My Approach to Intracardiac Echocardiography During Atrial Fibrillation Ablation

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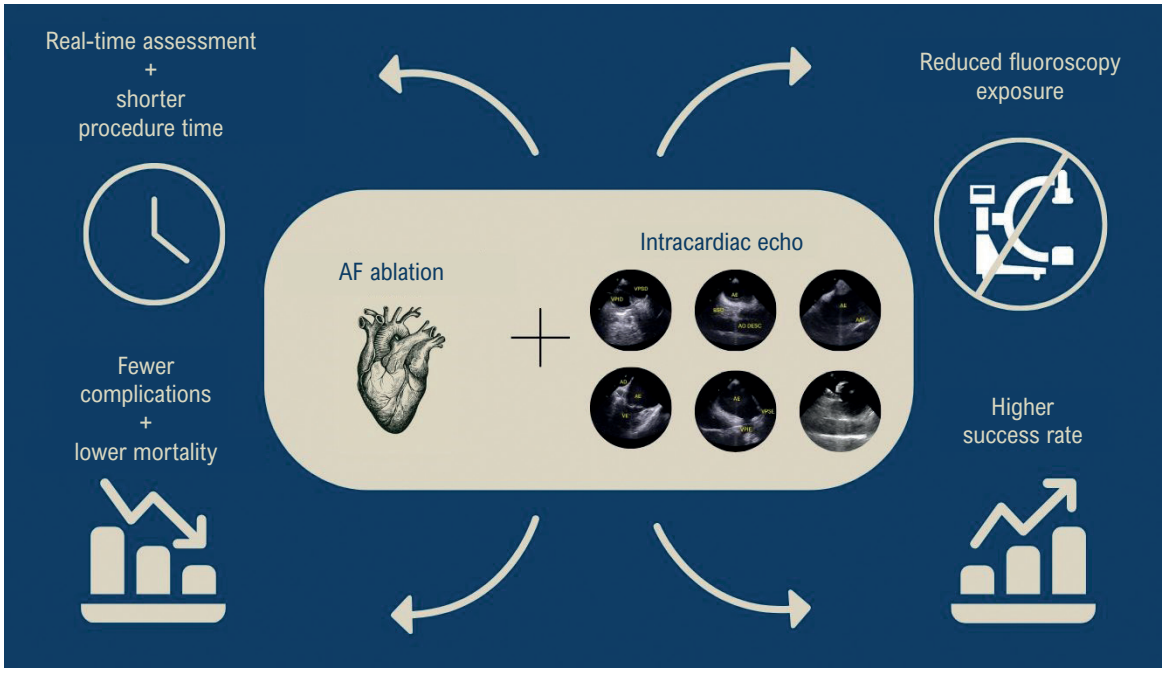
Central Illustration: My Approach to Intracardiac Echocardiography During Atrial Fibrillation Ablation



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AF: atrial fibrillation.

Abstract

Atrial fibrillation (AF) is the most common arrhythmia encountered in clinical practice and is associated with serious complications such as stroke and heart failure. The prevalence of AF is increasing significantly due to population aging and related comorbidities.[1] In addition, advances in technology — particularly the detection of AF through wearable devices such as smartwatches — have enabled earlier diagnosis. Intracardiac echocardiography (ICE) is a valuable imaging modality in electrophysiology and hemodynamic labs and is well-supported by the literature.[2-5] Since the early studies conducted at the Mayo Clinic,[6,7] ICE has rapidly become an indispensable tool for assessing cardiac anatomy. ICE enables real-time visualization of catheter positioning, tissue contact, its relationship to arrhythmogenic substrates and ablation targets, lesion formation, and procedural complications. Several recent studies have demonstrated the benefits of ICE in complex ablations, including reduced procedure times and complication rates, such as lower risks of cardiac tamponade and mortality, along with higher success rates (Central Illustration).[8-12] ICE-guided procedures are increasingly used in clinical practice across a variety of settings. They are considered feasible, safe, and associated with decreased

Keywords

Intracardiac Echocardiography; Catheter Ablation; Atrial Fibrillation

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fluoroscopy exposure — or even complete fluoroless procedures, as implemented by several groups in Brazil and worldwide.[8,13-15] This article provides a step-by-step "My Approach to" guide on how to perform ICE during AF ablation.

Step 1 – Getting to know the system

The catheter used employs a phased-array system (8 and 10 Fr) with a high-resolution ultrasound transducer located at the distal tip (5 to 10 MHz). Images are acquired in the longitudinal plane, with the imaging field aligned with the catheter axis. The catheter can be manipulated in four directions using bidirectional steering: anterior-posterior and right-left (Supplementary Video 1).

There are two models currently available in Brazil: i) SoundStar® eco (Biosense Webster), compatible with the GE ultrasound systems Vivid™ i and Vivid™ q; ViewFlex™ Xtra (Abbott), compatible with the Zonare Z.One Ultrasound System (Figure 1A and 1B).

Step 2 – Inserting the catheter

Following ultrasound-guided venous puncture, the catheter is advanced from the left femoral vein through the ipsilateral iliac vein and the inferior vena cava until it reaches the right atrium (RA). During this progression, attention must be paid to possible vessel curvatures and draining veins. At this stage, anterior and/or posterior deflection of the catheter should be used to navigate curves. The catheter should always be advanced within the vessel while visualizing the "echo-free space" on ultrasound, which reduces the risk of vascular perforation and eliminates the need for fluoroscopy (Supplementary Video 2).

Step 3 – Identifying intracardiac anatomy and adjacent structures

With the catheter positioned in the RA, the Eustachian valve and its morphology — whether rigid, prominent, or filamentous — can be identified. A filamentous Eustachian valve with erratic motion within the RA, if not previously recognized, may be mistaken for filamentous thrombi adherent to sheaths or catheters.

From the mid-RA, with the transducer directed toward the tricuspid valve (TV), the image known as the "Home View" is obtained. This view displays the RA, TV, and the inflow tract of the right ventricle (RV). For operators in the early stages of the learning curve, this image serves as a reference point to return to when anatomical structures are not clearly identified. By rotating the catheter clockwise approximately 10-20 degrees from the Home View, the following structures are sequentially visualized: i) aorta and RV outflow tract (RVOT); ii) aorta and left ventricular (LV) outflow tract (LVOT); iii) left atrium (LA) and interatrial septum (IAS); iv) LA, mitral valve (MV), and LV; v) LA and left atrial appendage (LAA); vi) LA and left pulmonary veins (PVs) in longitudinal view; vii) posterior wall (PW) of the LA, esophagus, and descending aorta; and viii) right PVs in transverse view.

There are no mandatory or predefined imaging planes. Cranial advancement or retraction of the catheter, as well as anterior-posterior and right-left flexion, are often required to obtain optimal images. Figure 2 (A-H) illustrates such imaging planes and the corresponding views obtained with the catheter positioned in the RA.

In atrial fibrillation (AF) ablation, it is often necessary to evaluate certain structures with the catheter positioned in the RV, which can be done without the use of fluoroscopy. With the TV in view, the catheter is gently deflected anteriorly and advanced into the RV. Once it crosses the TV, the deflection is released, allowing visualization of the inferior portion of the RV and its anatomical landmarks, such as the moderator band and papillary muscles, as well as the pericardial space. This view is particularly important for detecting any preexisting pericardial effusion (PE) at the start of the procedure. From the RV,

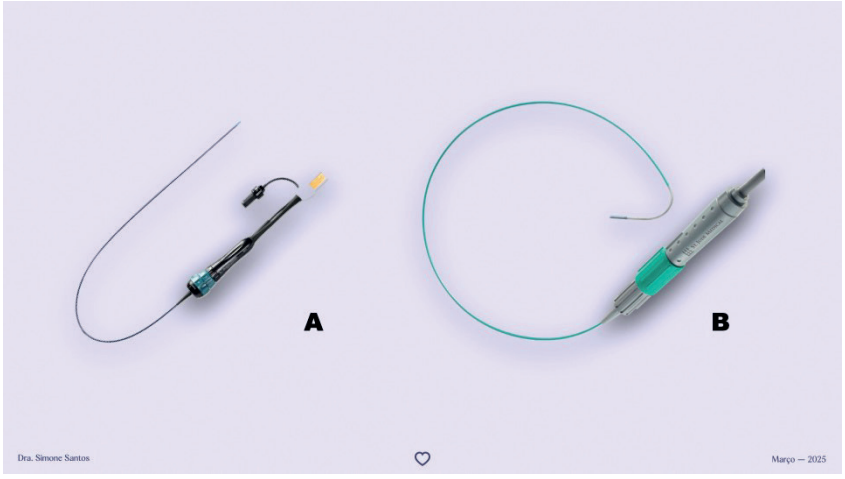

Figure 1 – *Phased-array catheters available in Brazil. A: SoundStar® (Biosense Webster); B: ViewFlex Xtra® (Abbott).*

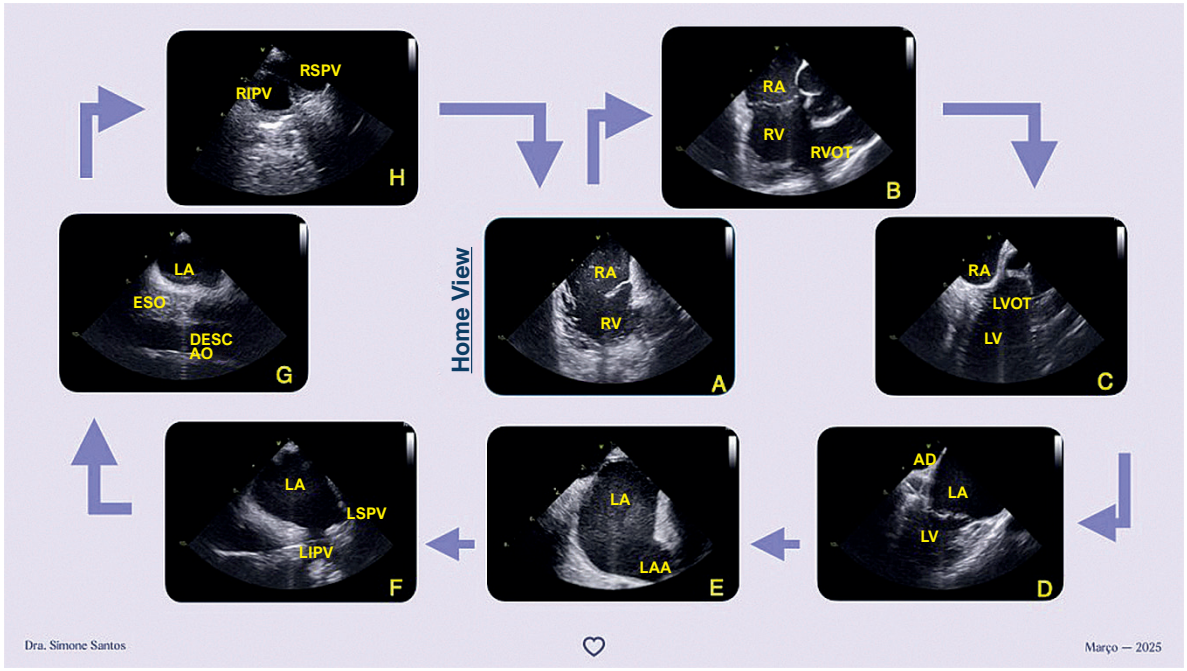

Figure 2 (A-H) – *Image sequence obtained with the catheter in the RA. A: Home View; sequential images from B to H show the progression of views obtained through clockwise catheter rotation starting from the Home View. LA: left atrium; AO: aorta; RV: right ventricle; LV: left ventricle; RA: right atrium; RVOT: right ventricle outflow tract; LVOT: left ventricular outflow tract; LAA: left atrial aappendage; LSPV: left superior pulmonar vein; LIPV: left inferior pulmonary vein; RIPV: right inferior pulmonary vein; RSPV: right superior pulmonary vein.*

clockwise torque enables sequential visualization of the interventricular septum (IVS) and the LV apex, followed by the posteromedial and anterolateral papillary muscles, the MV, the aortic valve in cross-section, the LAA, and the origin of both the left and right coronary arteries. In some cases, it is necessary to advance the catheter through the RVOT and into the pulmonary artery (PA) trunk to improve visualization of the LAA tip and to rule out the presence of thrombi (Figure 3A-F).

Step 4 – Rule out intracavitary thrombi before transeptal puncture

Thrombus detection in the LA or LAA is essential prior to AF ablation in order to prevent thromboembolic events related to the procedure. Although transesophageal echocardiography (TEE) is the gold standard for this purpose, anatomical limitations can lead to false-negative results. In our practice, TEE is performed before the procedure only in high-risk patients — those with persistent AF and MV disease, a history of stroke, or elevated CHA_2DS_2-VASc scores in the setting of poor anticoagulation adherence. We routinely use intracardiac echocardiography (ICE) to rule out thrombi prior to transeptal puncture, visualizing the LAA from the RA, RV (Figures 2 and 3), and PA. ICE catheter positioning in the RVOT, near the pulmonary valve, or within the main PA trunk provides the clearest images for thrombus detection (Supplementary Video 3).[16-18]

Step 5 – Guiding the transeptal puncture

To perform transeptal puncture, the catheter is positioned in the mid-RA, allowing direct visualization of IAS and LA. Since the procedural target is the electrical isolation of PVs — which drain into the PW of the LA — the ideal puncture site on the IAS is at the level of the left PVs or slightly more posterior. This facilitates maneuverability of the ablation catheter and improves safety by avoiding anterior puncture paths that may be directed toward the LAA, aortic root, or ascending aorta (Figure 4). From the Home View, clockwise rotation is performed until the entry of the left PVs into the LA becomes visible. In some cases, posterior deflection is also required, pulling the catheter slightly away from the IAS to optimize the view of the RA, IAS, and LA, thereby facilitating more accurate guidance of the transeptal puncture.

With ICE, we can rapidly identify the anatomy of the IAS and its relatively common anatomical variations that may complicate transeptal puncture, such as lipomatous hypertrophy, aneurysms, double fossa ovalis, and the presence of surgical patches or occluder devices.[19-22]

Whenever possible, we target the thinnest region of the IAS. In cases of redundant or aneurysmal septa, we select the lowest possible puncture site — while carefully avoiding the risk of perforating a pericardial recess. This strategy provides better anchoring of the needle and facilitates transeptal access in these more challenging scenarios.

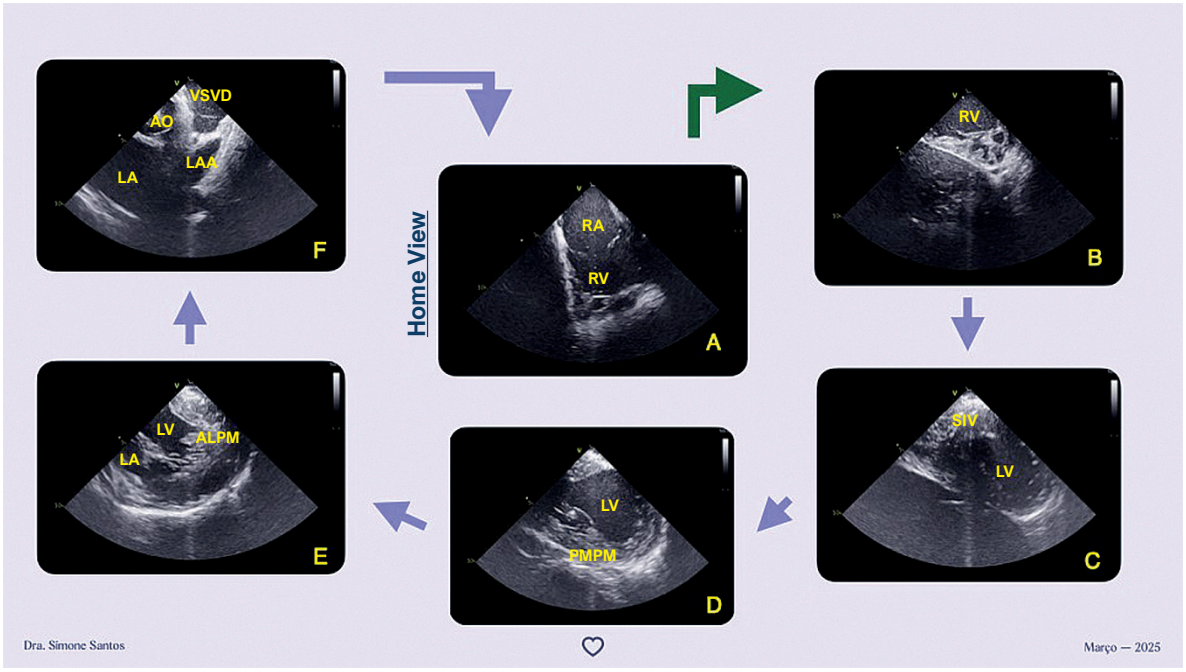

Figure 3 (A-F) – *Image sequence obtained from the RV. A: Home View; B: Green arrow shows anterior deflection with catheter positioned in the RV; C-F: Sequential views acquired via clockwise rotation of the catheter in the RV (blue arrows). PMPM: posteromedial papillary muscle; ALPM: anterolateral papillary muscle; AO: aorta; LA: left atrium; AO: aorta; RV: right ventricle; LV: left ventricle; RA: right atrium; LAA: left atrial appendage.*

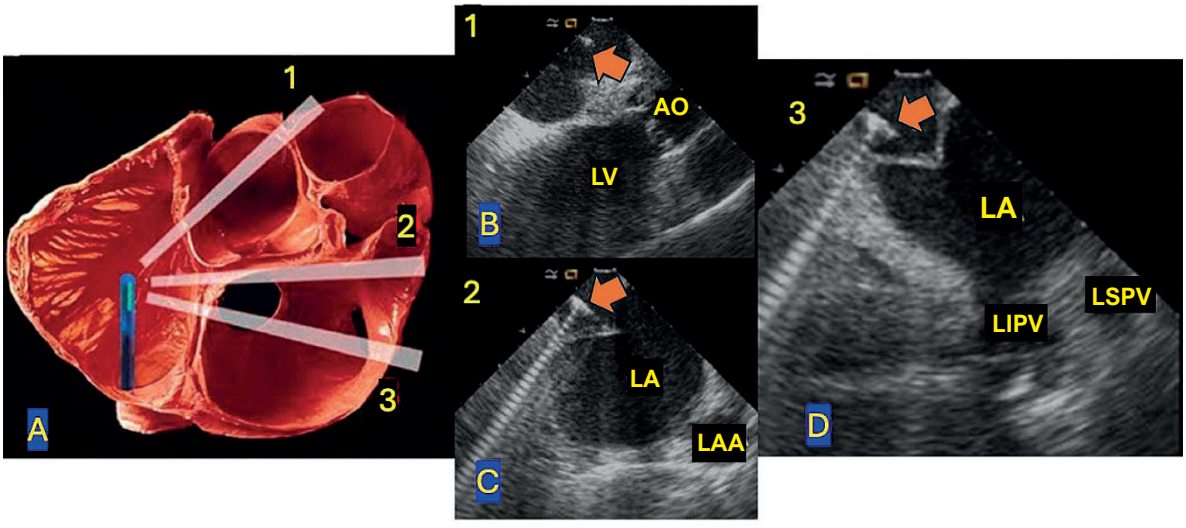

Figure 4 (A-D) – *Imaging planes for transeptal puncture. A: Schematic view of the heart and corresponding ICE imaging planes (1-3); B: Plane 1 – more anterior, with risk of aortic perforation; C: Plane 2 – anterior view of the LAA, which may hinder catheter manipulation; D: Plane 3 – ideal for transeptal puncture in AF ablation procedures, visualizing the entry of the left PVs. The orange arrow indicates the transeptal needle. Figure adapted from Enriquez, A. et al.19 LA: left atrium; LV: left ventricle; LAA: left atrial appendage; LSPV: left superior pulmonar vein; LIPV: left inferior pulmonary vein.*

Step 6 – Guiding circular catheter contact during electroanatomic mapping

We perform two ICE-guided transeptal punctures and insert two long sheaths: one for the electroanatomic mapping catheter and another for the ablation catheter. Once the anatomy of the LA and PVs is defined — whether there is a common trunk, separate ostia, or their relationship with the LAA — ICE is used to guide the mapping catheter's contact with atrial tissue, avoid proximity to the MV, and identify the ridge separating the left PVs from the LAA. This facilitates the rapid construction of the electroanatomic map of the LA and PVs. In some centers, the CARTOSOUND™ system (Biosense Webster) is used to generate chamber geometry based on multiple ICE imaging slices.

Step 7 – Monitoring ablation catheter contact and lesion formation

Once electroanatomic mapping is complete, the next step is real-time, accurate monitoring of the ablation catheter's contact with atrial tissue. This improves the efficacy of energy delivery while reducing the risk of complications. Inadequate tissue contact may result in ineffective lesion formation, leading to incomplete electrical isolation and increased blood heating, which raises the risk of thrombus formation. Energy delivery can also be titrated based on the gradual increase in tissue echogenicity observed on ICE. A sudden or excessive increase in echogenicity may precede a steam pop, which is associated with tissue perforation and an increased risk of cardiac tamponade (Supplementary Video 4). Such events are often accompanied by the formation of microbubbles, reflecting tissue heating and cellular leakage, and may pose a risk of cerebral microembolization.[5] Although current technologies provide contact force monitoring and recommend specific energy parameters for radiofrequency delivery, individual variations must be considered. Fragile patients, atrial scarring, or calcifications may result in either excessive or ineffective lesions.[23]

Step 8 – Monitoring esophageal proximity to ablation sites

Ablation of the PW — either for PV isolation or direct PW targeting — carries a potential risk of esophageal injury due to the close anatomical relationship between the esophagus and the LA. This may result in an atrioesophageal fistula.[24,25] To prevent esophageal injury, energy delivery near the esophagus is typically reduced in both force and duration, and esophageal temperature monitoring is routinely employed. However, despite these precautions, cases of esophageal injury detected by upper endoscopy after ablation have been reported.[26,27] In our esophageal temperature monitoring protocol, we first use ICE to visualize the position of the esophagus and its relationship to the PVs. We then insert a deflectable catheter orally for temperature monitoring, with excellent outcomes[28] (Figure 5).

Detecting complications

ICE imaging is used throughout the entire AF ablation procedure. Therefore, the early detection of potential complications should not be considered a single step in the process. From the initial femoral venous puncture, ICE can assist in identifying thrombi, occlusions, dissections, and extrinsic venous compressions along the pathway to the RA. Below, we highlight the most common complications that may occur during the procedure.

Pericardial effusion

One of the potential complications of radiofrequency ablation (RFA) for AF is cardiac tamponade. ICE allows for the rapid detection of PE, often before hemodynamic instability or tamponade develops.[29] This enables early intervention, reversal of anticoagulation, and, if necessary, pericardiocentesis. Initially, PE is typically visualized in the inferior region of the RV and the posterior aspect of the RA, and may progressively extend to the apical and anterior regions of the RV, eventually surrounding the entire heart.

Upon reaching the RA, the catheter is advanced into the RV, and clockwise rotation allows visualization of the pericardial space adjacent to both the RV and the LV (Figure 3). This approach enables early identification of any preexisting PE before catheter manipulation begins. With this baseline reference, if there is any suspicion of perforation or an episode of arterial hypotension, the pericardial space is promptly reassessed and compared to the initial images. As part of our standard protocol, we perform repeated ICE evaluations of the pericardial space from the RV at specific stages of the procedure: after isolation of the left PVs, after isolation of the right PVs, following any additional RF applications, and again after catheter withdrawal at the end of the procedure.

Intracavitary thrombi

Thrombus formation on sheaths and catheters can be readily detected in real time using ICE, allowing for immediate intervention and the prevention of potentially imminent embolic events.[30,31] Although less common due to the use of irrigated-tip catheters and direct oral anticoagulants, thrombi may still be observed adherent to sheaths or catheters while they are positioned in the RA, enabling early management before transeptal puncture. If thrombi are identified on catheters within the LA during the procedure, management strategies may include intensifying systemic heparinization, aspirating the thrombus into the sheath, or, in extreme cases, deploying bilateral carotid artery filters to prevent cerebral embolization.

Conclusion

ICE is the only tool that provides direct, real-time visualization throughout all phases of AF ablation. Mastery and systematic use of ICE enhance both the effectiveness and safety of the procedure.

Author Contributions

Conception and design of the research and writing of the manuscript: Santos SN; critical revision of the manuscript for intellectual content: Santos SN, Henz BD, Silva LRL, Silva MEL.

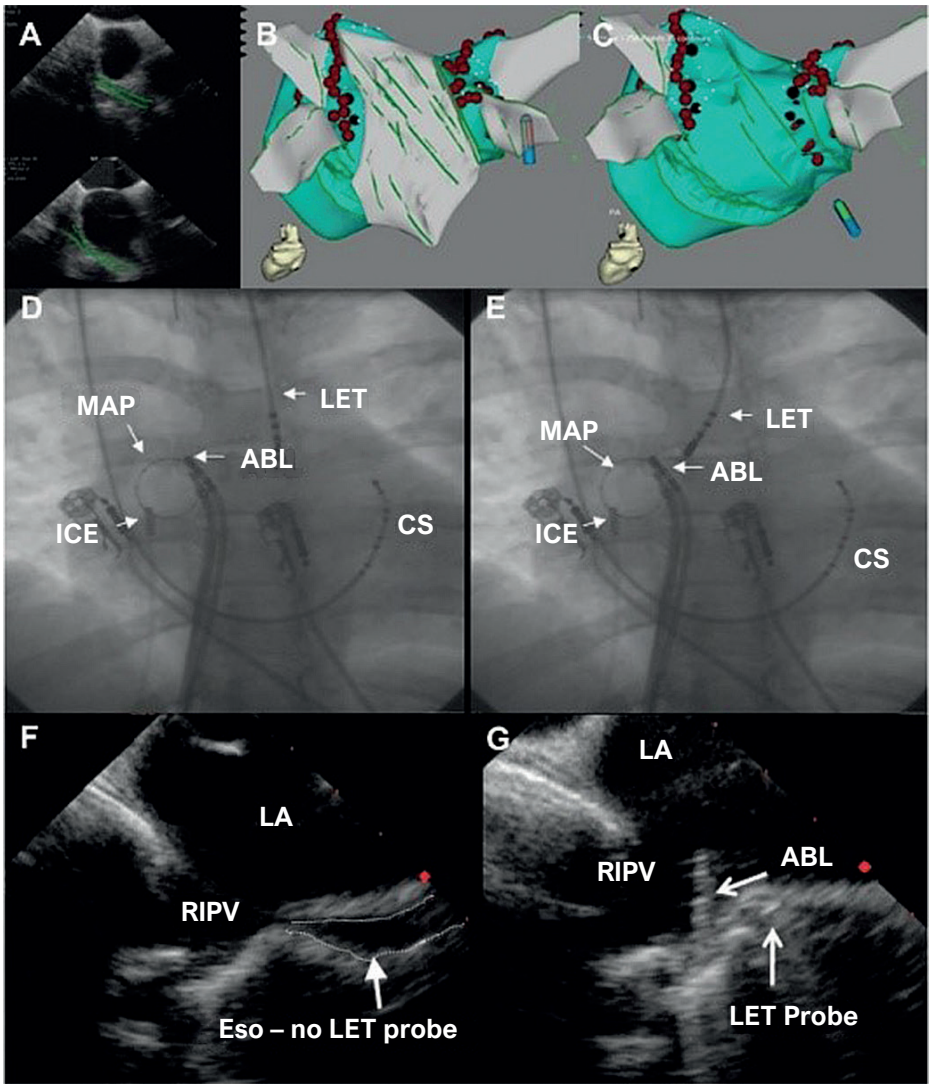

Figure 5 – *ICE-guided deflection of the esophageal temperature monitoring catheter. A: ICE showing the esophagus in relation to the left and right PVs (green contours); B: Esophagus (in gray) visualized in the electroanatomic map, broad and in contact with both left and right PVs; C: Electroanatomic map with black markers indicating esophageal temperature rise >2 °C; D: Fluoroscopy showing the luminal esophageal temperature (LET) probe in a neutral position, apparently distant from the right PVs; E: Fluoroscopy showing LET deflected to the right, approaching the ablation catheter; F: ICE image of the right PVs and esophagus without LET positioning, corresponding to fluoroscopic image D; G: ICE image with LET probe in place and in close proximity to the ablation catheter, corresponding to fluoroscopic image E. Eso: esophagus; MAP: circular mapping catheter; CS: coronary sinus catheter; LET: luminal esophageal temperature; ICE: Intracardiac echocardiography; LA: left atrium; RIPV: right inferior pulmonary vein; ABL: ablation catheter. Figure reproduced with permission from Leite L.R. et al.*[28]

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 thesis or dissertation work.

Ethics Approval and Consent to Participate

This article does not contain any studies with human participants or animals performed by any of the authors.

Use of Artificial Intelligence

The authors did not use any artificial intelligence tools in the development of this work.

Availability of Research Data

The underlying content of the research text is contained within the manuscript.

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*Supplemental Materials

See the Supplemental Video 1, please click here.

See the Supplemental Video 2, please click here.

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See the Supplemental Video 4, please click here.