Intracardiac EchoCardiography (ICE)

Common Views

Introduction

What is ICE?

- Catheter with microscopic ultrasound transducer tip and doppler capabilities inserted into the heart via the IVC (typically) or SVC.

Why is it useful?

- Allows direct visualization of anatomical cardiac structures targeted in abalations
- Helping guide catheters; in detecting thromboemoboli, pericardial effusion, preventing esophageal damage and in evaluating hemodynamic consequences of ablation (eg increased velocities in pulmonary vein stenosis).

Introduction

What types?

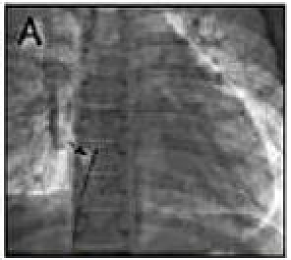
- There are two types of ICE - phased array and radial.
  - Phased array: more common as it creates a view that is easier to interpret as it resembles a TTE or TEE.
  - Radial ICE: greater resolution, but is more difficult to interpret and is best for discriminating near-field structures and therefore requires transseptal puncture to visualize left heart structures.

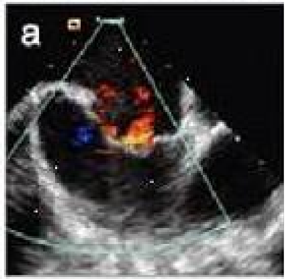
Process:

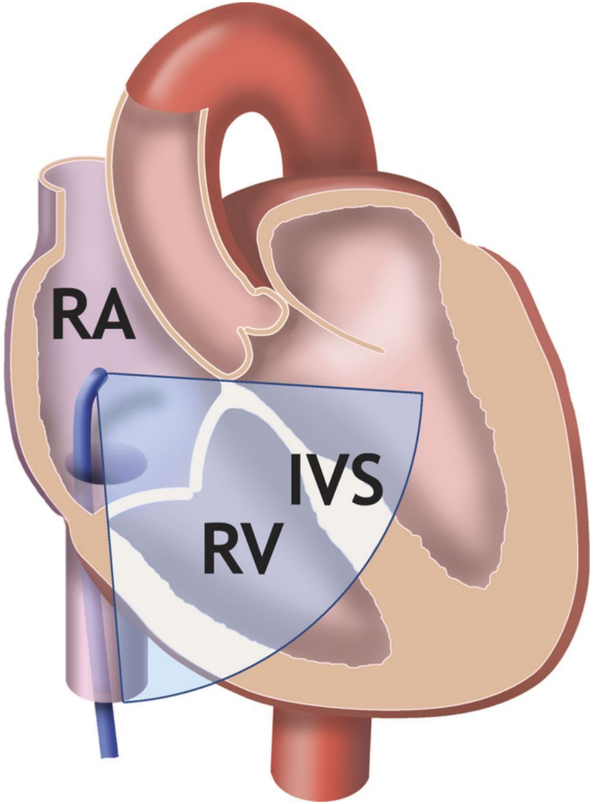
- Insert catheter through the femoral vein up through the IVC to the right atrium (most commonly), “the home base” for the ICE catheter. The catheter can also be inserted via the right IJ or left subclavian and then through the SVC however this will give “upsidedown” images; this method is preferred by some who wish to avoid entanglement/interaction with other wires placed through the IVC.
- Since the pulmonary veins are of primary importance in ablation procedures, to gain access to to the LA where the PVs insert, a transseptal puncture of the interatrial septum is performed. Prior to performing this puncture, it is crucial to evaluate for the presence of an intracardiac thromboemboli in the left atrium that could then potentially pass through the puncture and embolize outside of the heart, for instance to the brain. Potential for thrombo-emboli would be seen as a spontaneous echographic contrast, also called “smoke (1) and (2)” Essentially, SCE appears as hyperdense substance where it should not be present (i.e. in the chamber of the left atrium which should appear hypodense). If SCE is detected, a trans-septal puncture should not be performed.

Phased Array

Home View



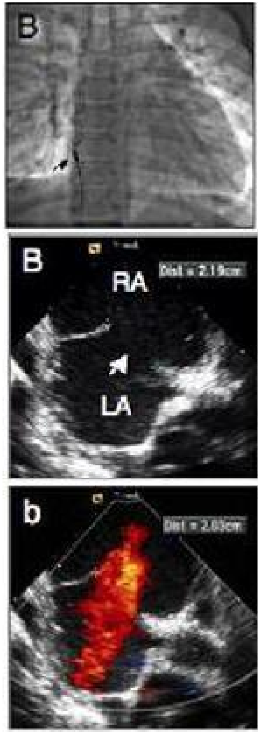




Home view showing the **right heart**, including the **interventricular septum**: the slightly **anteflexed probe** is positioned in the **mid-right atrium**.

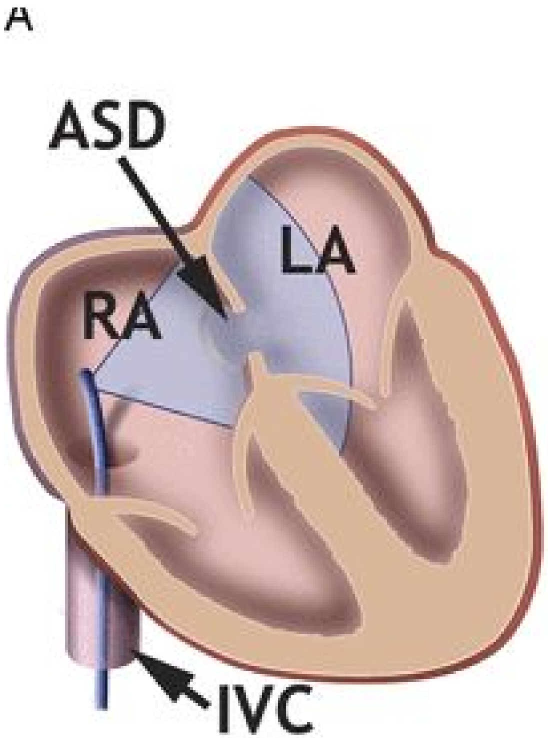
IVS, interventricular septum; RA, right atrium; RV, right ventricle.

Septal View



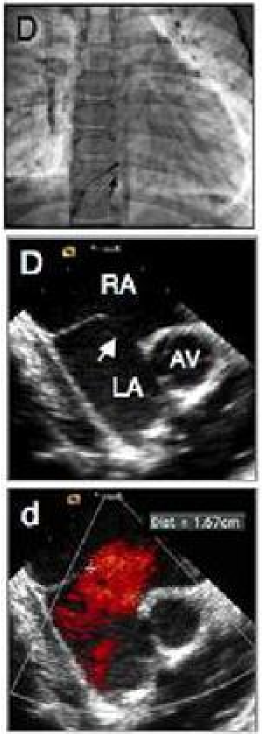
- To obtain the view - While the catheter is in **neutral** position, rotate **slightly posterior and slightly rightward**, so that the transducer will **face the interatrial septum**. This is the **septal view**. In this view, the entire length of the **atrial septum, the coronary sinus, and the pulmonary veins** are well seen.
- Septal view without and with color Doppler demonstrating a large 22 mm defect (arrow).

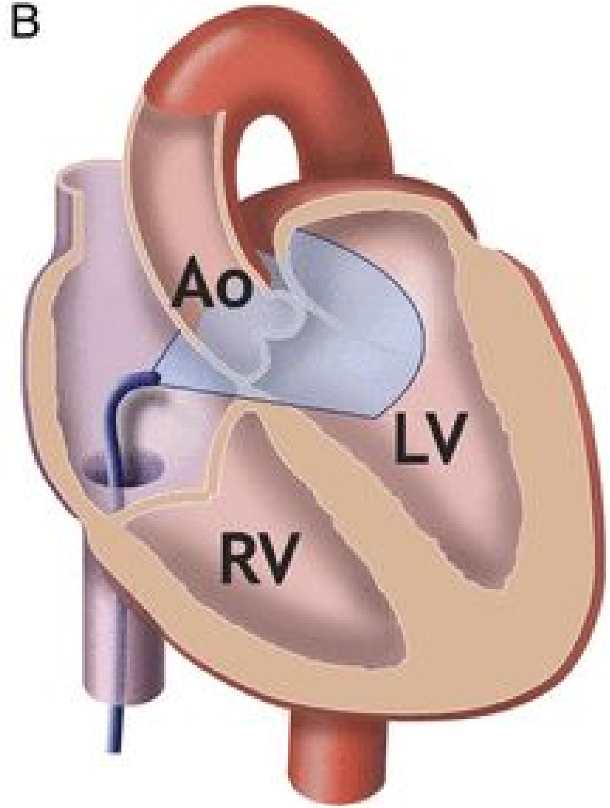
Long axis/caval view



- To obtain the view - **Advance more cephalad toward the SVC** to obtain the SVC or long-axis view. In this plane, the **transducer faces the interatrial septum**, and the SVC can be seen as it relates to the right atrium.
- The **interatrial septum is shown in a superior/inferior plane** and corresponds to the TEE long-axis view.
- Greater portions of the **SVC** can be seen as the ICE catheter is further advanced in this flexed position toward the SVC with slightly more rightward flexion. Greater portions of the **inferior septum** can similarly be imaged by withdrawing the ICE catheter toward the IVC.
- A **defect in the interatrial septum** (ASD/PFO) can be well profiled, and the superior and inferior rims as well as the **diameter of the defect** can be measured.
- In this view, both the **right and left pulmonary veins** may also be imaged, depending on the exact angle of the imaging plane. The imaging angle can be manipulated with clockwise and counterclockwise rotation as well as flexion/anteflexion to achieve these views.

Short axis view

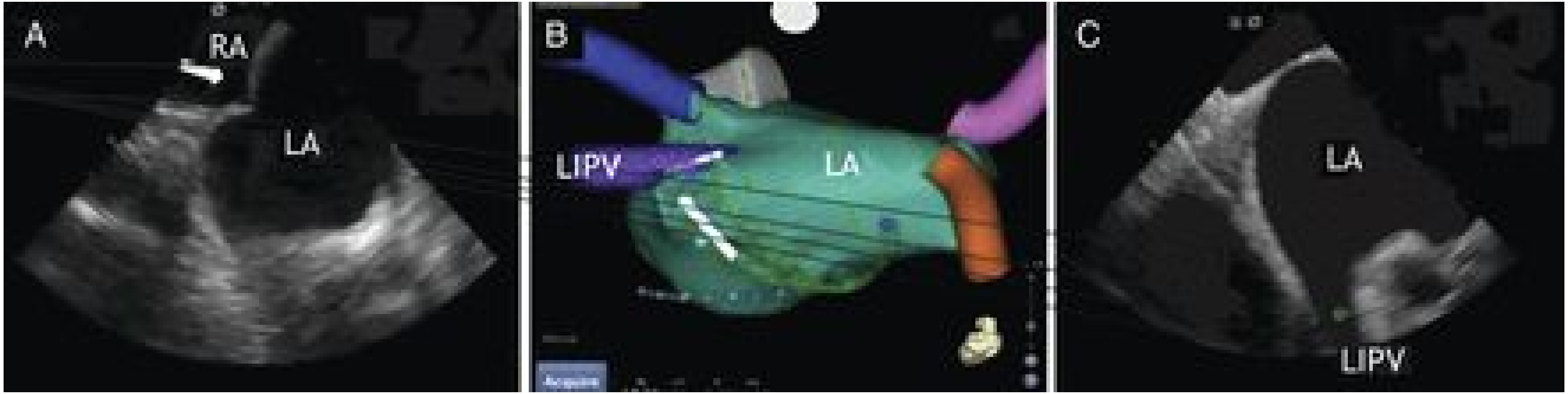




- To obtain the view - Lock the ICE catheter, then rotate the entire handle with the catheter shaft at the sheath hub **clockwise** until it sits with the transducer **near the tricuspid valve annulus and inferior to the aorta**. Minor adjustments of less posterior flexion and more leftward rotation can demonstrate the **short-axis view.**
- In this view, anatomic structures seen include the **aortic valve** in short axis and the **interatrial septum**.
- This view is very similar to the basal short-axis view obtained by TEE. However, the right atrium is shown in the near field, and the left atrium is in the far field, which is opposite of that seen with TEE.

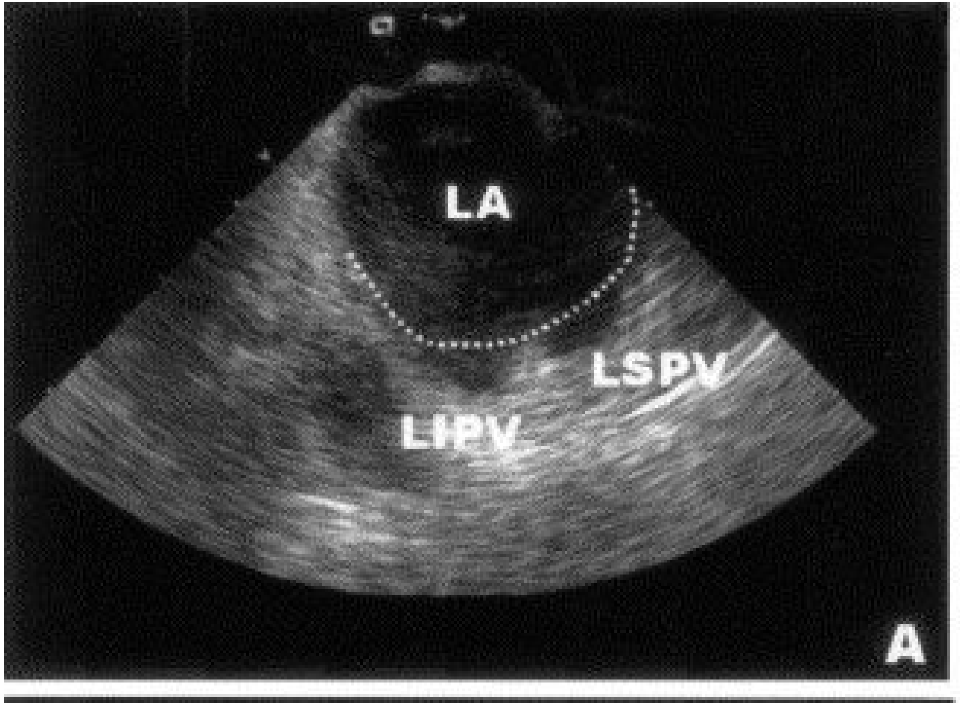
Septal Perforation

(*A*) AF ablation with desired atrial septal ‘tenting’ (arrow) when the transseptal needle is about to cross from right atrium into left atrium.
(*B*) Posterior view of a electroanatomic + ICE map of the left atrium with the ablation catheter tip (arrow) in the left inferior pulmonary vein
(*C*) The circle, representing the ablation catheter tip in (*B*), confirms ICE location in the left inferior pulmonary vein.



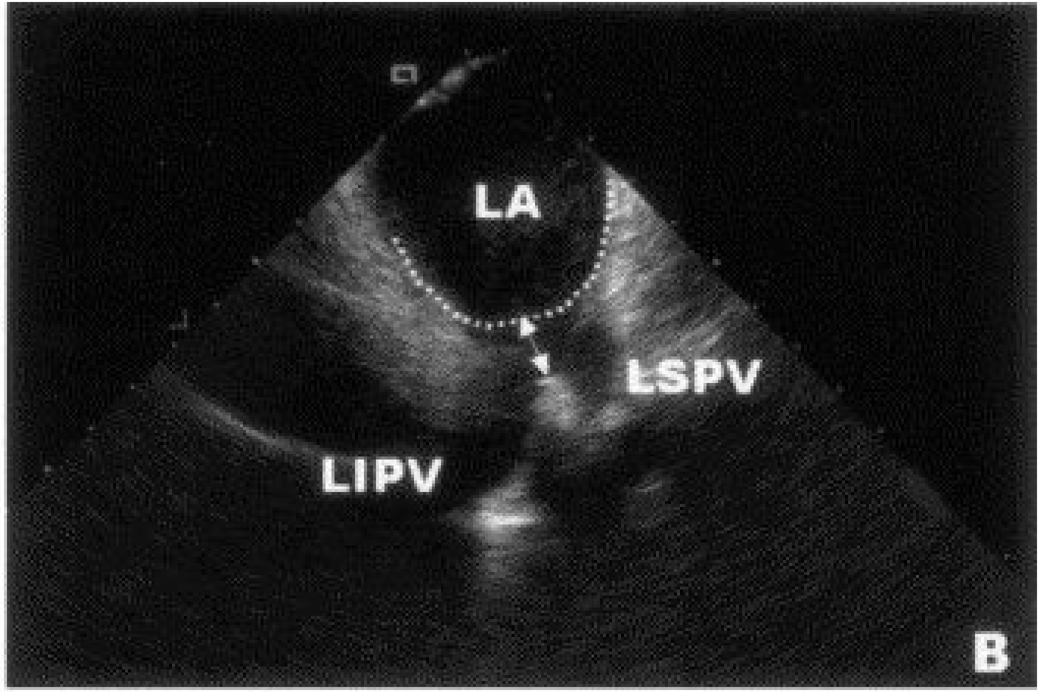
Views of the left heart

- These NEXT 3 views taken from the RA. The catheter has a high resolution multiple frequency transducer that allows tissue penetration enhancement and thus depth control which allows visualization of the LA and PVs
- Border Between the LA and PVs can be determined by extrapolating the left atrial contour (see dotted line) thus revealing the atrial-PV junction
- LIPV and LSPV are the hypoechogenic structures entering the LA in this view.



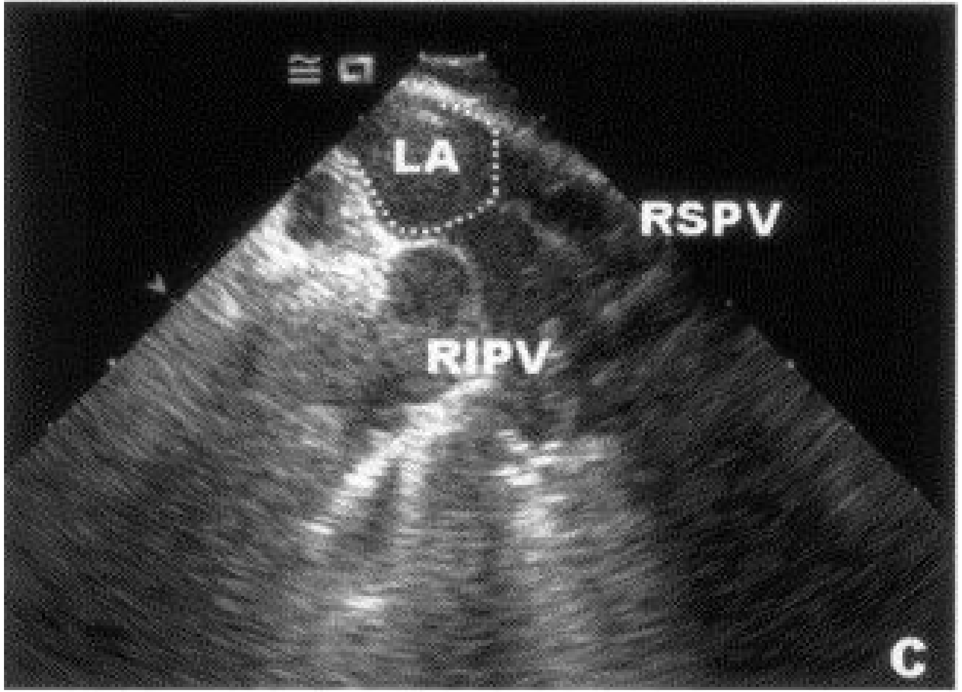
Views of Left Pulmonary Veins

- Here we see a common ostium of the LIPV and LSPV (see double arrow).
- Using Long Axis view, the PVs can be visualized. From this view, the Superior PV is on the right and the Inferior on the left.



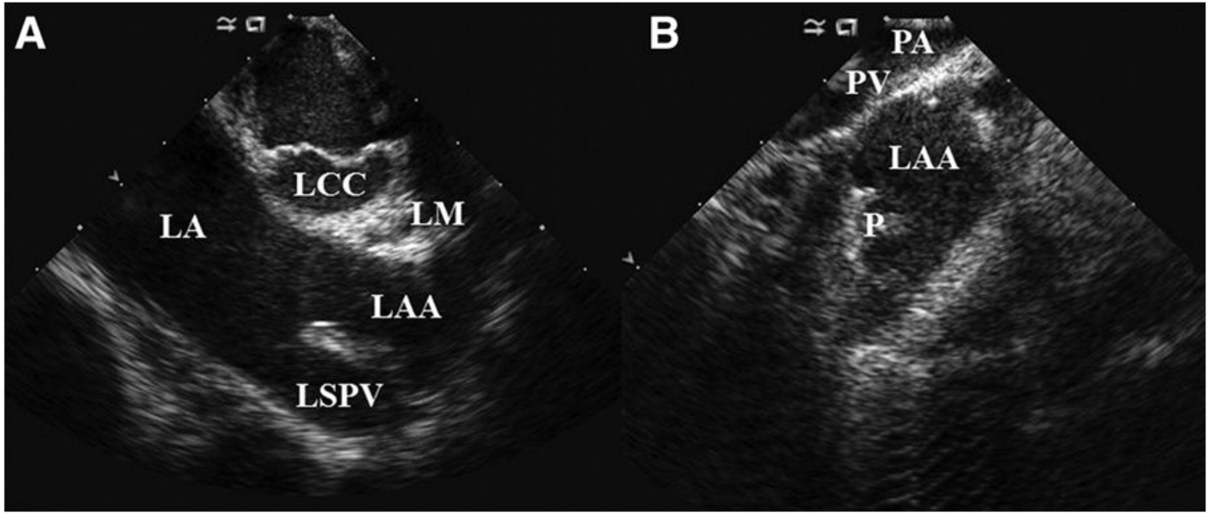
Views of Right Pulmonary Veins

- Here we see the RIPV and RSPV entering the LA without a common ostia
- Again, viewed by turning the catheter slightly in the RA, long axis view to view the right PVs. The Superior PV is on the right of the screen, the Inferior PV on the left



Left Atrial Appendage view

- The imaging catheter is placed through the tricuspid valve and rotated 180° to obtain a superior view.
- Important for LAA thrombus monitoring



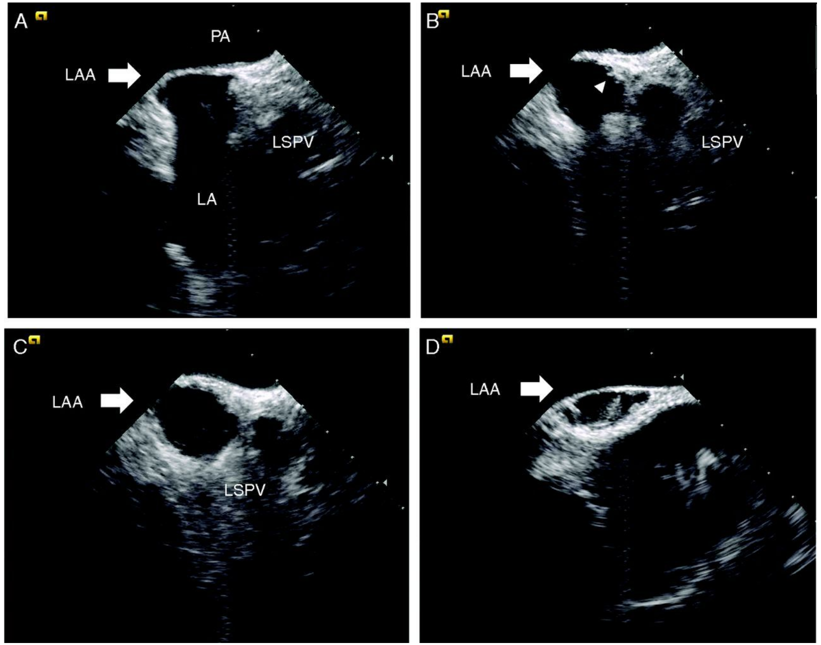
(A) The aortic valve is seen in short axis, with the mouth of the LAA visible adjacent to the left coronary cusp. Note the proximity of the left main coronary artery to the LAA. The proximal segment of the left superior pulmonary vein also is visible in this view.

(B) The imaging catheter is now deflected superiorly, inserted through the pulmonic valve and directed leftward in the pulmonary artery. The LAA is now seen in the near field with detailed visualization of the pectinate musculature.

Left Atrial Appendage view

ICE catheter is placed through the PA to visualize the LAA.

LA left atrium, RV right ventricle, LV left ventricle, LPV left pulmonary vein, LAA left atrial appendage



(A) Long-axis view of LAA and orifice. LSPV also observed. (B) pectinate muscles of the LAA observed (arrowhead). (C) Short-axis view of the LAA. (D) Apex of the LAA

Ablation views

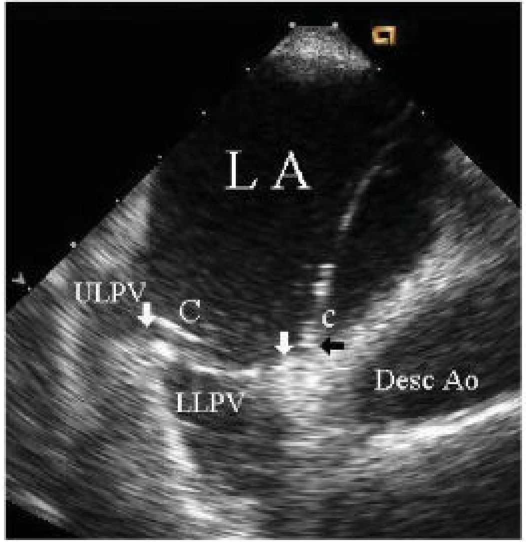


Figure 7.10 ICE image of left atrium (LA) with the transducer placed in the right atrium, showing the ablation catheter electrode (horizontal black arrow) placed near LA wall proximal to the LASSO poles (between two vertical arrows) just at the lower (L) left pulmonary vein (LPV) ostium. C: Lasso catheter; c: ablation catheter; Desc Ao: descending aorta; ULPV: upper LPV.

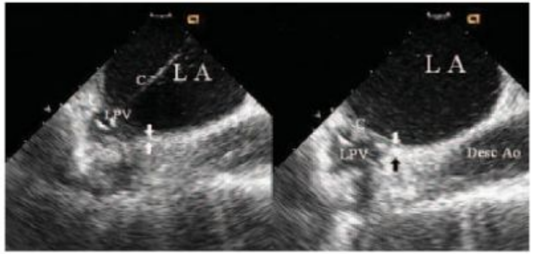


Figure 7.18 ICE images of left atrium (LA) with the transducer placed in the right atrium, showing the atrial wall thickness adjacent to the left pulmonary vein (LPV) ostium measured 3 mm pre-ablation (between arrows, left panel) and 5.5 mm with increased echodensity post-ablation (between arrows, right panel). C: catheter; Desc Ao: descending aorta.

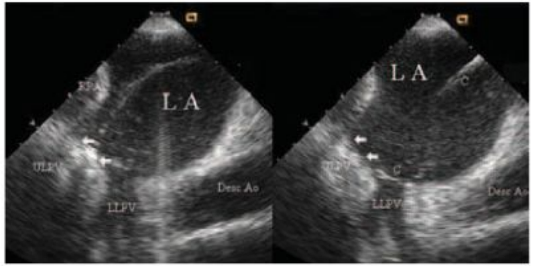


Figure 7.19 ICE images of left atrium (LA) with the transducer placed in the right atrium, showing increased echodensity and small bubbles around the lesion during radiofrequency ablation at the ligament of Marshall tissue area (arrows, left panel) and increased thickness post-radiofrequency lesion (arrows, right panel). C: catheter; Desc Ao: descending aorta; LLPV and ULPV: lower and upper left pulmonary vein; RPA: right pulmonary artery.

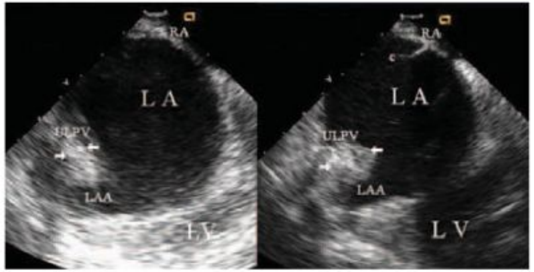


Figure 7.20 ICE images of left atrium (LA) with the transducer placed in the right atrium (RA), showing the thickness of the ligament of Marshall tissue area measured 7 mm pre-radiofrequency (RF) ablation (arrows, left panel) and increased to 16 mm with echodensity post-RF (arrows, right panel). C: catheter; LAA: LA appendage; LV: left ventricle; ULPV: upper left pulmonary vein.

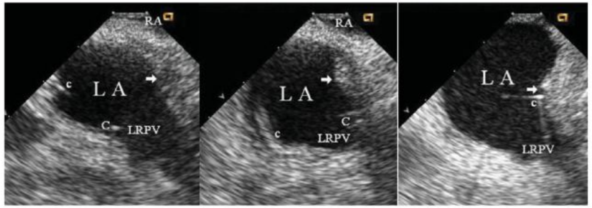


Figure 7.21 ICE images of lesion morphologic changes in the left atrial (LA) wall adjacent to the lower right pulmonary vein (LRPV) ostium (using 8 mm electrode ablation), showing LA wall thickness (3 mm, arrow) before ablation (left panel), swelling and increased wall thickness (6.8 mm) and echogenecity (arrow) after a lesion delivered (middle panel) and further wall thickening (12 mm) and crater formation (arrow) with repeat radiofrequency energy delivered (right panel). C: catheter; RA: right atrium.

Hemodynamic changes during ablation

Increased flow velocity following ablation. Important in monitoring for pulmonary vein stenosis.

Example: LIPV ostium

- Pre - 84 cm/sec
- Post - 211 cm/sec (increased turbulence)
- 1.6 months later - 175 cm/sec (improved flow)

Table 7.1 Changes in pulmonary vein ostial flow velocities/pressure gradients after radiofrequency ablation.

	ULPV	*URPV*	*LLPV*	*LRPV*
n	81	73	43	22
Ostial diameter (mm)	15.6 ± 2.0	15.3 ± 1.9	15.6 ± 2.0	16.2 ± 1.4
Pre-ablation V (cm/s)	59 ± 12	54 ± 11	58 ± 13	44 ± 10
PG (mmHg)	1.5 ± 0.6	1.2 ± 0.5	1.5 ± 0.6	0.8 ± 0.3
HR (bpm)	76 ± 17	81 ± 20	76 ± 15	84 ± 16
Lesions/PV	14 ± 7	12 ± 6	11 ± 5	15 ± 9
Post-ablation V (cm/s)*	109 ± 21	97 ± 20	101 ± 25	79 ± 22
PG (mmHg)*	5.0 ± 3.4	4.0 ± 1.5	4.5 ± 2.3	2.8 ± 1.4
HR (bmp)	81 ± 15	83 ± 15	79 ± 15	81 ± 16

* All $p < 0.001$: post- versus pre-ablation. LLPV and LRPV: lower left and right pulmonary vein; PG: pressure gradient; ULPV and URPV: upper left and right pulmonary vein; V: peak flow velocity. Reproduced with permission [10].

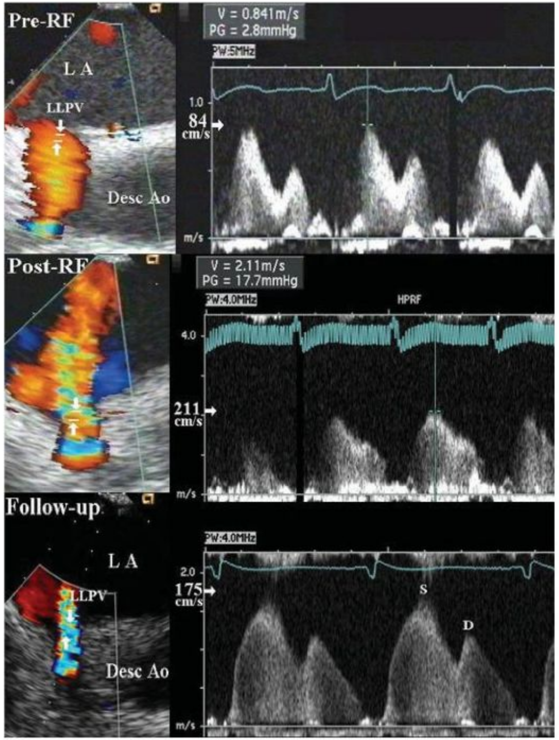
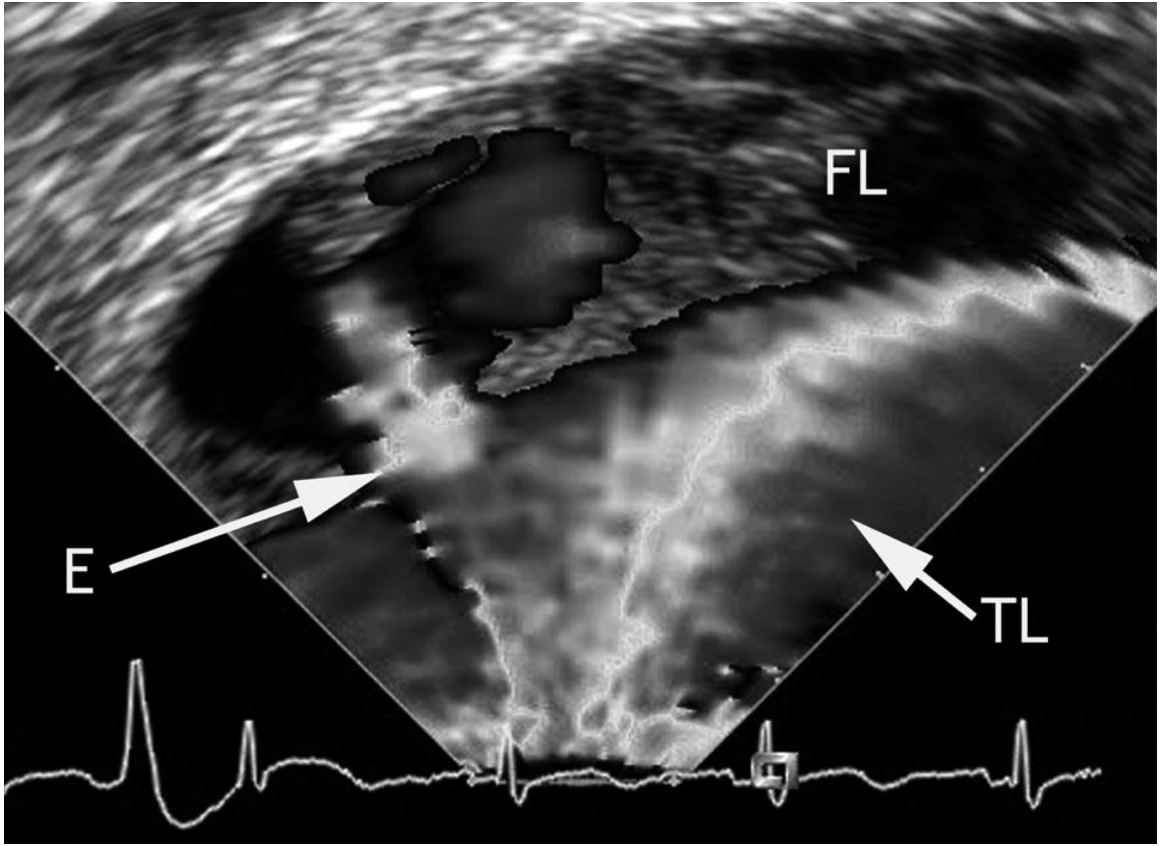


Figure 7.12 Color flow image and pulsed Doppler spectrum recorded peak flow velocities of the lower left pulmonary vein (LLPV) ostium (sampling gate, arrows) show a maximal velocity of 84 cm/s with phasic wave during systole and diastole before ablation (upper panels). After ablation, the ostial peak flow velocity increased to 211 cm/s with increased turbulent duration and little phasic variation, which is recorded with no aliasing by high pulse repetition frequency pulsed Doppler after ablation (middle panels). Ostial velocity follow-up after 1.6 months shows the maximal velocity decreased to 175 cm/s with phasic variation indicative of improved flow features (lower panels). Desc Ao: descending aorta; LA: left atrium. Reproduced by the permission [10].

Pathology Seen Using ICE

Aortic Dissection

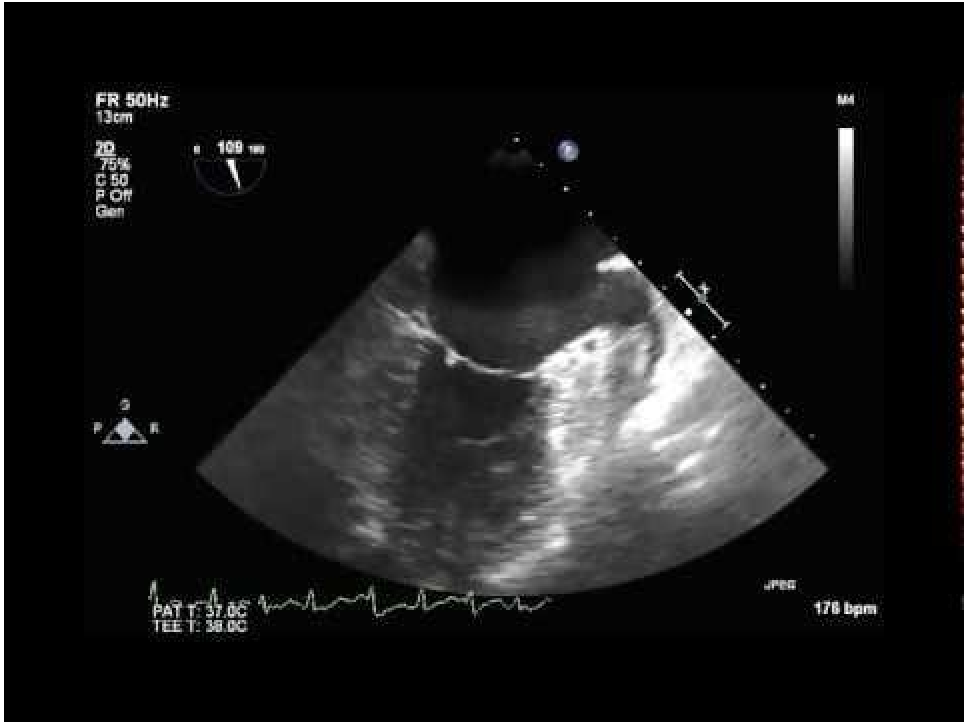
E = the Entry point through the tear in the intima.
TL = the True Lumen of the aorta
FL = the False Lumen between the intimal and medial layers of the aortic wall



Pericardial effusion

Left Atrial Appendage Thrombus

As visualized by TEE (double click image to play video)



Esophageal Mapping

To prevent esophageal injury, including perforation and atrioesophageal fistula

- Mostly achieved with esophageal temperature monitoring. Also can be imaged with electroanatomic mapping and 2D ICE (3D has been suggested).
- To image and monitor the esophagus and the left atrial posterior wall contiguous to esophagus, place the ICE transducer in the mid/high RA and rotate clockwise to scan between the left and right mid/lower PV ostia.

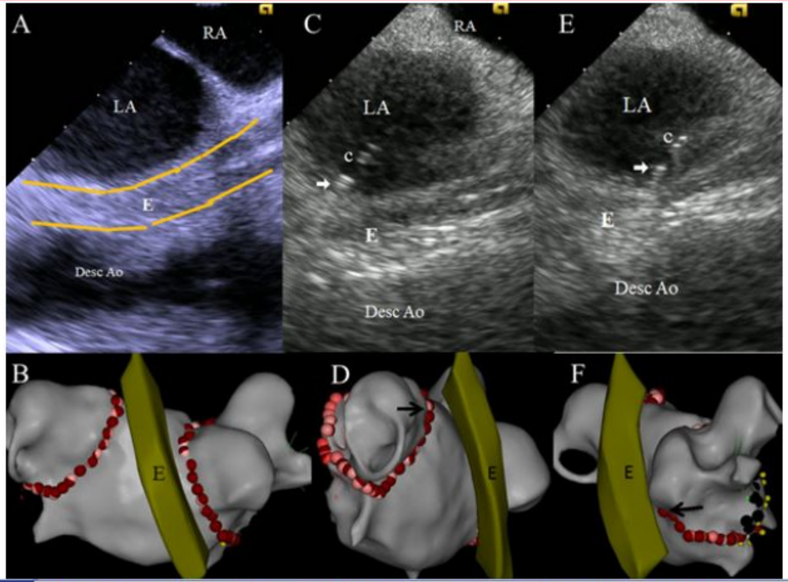


Figure 1: 2D- and 3D-ICE/Cartosound imaging of esophagus (E) and guiding radiofrequency (RF) lesions at the left atrium (LA) posterior wall (PW) contiguous to the E in a 59 year old man with successful pulmonary vein (PV) isolation (PVI) for paroxysmal atrial fibrillation. This patient had mildly enlarged LA (diameter=4.2 cm), normal left ventricle in size and function (ejection fraction = 60%), normal right ventricular size and pulmonary artery systolic pressure estimated at 37 mmHg. 2D ICE image at the baseline of LA immediately contiguous to the E (the outline traced with yellow lines) (Fig.1A), and 3D ICE/Cartosound image of the E and LAPW with complete PVI lesions around the PVs (pink to red tags, representative of different contact force ranged from 6 to 34 g/300 to 600 gsec detected by SmartTouch™) in a postero-anterior projection (Fig.1B); 2D ICE image of LA with significantly swollen wall except the wall contiguous to the E post RF lesions (Fig.1C), and 3D ICE/Cartosound image of the E and LAPW with left PVI lesions, defined the spatial relationship between the most medial lesion (arrow, corresponding to that lesion indicated with an arrow in Fig.1C) for left PVI and the left border of the E in a left posterior oblique projection (Fig.1D); similarly, 2D ICE image of LA contiguous to the E post PVI lesions (Fig.1E), and 3D ICE/Cartosound image of E and LAPW with right PVI lesions, defined the spatial relationship between the most medial lesion (arrow, corresponding to that lesion indicated with an arrow in Fig.1E) for right PVI and the right border of the E in a right posterior oblique projection (Fig.1F). The esophageal diameter measured 10 mm in 2D ICE images and its segmental contract movement with a little change in lumen diameter noted in Fig.1E. c=ablation catheter; Desc Ao=descending aorta; RA=right atrium.

Miscellaneous views

More views of the SVC

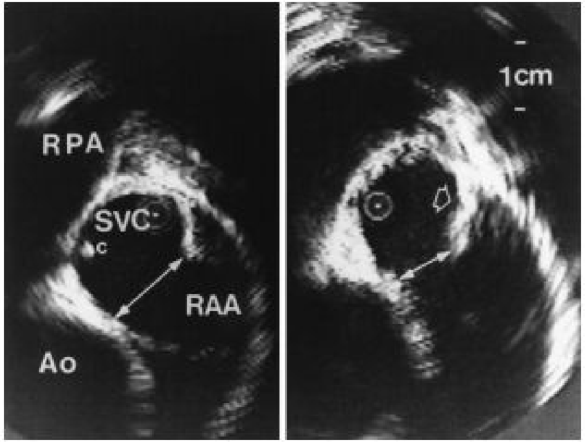


Figure 1. Narrowing of the SVC-RA junction with RF delivery. The ICE images are 10° oblique cross-sectional views oriented such that the ultrasound transducer is in the center of the image, posterior and superior structures are at the top of the image, anterior and inferior structures at the bottom and right-sided (lateral) structures to the viewer's right. The **arrows** refer to the SVC-RA junction at the level of the superior lateral crista terminalis. In the **left frame,** the SVC-RA junction is shown at baseline **(arrows).** After RF delivery to the lateral crista terminalis **(right frame),** circumferential tissue swelling was noted, with a 40% reduction in the SVC-RA junction. The **open arrowhead** demonstrates a crater at RF lesion site. Ao, aorta; c, catheter; RPA, right pulmonary artery; RAA, right atrial appendage; SVC, superior vena cava.

Long axis/caval view

Radial ICE

Transseptal perforation

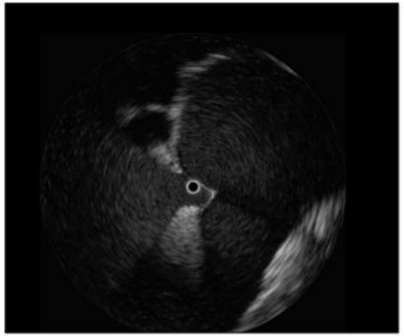


Figure 1: Transverse cross-sectional view of the right atrium during transseptal puncture. The right atrium is leftward, the left atrial body is rightward, and the fossa ovalis is at the center of the image. The fossa is tenting from the pressure of the advancing transseptal sheath and Brockenbrough needle. Note that the aortic root is easily identified anterior to the fossa ovalis.

Figure 2: ICE image (left panel) and cutaway CT image (right panel) of the left atrium with a semi-coronal imaging plane as the axis of the imaging catheter courses from the transseptal puncture to the left superior pulmonary vein. The ICE image clearly shows the left pulmonary veins, LPV ridge, and left atrial appendage. The corresponding CT image shows the left pulmonary veins, the LPV ridge, and the aortic root.

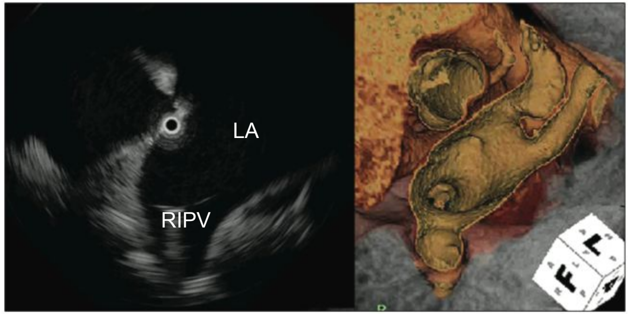


Figure 3: ICE image (left panel) and cutaway CT image (right panel) of the left atrium with a transverse cross-sectional imaging plane as the axis of the imaging catheter courses from the transseptal puncture directly superiorly to the right superior pulmonary vein. The ICE image shows the transseptal crossing (point of imaging from the ICE transducer), the right inferior pulmonary vein (posterior) and the left atrial body (rightward). If the imaging catheter was advanced, it would enter the right superior pulmonary vein, which would be imaged in cross section.

Radial ICE views

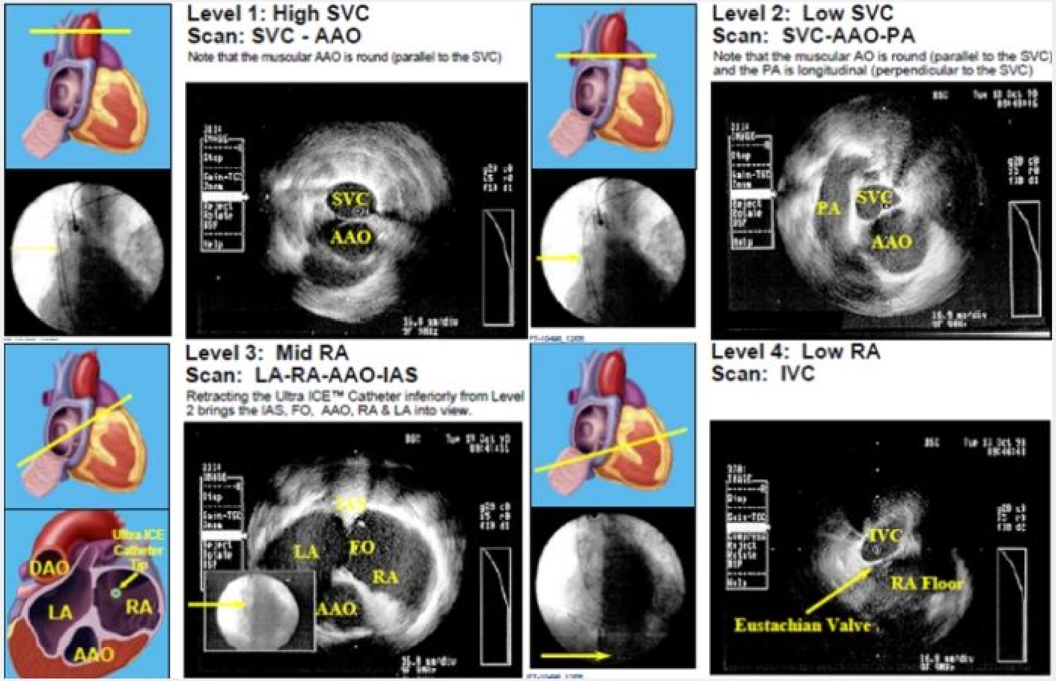


Figure 1 Basic Cardiac Anatomy with Radial Intracardiac Echocardiography (ICE).

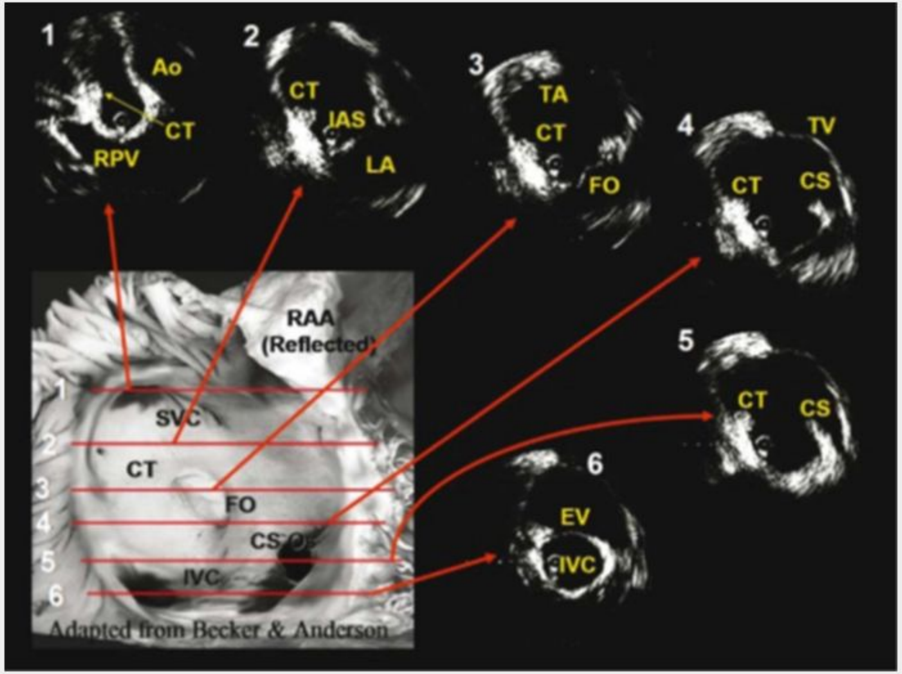


Figure 4 Radial ICE Assessment of RA Anatomy. Figure from Springer, Journal of Interventional Cardiac Electrophysiology

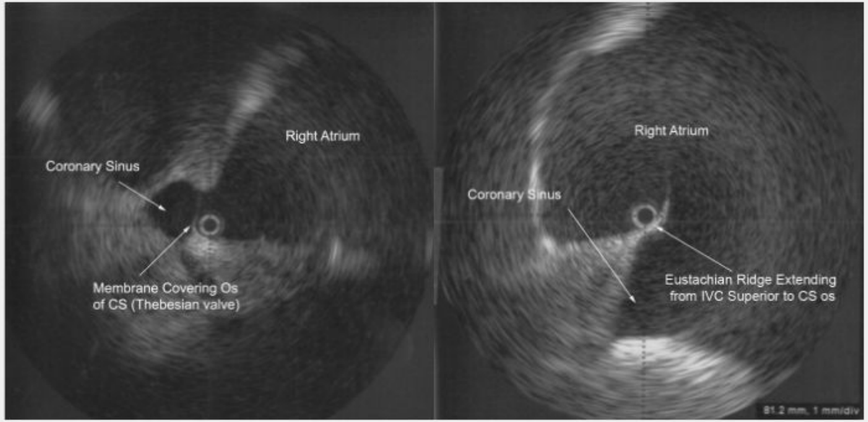


Figure 5 Radial ICE Imaging of CS Anatomic Variants.

Figure 5 Radial ICE Imaging of CS Anatomic Variants. The left image shows a Thebesian valve with no obvious fenestrations covering the CS os. The right image shows a prominent Eustachian ridge extending from the IVC and overlying the superior aspect of the CS os.

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Cardiac Anatomy

Gross Anatomy of the Left Atrium (LA)

Four Parts (+1):

1. Venous component - receives the Pulmonary Veins (PV)
2. Vestibule - between the body and the mitral valve (MV)
3. Left Atrial Appendage (LAA)
4. Interatrial Septum (IAS)

+1 = The body of the LA. The body is the part of the LA between the PV components and the vestibule.

Average size (A-P diameter) of LA: 38.4 +/- 4.9mm

LA Images

Longitudinal section through the heart
Floor - Mitral Valve
Roof = superior wall ("atrial dome")
Posterior wall = adjacent to the LIPV.
The coronary sinus can be seen on the inferior portion of the LA adjacent to the atrial infolding
LLR = Left Lateral Ridge. The LLR is a useful landmark. On the supero-posterior side of the LLR are the ostia for the LIPV and LSPV. On the antero-inferior side of the LLR is the Left Atrial Appendage.