain the ablation of atrial fibrillation

The catheter ablation of AF was initially described by Chen and Haissaguere[14] and has, as a primary objective, the elimination of triggering ectopic foci within the pulmonary veins, through the electrical isolation of the connections of the pulmonary veins with the left atrium.

In contrast with other ablations of supraventricular tachycardia, the ablation of AF requires access to the left atrium through two transseptal punctures, with the patient fully anticoagulated and a more extensive approach through multiple radiofrequency lesion; thus, the ablation of AF has a longer duration and presents a higher risk of complications (thromboembolism, pulmonary vein stenosis or esophageal injury)[15].

Several strategies to guide the isolation of the pulmonary veins have been described and among them, the angiography-guided ablation, the electroanatomic mapping and the electrophysiological mapping guided by the ICE.

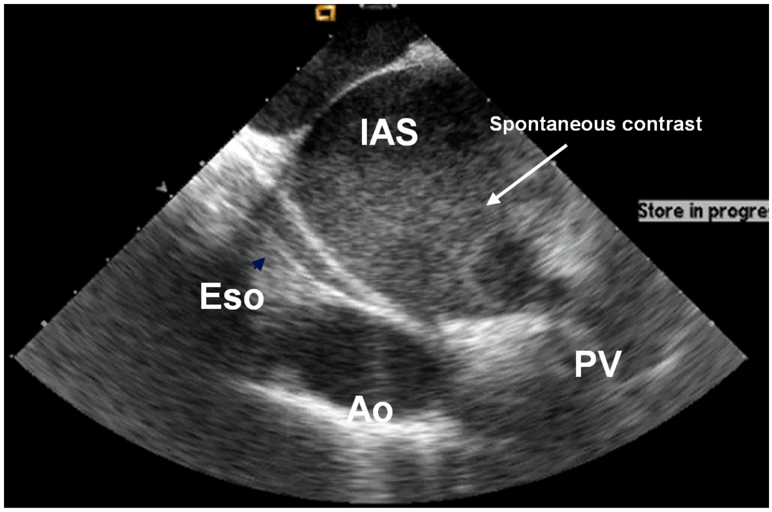

Figure 2 - Visualization of endocardial structures of the heart. IAS - interatrial septum. Eso - esophagus. Ao - aorta. PV - pulmonary vein. Significant spontaneous contrast in the left atrium.

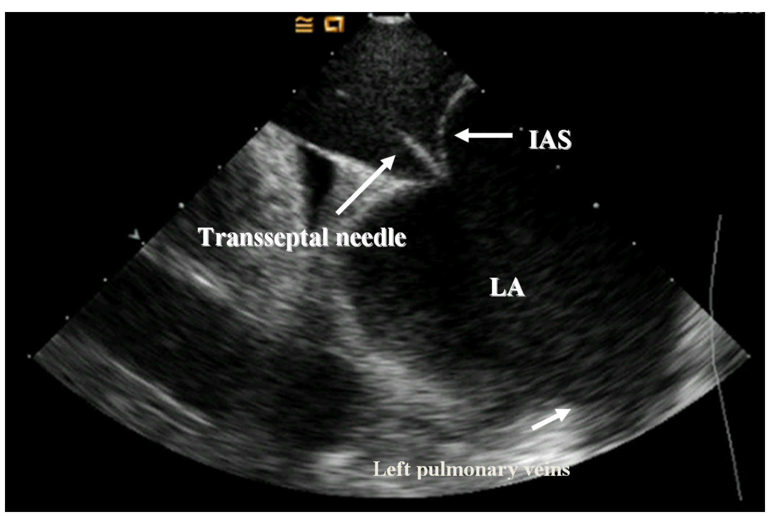

Figure 3 - Transseptal puncture carried out under direct visualization of the interatrial septum (IAS) through intracardiac echocardiography. Atrial septum "tenting" can be observed due to sheath pressure. LA - left atrium.

The ICE supplies precise information on the anatomy of the pulmonary veins and clearly demonstrates the presence of anatomic variations, such as the common drainage and accessory veins.

The HRS/EHRA/ECAS Expert Consensus Statement on Catheter and Surgical Ablation of Atrial Fibrillation[16] recommends the use of ICE based on the following advantages:

1. Safer transseptal puncture (through the direct visualization of the interatrial septum, without the need to use iodine contrast). The ICE allows such punctures to be performed in patients that are fully anticoagulated, which decreases the probability of thrombus formation within the left atrium and decreases the incidence of cardiac tamponade.
2. Defines the anatomy of pulmonary veins.
3. Allows the precise positioning of circular mapping catheters in the ostium of pulmonary veins, helping to determine the sites where the radiofrequency must be applied, preventing its use within the pulmonary veins (which increases the risk of vein stenosis) Packer et al[17] demonstrated that the angiography-guided technique can present a discrepancy > 10 mm when defining the ostium of pulmonary veins with precision, when compared to ICE

(Figure 2). This is an important aspect, considering that the pulmonary vein stenosis is a severe condition with a high rate of morbimortality.

4. Evaluates the contact between the catheter and the cardiac tissue, which is essential to promote the transmurality of ablation lesions[18].
5. Early identification of thrombus formation within the left atrium[12,13].

Table 2 - Structures/images visualized through the intracardiac echocardiography that are useful for electrophysiology

Cardiac images/structures	Clinical use
Interatrial septum/foramen ovale	Transseptal puncture
Coronary sinus ostium	Implant of left ventricular electrode, ablation of supraventricular tachyarrhythmias
Cavotricuspid isthmus	Ablation of atrial flutter
Koch's triangle	Ablation of AV node reentry
Pulmonary veins	Vein anomalies, ablation of atrial fibrillation
Left atrial appendage	Thrombus, flow velocity
Esophagus	Atrial fibrillation ablation, prevention of atrioesophageal fistula
Radiofrequency lesions	Ablation of flutter and atrial fibrillation and VT
Endocardial microbubbles	Ablation of atrial fibrillation
Thrombus in the left atrium	Acute complication of ablation in left atrium
Pericardium	Stroke, tamponade, epicardial ablation

6. The success of the AF ablation depends on the transmurality of the lesion to guarantee the electrical isolation[17-20]; large-caliber catheters (8 mm) or those with irrigation result in high-potency release and greater tissue damage, and, consequently, a higher risk of complications[21,22]. The ICE promotes the monitoring of microbubble formation, which reflect tissue overheating, with consequent potency titration of radiofrequency use, when the 8-mm catheter is employed[23,24].
7. Identifies and predicts stenosis of the pulmonary veins, through the measurement of the flow velocity in the ostium of the pulmonary veins before and after the procedure[25].
8. Prevents esophageal injury through the identification of the esophagus and visualization of morphological changes on the posterior atrial wall adjacent to the anterior esophageal wall. The radiofrequency energy can be titrated based on the echogenicity of the formed lesion[26,27].

The occurrence of pulmonary vein stenosis can be monitored by ICE through the measurement of the ostium of the pulmonary veins and systolic and diastolic flow velocities before and after the catheter ablation for AF. Generally, acute alterations in the flow velocity of the pulmonary veins resolve within three months; however, cases of severe stenosis can occur[28]. Acute changes of mild to moderate intensity in hemodynamics and the measurements of the ostium of the pulmonary veins do not seem to be correlated with the late stenosis of the pulmonary veins[25].

ICE in the ablation of atrial flutter

The ablation of the typical flutter is carried out through a cavotricuspid isthmus block line. Sometimes, there are anatomical diversities that make the ablation of this isthmus

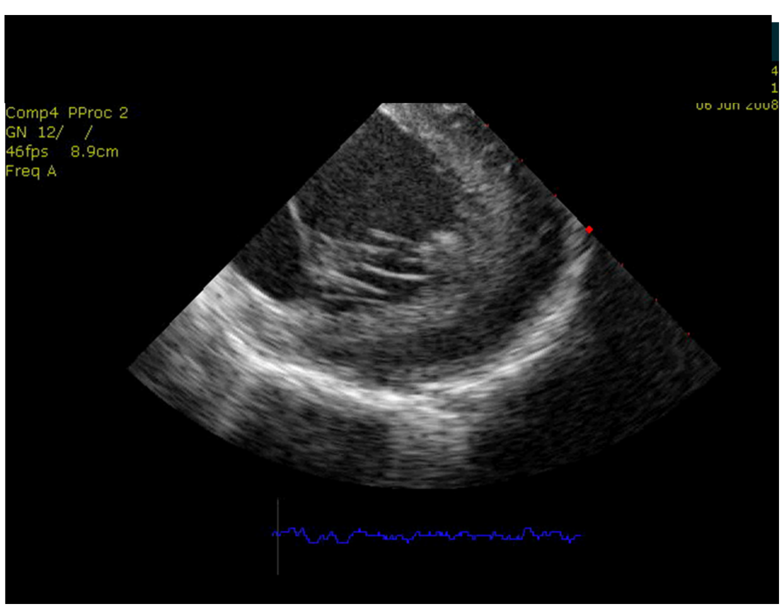

Figure 4 - Visualization of moderate pericardial effusion during AF ablation procedure.

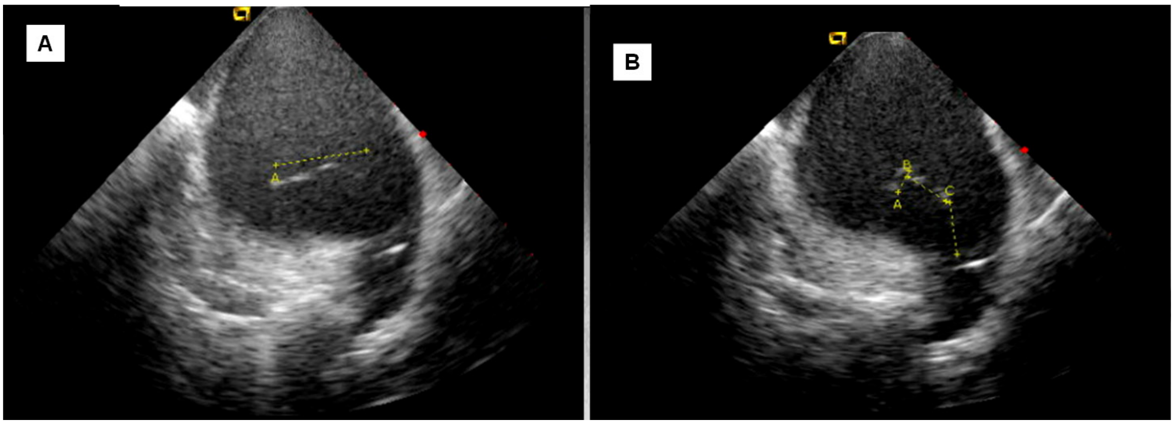

Figure 5 - Intracardiac echocardiographic images showing thrombus in the left atrium (yellow-dotted line), adhered to the circular decapolar catheter (Lasso™) located in the left upper pulmonary vein.

difficult. The ICE provides a direct visualization of this isthmus and its variations, such as the presence of crests, recesses, sacs, trabeculations, facilitating the ablation of the isthmus flutter[10,29]. The ICE becomes quite useful in patients with Ebstein's anomaly, who frequently present cavotricuspid isthmus abnormalities due to the low implantation of the tricuspid valve.

The ICE also helps in the positioning of the ablation catheter, in the visualization of the contact between the catheter and the tissue and the observation of the radiofrequency lesion in deep recesses and prominent trabeculations.

ICE in the ablation of ventricular tachycardia

The use of ICE in the ablation of ventricular tachycardia presents the following advantages:

1. Identification of the arrhythmogenic substrate: scars, aneurysms, akinesia or dyskinesia.
2. Continuing monitoring of complications during the ablation: cardiac perforation and tamponade, valvular injury, thromboembolic events.
3. Accurate location of the catheter and its contact with the endocardium.
4. Identification of the ostia of the coronary arteries and their association with the positioning of the ablation catheter in cases of ventricular tachycardia related to the left ventricular outflow tract[4] (Figure 6).
5. Monitoring of tissue injury by radiofrequency through the formation of microbubbles.
6. Helps in procedures carried out on the epicardial surface by guiding the subxiphoid pericardial puncture, visualization of puncture-related complications (ventricular perforation) and the accurate position of the catheter[27].

Other uses of ICE in cardiac arrhythmias

1. Location of the ostium of the coronary sinus for catheter and resynchronization pacemaker electrode implant: the ICE provides images of the anatomy of the coronary sinus (it can present valves at several points) and discloses dynamic alterations according to the cardiac cycle that make its cannulation difficult[30].
2. Helps in the occlusion of the left atrial appendage: the occlusion of the left atrial appendage by percutaneous prosthesis is an additional therapy being developed in patients with AF and high risk of embolic events. The ICE facilitates the performance of the procedure by locating the left atrial appendage and helping in the positioning of the prosthesis, in addition to facilitating the transseptal puncture[31].

Limitations

When routinely adopting any new technology, one must consider its limitations in community practice. Regarding the ICE, 3 items deserve to be discussed:

a) *Additional costs* - the use of ICE increases the cost of the ablation procedure; however, this increase is comparable to other broadly used technologies, such as the electroanatomic mapping. In fact, a system that integrates these two technologies is already available in the market (Carto Sound™ - Biosense Webster).
b) *Morbidity* - this technique requires an additional venous puncture with a large-caliber vascular sheath (11F), which could, in theory, result in vascular complications; however, the authors' experience does not corroborate this concern, as there have been no cases of significant vascular complications related to the sheath diameter in more than 5,400 procedures carried out by them.
c) *Easy to use* - the ICE requires a learning curve for the operator to become independent and comfortable when handling it, which can be achieved through a brief training period (we estimate that as being 10 to 15 cases).

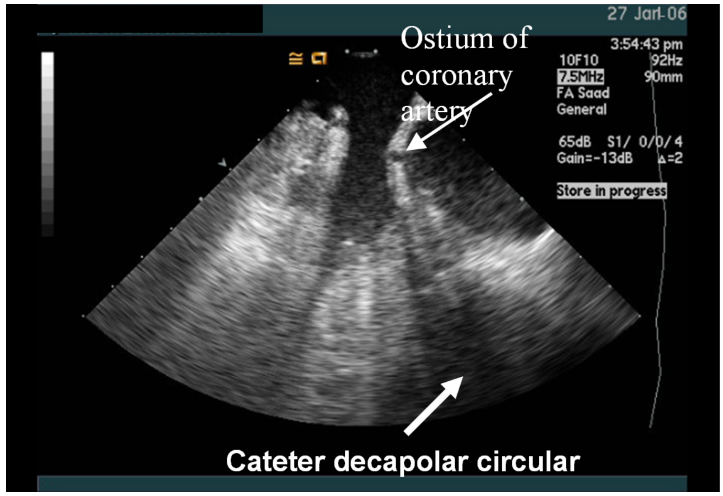

Figure 6 - Visualization of the ostium of coronary arteries during ablation of ventricular extrasystole in aortic cusp.

In general, the handling is easy and fast, being also comparable to other technologies used in the laboratory of electrophysiology.

With the acquired experience, the authors strongly recommend the routine use of ICE, particularly for the ablation of AF, even if we acknowledge that its use is not mandatory. This procedure is often carried out in the community in Services with little experience with the procedure, which is clearly more complex than other electrophysiological procedures. It is exactly in this scenario that we believe ICE can make the procedure easier to apply, increase the operator's comfort and precision and help decrease complications.

Its additional cost seems fully justifiable by the benefits of the method, even in the absence of specific randomized studies.

Conclusions

The ICE is a very useful tool when performing complex electrophysiological procedures, as it provides a real-time and precise visualization of the catheters; moreover, it is easy to handle and its use is easy to learn. Its use helps in the early detection of complications and mainly, in the decrease of these adverse events.

Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

Sources of Funding

There were no external funding sources for this study.

Study Association

This study is not associated with any post-graduation program.

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