Received: 8 July 2022 | Revised: 28 August 2022 | Accepted: 17 September 2022

DOI: 10.1111/jce.15687

REVIEWS

WILEY

Intracardiac echocardiography from coronary sinus

Jalaj Garg MD, FACC, FESC[1] | Jakrin Kewcharoen MD[1] | Rahul Bhardwaj MD[1] | Tahmeed Contractor MD[1] | Sarika Jain MD[2] | Ravi Mandapati MD, FHRS[1]

[1]Division of Cardiology, Cardiac Arrhythmia Service, Loma Linda University Health, Loma Linda, California, USA

[2]Division of Cardiothoracic Surgery, Loma Linda University Health, Loma Linda, California, USA

Correspondence
Jalaj Garg, MD, FACC, FESC, Division of Cardiology, Cardiac Arrhythmia Service, Loma Linda University Health, 11234 Anderson St, Loma Linda, CA 92354, USA.
Email: garg.jalaj@yahoo.com

Disclosures: None.

Abstract

Intracardiac echocardiography (ICE) has become an essential tool and is an integral part of percutaneous interventional and electrophysiology (EP) procedures. Intracardiac echocardiography offers real-time, high-quality, near-field evaluation of cardiac anatomy. Standard ICE imaging includes placing the catheter in the right atrium (RA), right ventricle (RV), or left atrium (LA, via the transeptal approach). Coronary sinus echocardiography (CSE) is another alternative, where the ICE catheter is positioned in the coronary sinus (CS). This approach offers better catheter stability and allows operators to visualize cardiac structure with particularly excellent views of the LA, LAA, left ventricle (LV), and mitral annulus. Additionally, CSE is an attractive alternative in cases with unfavorable interatrial septum or fossa ovalis anatomical features that could lead to difficulty advancing ICE catheter in left atrium. In this article focusing on CSE, we provide illustration-based guidance to help operators identify critical cardiac structures from CSE.

KEYWORDS

coronary sinus, ICE, intracardiac echocardiogram

1 | INTRODUCTION

Intracardiac echocardiography (ICE) has become an essential tool and is an integral part of percutaneous interventional and electrophysiology (EP) procedures.[1] Intracardiac echocardiography offers real-time, high-quality, near-field evaluation of cardiac anatomy. Compared with transesophageal echocardiogram (TEE), ICE confers certain advantages: it may be performed by the primary operator—which eliminates the need for a second operator, is intravascular thus eliminating the risk of oropharyngeal or esophageal injury. In addition, ICE offers real-time procedural guidance (i.e., transseptal puncture, catheter ablation procedures, endomyocardial biopsy, left atrial appendage closure, etc.) and can reliably diagnose procedure-related complications—pericardial effusion or the presence of intracardiac thrombus.[2,3]

Standard ICE imaging includes placing the catheter in the right atrium (RA), right ventricle (RV), or left atrium (LA, via the transseptal approach). In addition, there are two other uncommon catheter placements techniques that have been described: percutaneous intrapericardial echocardiography (IPE) and coronary sinus echocardiography (CSE).[4,5] IPE utilizes catheter-based ultrasonography by introducing the ICE catheter into the pericardial space. This offers significant advantages as it allows the operator to manipulate the catheter and visualize the heart in any orientation without anatomic limitations or interference from other mapping or ablation catheters. CSE is another alternative, where the ICE catheter is positioned in the coronary sinus (CS). This approach offers better catheter stability and allows operators to visualize cardiac structure with particularly excellent views of the LA, LAA, left ventricle (LV), and mitral annulus. Additionally, CSE is an

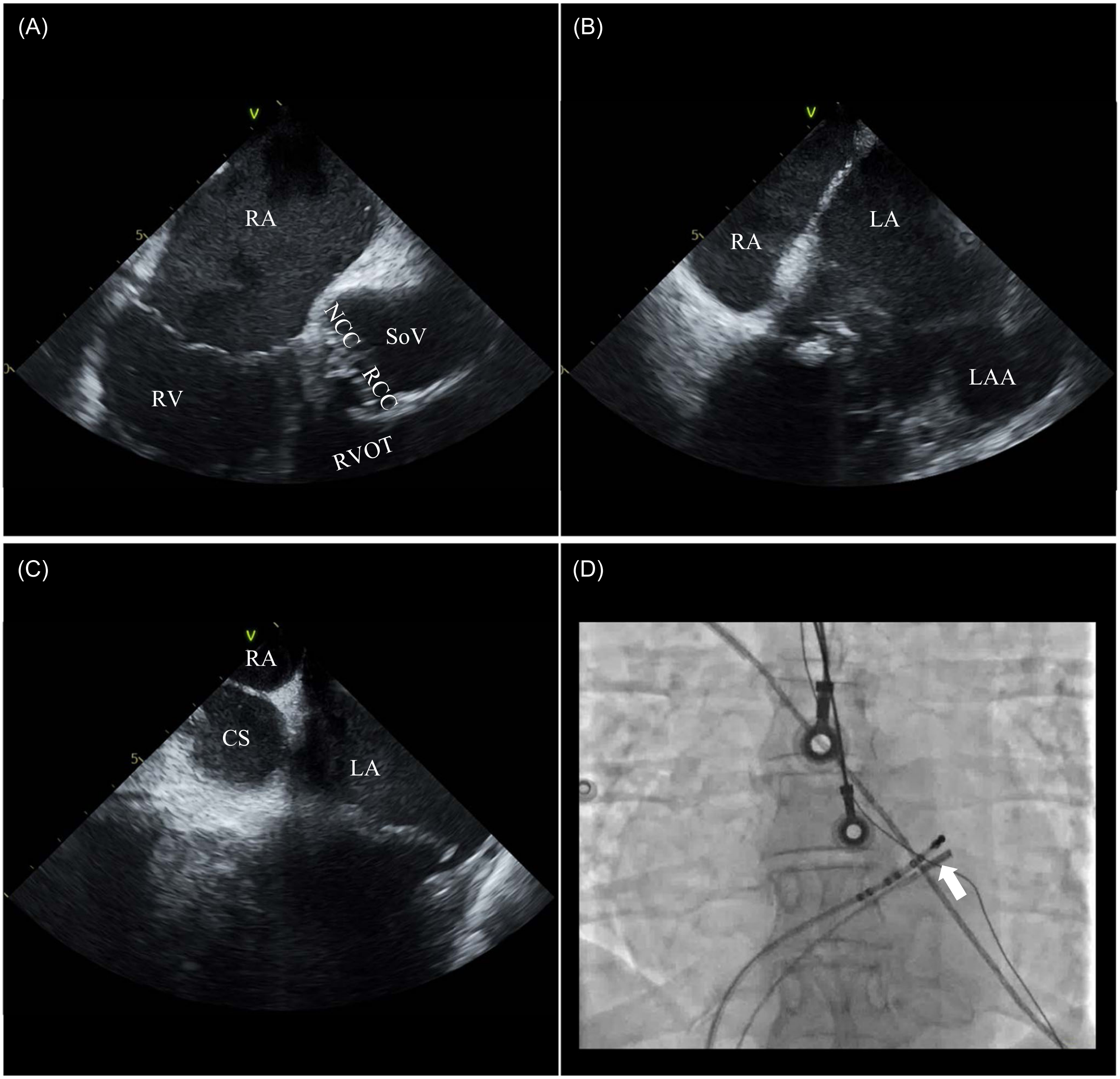

FIGURE 1 Intracardiac echocardiogram catheter positioned in right atrium (home view). White arrow: Intracardiac echocardiogram catheter. CS, coronary sinus; LA, left atrium; LAA, left atrial appendage; NCC, noncoronary cusp; RA, right atrium; RV, right ventricle; RVOT, right ventricular outflow tract; RCC, right coronary cusp; SoV, Sinus of Valsalva.

attractive alternative in cases with unfavorable interatrial septum or fossa ovalis anatomical features that could lead to difficulty advancing ICE catheter in LA.[6,7]

As the field of EP continues to evolve and expand, IPE and CSE will have a growing role in an EP laboratory. Despite the wide range of images from unique angles these two distinct techniques offer, experience, and familiarity are crucial to safely performing complex EP procedures with image angles that the EP team members do not familiarize. In this article focusing on CSE, we provide illustration-based guidance to help operators identify critical cardiac structures from CSE.

2 | NAVIGATING THE ICE CATHETER

We use a standard phased-array ICE, consisting of a 64-element transducer mounted on the distal end of an 8- or 10-French (Fr) four-way steerable catheter (anterior, posterior, right, and left).[8] The marker setup is conventional, with the marker position on the left side of the image sector, indicating that the shaft of the catheter is to the left of the image while the tip of the catheter is on the right. The ICE catheter is inserted via a femoral venous introducer sheath (9 Fr or 11 Fr sheath, respectively) and advanced into the RA. The technical aspects of ICE catheter advancement from the femoral vein

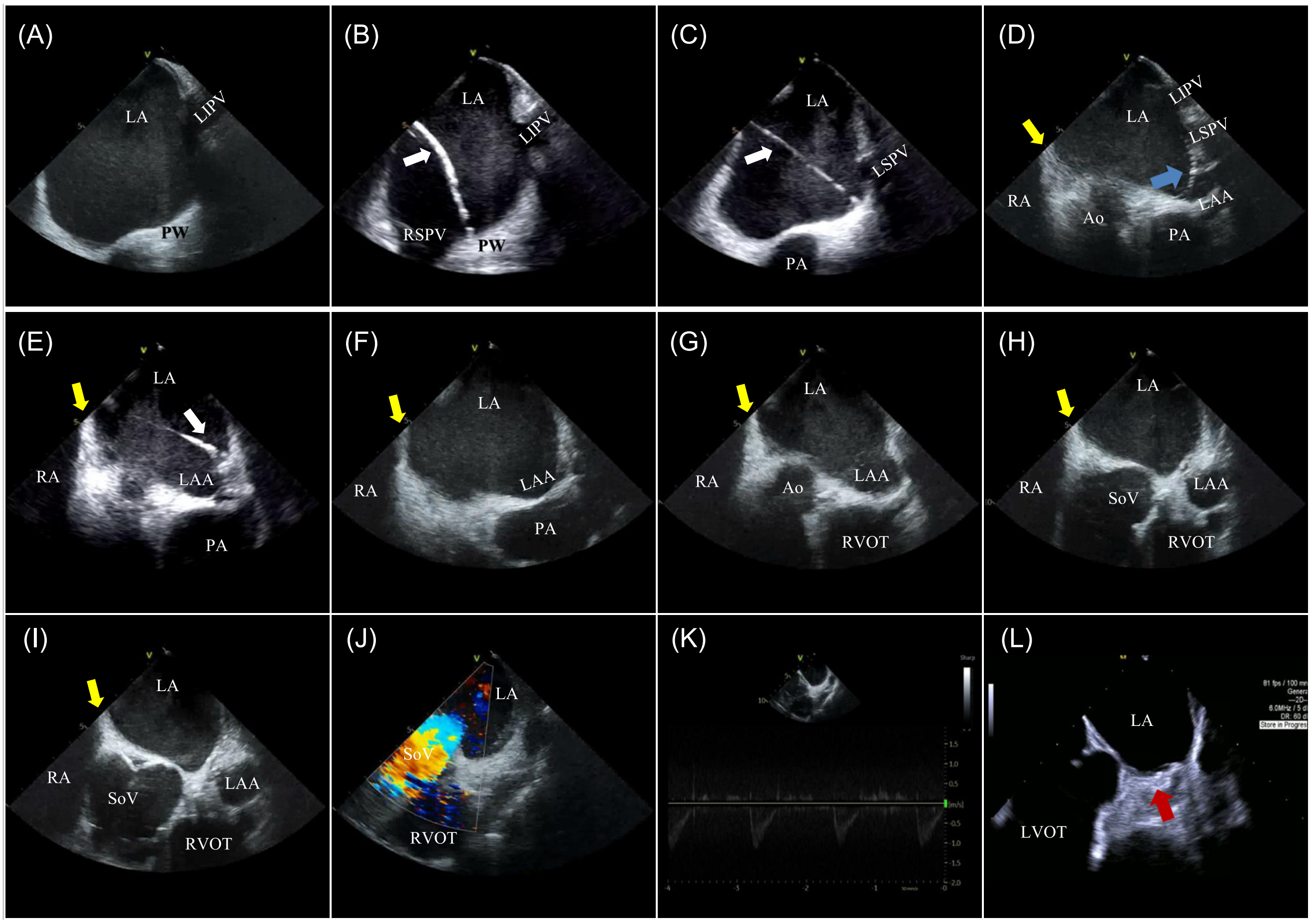

FIGURE 2 Left atrium views from coronary sinus echocardiogram. White arrow: Ablation catheter; Blue arrow: OctaRay mapping catheter; Yellow arrow: Interatrial septum, Red arrow: left atrial appendage occlusion device. AO, aorta; LA, left atrium; LAA, left atrial appendage; LIPV, left inferior pulmonary vein; LSPV, left superior pulmonary vein; LV, left ventricle; MV, mitral valve; PA, pulmonary artery; RA, right atrium; RSPV, right superior pulmonary vein; RV, right ventricle; RVOT, right ventricular outflow tract; SoV, Sinus of Valsalva.

to RA have been described elsewhere.[8] Catheter manipulation involves either clockwise or counterclockwise rotation, probe advancement/withdrawal or manipulation of four-way deflection mechanism. We recommend maintaining a clear echocardiographic space (black) upfront of the ICE catheter (before advancing) and avoid pushing when an echogenic space (white) is visualized. A gentle withdrawal and flexion with slight counterclockwise rotation often help maintain a long-axis view of the vein.

The basic ICE view starts with the home view, with an ICE catheter positioned in the mid-RA (Supporting Information: Video 1). The home view (with minimal clock and counterclockwise rotation; also dependent upon inferior vena cava angle) provides visualization of RA, tricuspid valve (TV), cavotricuspid isthmus (CTI), aortic cusps, and RV (Figure 1A). From the home view, gentle clockwise rotation of the ICE catheter brings into view the long axis view of the aortic root and right ventricular outflow tract (RVOT). The cusp closer to the transducer is the noncoronary cusp (typically in close proximity to the parahisian region), while the opposite cusp is the right coronary cusp (the most anterior cusp). A gentle clockwise rotation helps visualize LV (anterior to the inferoseptal aspect of RA) and CS ostium (Figure 1B); an aggressive clockwise rotation allows visualization of the mitral valve, interatrial septum, LA, and LAA (this is the view often used for transseptal puncture; Figure 1C). With a gentle flexion and counterclockwise rotation (keeping the CS ostium ahead of the catheter, i.e., closest to the transducer), the ICE catheter is gently advanced (maintaining the flexion) and engages the CS ostium. The deflection is now released (while maintaining slight counterclockwise rotation), the catheter is then gently advanced, carefully maintaining a clear echocardiographic space ahead (Supporting Information: Video 2). Until the operator has sufficient experience, the ICE catheter can be advanced into the CS under fluoroscopy using a CS mapping catheter as a fluoroscopic reference (Figure 1D). Once the ICE catheter is in a stable position in the CS, retroflection or anterior flexion is constrained by the CS anatomy—thus only allowing clockwise and counterclockwise rotation.

3 | IMAGES ACQUIRED FROM CSE

3.1 | Left atrium

After gaining access to the CS, the ICE catheter is advanced into the distal CS in a neutral position. We suggested the LA to be the home

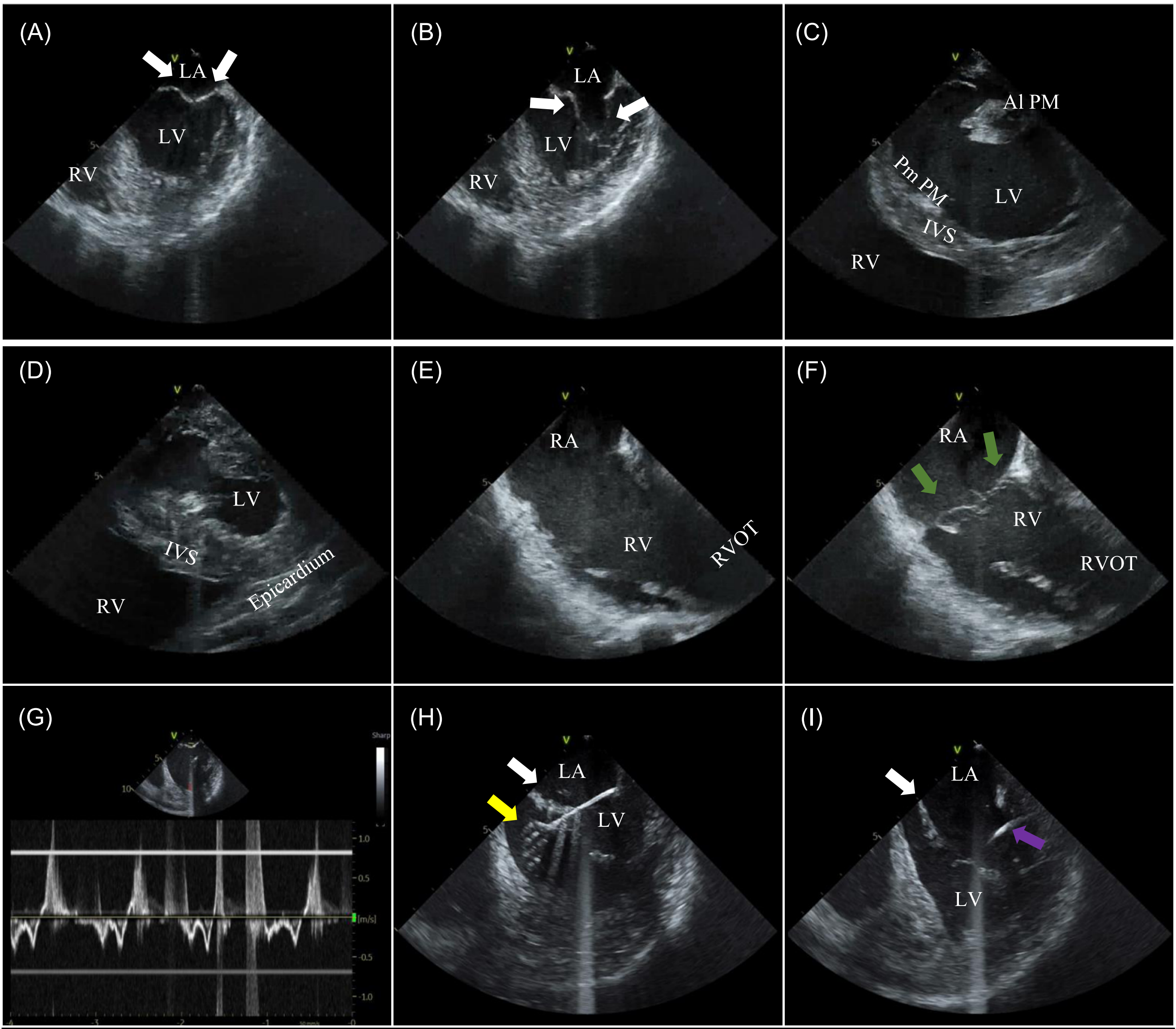

FIGURE 3 Ventricular views from coronary sinus echocardiogram. White arrow, Mitral valve leaflet; green arrow, tricuspid valve leaflet; yellow arrow, Advisor™ HD Grid mapping catheter positioned on the LV septum; purple arrow, Irrigated ablation catheter positioned on the lateral wall of LV. IVS, Interventricular septum; LA, left atrium; LV, left ventricle; MV, mitral valve; RV, right ventricle; RVOT, right ventricular outflow tract.

view of CSE (Figure 2A). Since the main CS body runs epicardially and posteriorly around the mitral annulus, this provides an epicardial vantage point. From this view, a gentle counterclockwise catheter rotation movement brings into view the left inferior pulmonary vein (LIPV) (closer to the transducer), and left atrial posterior wall (PW) (Figure 2A,B). Subsequent counterclockwise rotation displays the long-axis view of the LSPV, LAA (Figure 2C,D; Figure *2D demonstrating Biosense Webster OctaRay mapping catheter in LAA ostium*); and eventually ridge (between LSPV and LAA) and LAA (Figure 2E, Supporting Information: Video 3-5). Further counterclockwise movement will reveal longaxis of pulmonary artery (Figure 2F). From the CSE home view (neutral position in CS), a clockwise catheter rotation yields the most anterior aspect of LA (in close proximity to aorta) (Figure 2G). A gentle clockwise rotation brings into view the aortic sinuses of Valsalva, distal RVOT (far end and sometimes pulmonary valve), and LAA body (Figure 2H,I). Doppler study of aortic valve can be done in this view to assess for aortic stenosis (Figure 2J,K, Supporting Information: Video 6). A gradual clockwise rotation displays the LAA ostium, the view which can be used as an adjunct (in addition to ICE from LA) for ICE-guided LAA occlusion (Figure 2L).

3.2 | Ventricles

From the CSE home view and gentle withdrawal into proximal CS, the clockwise rotation allows visualization of the LA, mitral valve, and long-axis of the right and left ventricles (Figure 3A–F). This view can be used to closely evaluate mitral valve leaflet morphology, and papillary muscles

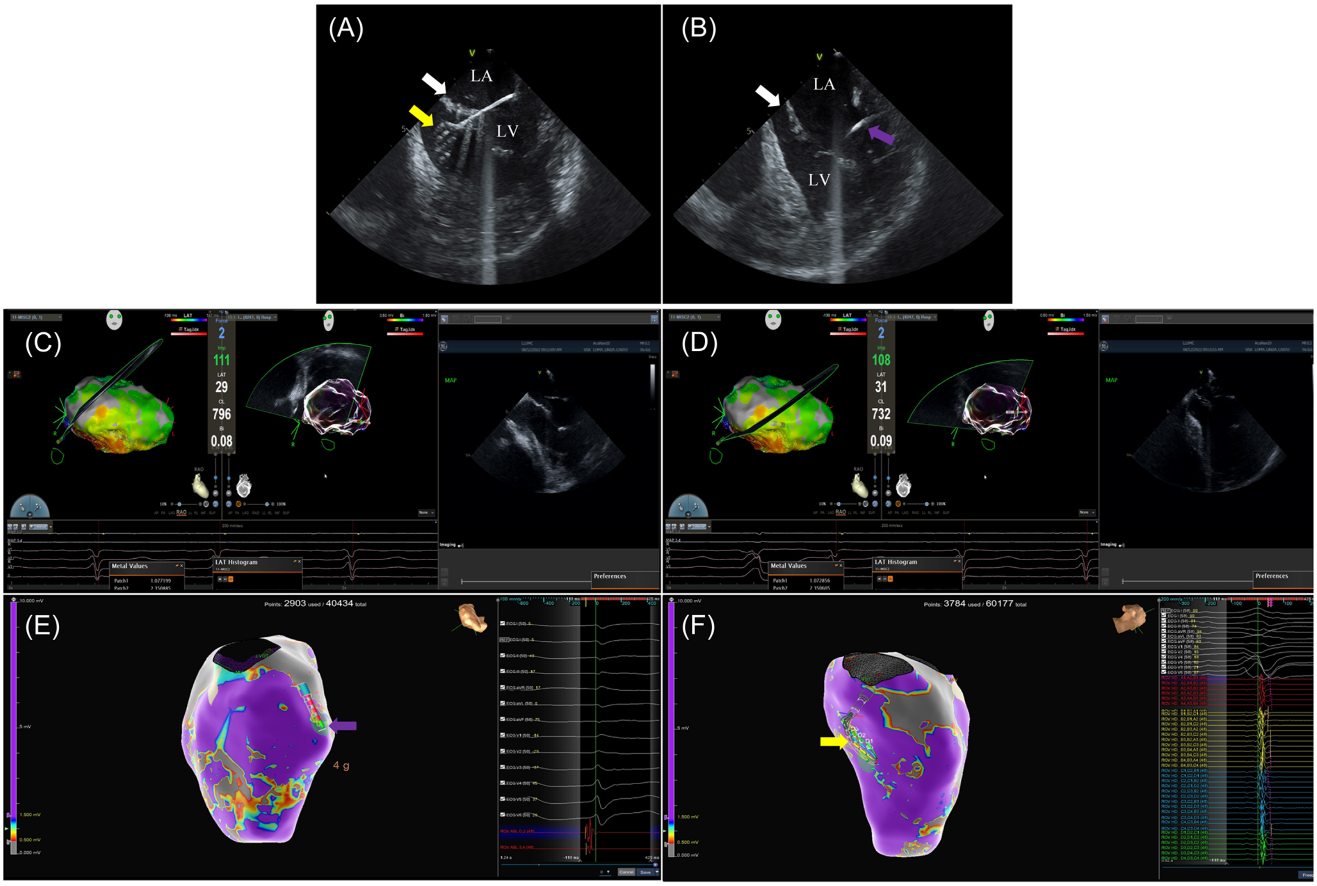

FIGURE 4 (A,B) Left ventricle views from coronary sinus echocardiogram during mapping and ablation of ventricular tachycardia; (C,D) Electroanatomic mapping of the left ventricle using CARTO 3D mapping system (Biosense Webster); (E,F) Electroanatomic mapping of the left ventricle using EnSite NavX (Abbott 3D mapping system. White arrow, mitral valve leaflet; Yellow arrow, Advisor™ HD Grid mapping catheter positioned on the LV septum; purple arrow, Irrigated ablation catheter positioned on the lateral wall of LV. LA, left atrium; LV, left ventricle.

(both in the LV and RV, Figure 3C–F). Doppler study of mitral valve can be done in this view to assess for valvular pathology (Figure 3G). This view can also be used for catheter manipulation and positioning during ventricular tachycardia (VT) ablation (Figure 3H–I and Figure 4A–F, Supporting Information: Video 7 and 8).

4 | FAST ANATOMICAL MAPPING

The fast anatomic mapping feature of the CARTO® 3 system (*Biosense Webster*) allows operators to create a 3D cardiac anatomy. The ICE catheter with a CARTO navigation sensor embedded close to the phased array (SoundStar) is positioned initially in the RA, RV, and subsequently in CS. Sequential image acquisition of electrocardiogram-gated intracardiac images is acquired. Video clips are recorded and imported into the CARTO system. Images were typically acquired in end expiration and gated to the R-wave or the pacing spike. Gated 2D snapshots are then selected from the video clips. The endocardial surface of the intracardiac chambers is then traced manually by the operator or defined using the edge detection software. The system then displays each traced contour in 3D space as a series of points (Figure 5). A family of contours could then be used to reconstruct the chamber of interest, thereby generating a registered 3D intracardiac shell (Figure 6A–D, Supporting Information: Video 9).

5 | FUTURE PERSPECTIVES

Development in ICE technology and operators' expertise in the past decades has increased the popularity of ICE utilization in many cardiac procedures, including transseptal catheterization, atrial septal defect closure, mitral valve valvuloplasty, transcatheter aortic valve replacement, ablation of atrial and ventricular arrhythmias, and left atrial appendage occlusion.[8] CS echocardiography particularly provides better images of the LA, LAA, LV, and mitral annulus than the traditional ICE catheter position. In addition to superior catheter stability, CSE might help better guide EP procedures involving those anatomy such as atrial fibrillation ablation, left-sided flutter ablation, VT ablation, LAA occlusions, or PV stenting (in rare scenarios).[8,9] Several potential areas of improvement of ICE in the future will further expand its applications and solidify its role in complex procedures, which will be applied to CSE

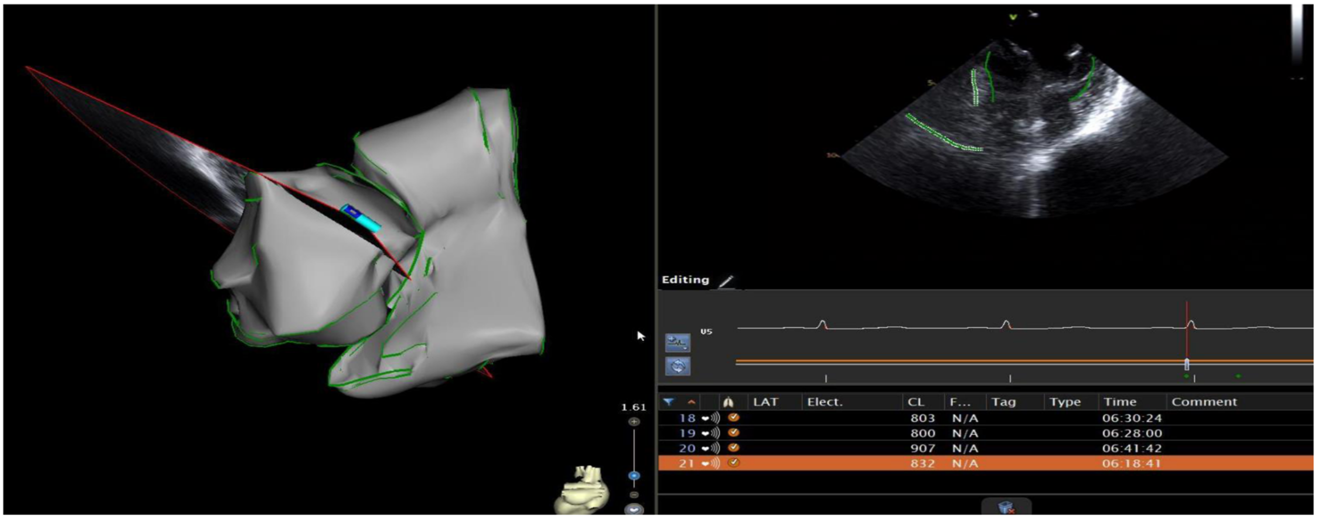

FIGURE 5 Acquisition of real-time registered intracardiac echocardiography (ICE) contours and 3-dimensional (3D) rendering. Fast anatomical mapping created by CARTO® 3 system (Biosense Webster) using intracardiac echocardiography positioned in the right atrium, right ventricle, and coronary sinus. *Right:* Gated 2D snapshots are selected and the endocardial surface of the intracardiac chambers is then traced manually by the operator or defined using the edge detection software. *Left:* The system then displays each traced contour in 3D space as a series of points.

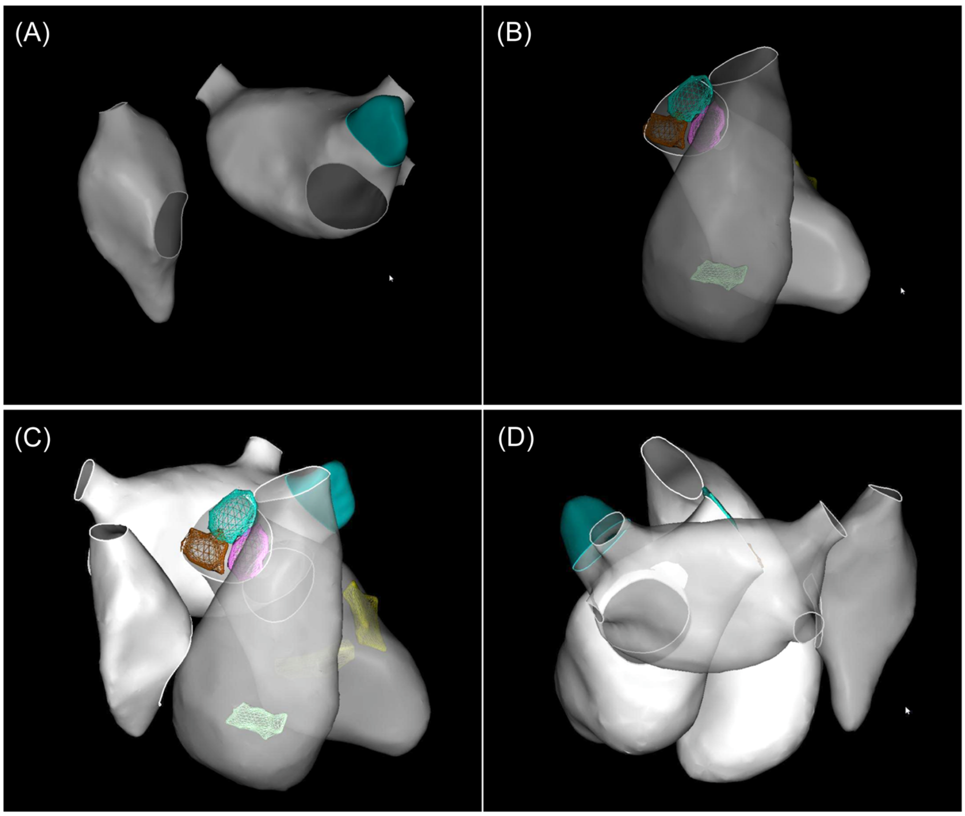

FIGURE 6 Fast anatomical mapping created by CARTO® 3 system (Biosense Webster, Inc) using intracardiac echocardiography positioned in the right atrium, right ventricle, and coronary sinus

as well. Although at the current state ICE can only provide two-dimensional (2D) images, the upcoming development of real-time three-dimensional (3D) and four-dimensional (4D) images of ICE may be favored over current 3D images from TEE in interventions such as transcatheter aortic valve replacement and LAA occlusions. The 2D speckle tracking for strain rate has been used to detect tissue deformation at PV ostia after PV isolation for AF.[10] Additionally, a promising micromachined ultrasonic transducer has a decreased size with better images resolution and is equipped with a central lumen that can be used to transport a variety of devices to the target area, such as radiofrequency ablation catheters.[11,12] This may reshape the way physicians perform ablations overall, and if utilized with CSE, this will help with target ablation reachable from the CS.

6 | SAFETY

One major safety concern of CSE is a risk of CS perforation. As CS is a narrow tubular structure, the maneuverability of ICE catheter in the CS is limited by CS anatomy.[4] While, anteflexion and retroflexion are prohibited as it carries a risk of perforating the CS, catheter can be advanced, withdrawn and rotated in a clockwise or counter-clockwise manner, though movement should always be cautious and steady at all times.

7 | CONCLUSIONS

Intracardiac echocardiogram is now routinely being used as adjunct tool during percutaneous interventional and EP procedures. ICE positioning in the CS may be more beneficial than standard right-sided ICE in certain EP procedures such as PV isolation, ablation of the target in LA and LV, and LAA occlusion. Anticipated development of ICE technology will further assist operators during the procedures.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

ORCID

Jalaj Garg http://orcid.org/0000-0002-6857-7418
Rahul Bhardwaj http://orcid.org/0000-0001-7734-8660

REFERENCES

1. Ren JF, Marchlinski FE. Utility of intracardiac echocardiography in left heart ablation for tachyarrhythmias. *Echocardiography*. 2007;24:533-540.
2. Baran J, Zaborska B, Pietrowski R, Sikora-Frac M, Pilichowska-Paszkiet E, Kulakowski P. Intracardiac echocardiography for verification for left atrial appendage thrombus presence detected by transesophageal echocardiography: the ActionICE II study. *Clin Cardiol*. 2017;40:450-454.
3. Saksena S, Sra J, Jordaens L, et al. A prospective comparison of cardiac imaging using intracardiac echocardiography with transesophageal echocardiography in patients with atrial fibrillation: the intracardiac echocardiography guided cardioversion helps interventional procedures study. *Circ Arrhythm Electrophysiol*. 2010;3:571-577.
4. Palmeri N, D'Avila A, Saad EB. Epicardial and coronary sinus echocardiography. *Card Electrophysiol Clin*. 2021;13:393-398.
5. Hijazi ZM, Shivkumar K, Sahn DJ. Intracardiac echocardiography during interventional and electrophysiological cardiac catheterization. *Circulation*. 2009;119:587-596.
6. Abed HS, Alasady M, Lau DH, Lim HS, Sanders P. Approach to the difficult transseptal: diathermy facilitated left atrial access. *Heart Lung Circ*. 2012;21:108-112.
7. De Ponti R, Cappato R, Curnis A, et al. Trans-septal catheterization in the electrophysiology laboratory: data from a multicenter survey spanning 12 years. *J Am Coll Cardiol*. 2006;47:1037-1042.
8. Enriquez A, Saenz LC, Rosso R, et al. Use of intracardiac echocardiography in interventional cardiology: working with the anatomy rather than fighting it. *Circulation*. 2018;137:2278-2294.
9. Ho IC, Neuzil P, Mraz T, et al. Use of intracardiac echocardiography to guide implantation of a left atrial appendage occlusion device (PLAATO). *Heart Rhythm*. 2007;4:567-571.
10. Smorgon A, Usenkov SYU, Lebedev DI. P2657 The intracardiac speckle-tracking echocardiography as a method of the radiofrequency ablation efficacy assessment in patients with the atrial fibrillation. *Eur Heart J*. 2017;38:38.
11. Khuri-Yakub BT, Oralkan O. Capacitive micromachined ultrasonic transducers for medical imaging and therapy. *J Micromech Microeng*. 2011;21:54004-54014.
12. Stephens DN, Cannata J, Liu R, et al. Multifunctional catheters combining intracardiac ultrasound imaging and electrophysiology sensing. *IEEE Trans Ultrason Eng*. 2008;55:1570-1581.

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Garg J, Kewcharoen J, Bhardwaj R, Contractor T, Jain S, Mandapati R. Intracardiac echocardiography from coronary sinus. *J Cardiovasc Electrophysiol*. 2022;33:2382-2388. doi:10.1111/jce.15687