

How to image individual pulmonary veins with transthoracic echocardiography

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ABSTRACT

Although Doppler analysis of pulmonary veins (PVs) is crucial in the assessment of cardiac hemodynamics, there is controversy regarding individual anatomical PV imaging with transthoracic echocardiography (TTE). This report is a discussion of how to image PVs accurately using TTE. To resolve any contradiction, multiple TTE images were obtained during the selective catheterization of the PV in patients undergoing atrial fibrillation ablation procedure. Fluoroscopic images were used as a reference for the identification of each PV and simultaneous echocardiographic imaging of the catheter positioned in the distal PV was used for accurate anatomical localization of the ostium and distal part of the PV. (*Anatol J Cardiol* 2017; 18: 304-8)

Keywords: pulmonary veins, transthoracic echocardiography

Introduction

The visualization of pulmonary veins (PVs) is of great importance for the diagnosis of several congenital or acquired heart diseases (1). Although imaging methods such as computerized tomography (CT) and magnetic resonance imaging (MRI) are preferred for anatomical imaging, the evaluation of pulmonary venous flow by Doppler echocardiography is crucial for the determination of left ventricular diastolic dysfunction, estimation of left ventricular filling pressures, evaluation of left atrial function, estimation of mitral regurgitation severity, and differential diagnosis of constrictive pericarditis and restrictive cardiomyopathy (2–6). Despite the widespread use of PV imaging by transthoracic echocardiography (TTE), there are potential challenges in visualizing all of the PV with TTE. These challenges are primarily caused by far-field location of PVs. Although it is reported that high quality PV flows can be obtained in nearly 90% of patients via existing device technology and experience (7–9), there is ambiguity in the literature and in the main textbooks about the identification of the PVs with TTE (10, 11). The general opinion is that the right upper PV (RUPV) is the most convenient vein for flow detection by Doppler echocardiography because it has a flow parallel to the interatrial septum on apical 4-chamber view,

whereas there is also a study reporting solid evidence for the fact that right lower PV (RLPV) is misidentified as RUPV in the current echo literature (12). In the above mentioned prospective study, selective PV angiography was combined with contrast TTE to identify the exact site of each PV in 20 patients with secundum atrial septal defect. This study demonstrated that, unlike in the literature, the RLPV has a flow parallel to the interatrial septum on apical 4-chamber view and stated that the previous literature on imaging of PVs with TTE may contain information based on subjective opinions not validated by other imaging techniques (12). In the present report, accurate identification of the site and flow of individual PVs using TTE is discussed. Multiple TTE images were obtained during selective PV catheterization of atrial fibrillation ablation procedure in patients without anatomical PV vein variation. Fluoroscopic images were used as a reference for the identification of each PV and simultaneous echocardiographic imaging of the catheter positioned in the distal PV was used for correct anatomical localization of the ostium and the distal part of the PV.

Left upper pulmonary vein

The left upper pulmonary vein (LUPV) carries oxygenated blood from the left upper lobe and lingula to the left atrium (LA).

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It approaches the LA in an anteroinferior direction and its ostium is located on the posterolateral wall of the LA (1).

Left lower pulmonary vein

The left lower pulmonary vein (LLPVV) carries oxygenated blood from the left lower lobe to the LA. It enters the LA in a posteroanterior direction, which is almost perpendicular to the posterior atrial wall. It is closer to the descending aorta compared with the LUPV, and its ostium is more medial and dorsal than that of the LUPV (1). It is the most difficult PV to visualize, as it can be masked by surrounding tissues and its ostium can be very close to the LUPV. There are anatomical variations associated with PVs in nearly 38% of population (13, 14). The most common variation is the formation of a short or long left common trunk through the convergence of the left PVs, which drains into the LA through a single ostium.

Right upper pulmonary vein

The right upper pulmonary vein (RUPV) carries oxygenated blood from the right upper and middle lobes to the LA. It approaches the LA in an anteroinferior direction, and drains obliquely into the posteromedial wall of the LA (1).

Right lower pulmonary vein

The right lower pulmonary vein (RLPV) carries oxygenated blood from the right lower lobe to the LA. It opens into the LA almost perpendicular to its posteromedial wall. Its ostium is more medial and dorsal than that of the RUPV. Anatomic variants of the right PVs are less common and tend to be more complex, with one or more accessory veins that have their own connections to the LA (1).

Imaging

Parasternal short-axis view

After obtaining a parasternal short-axis view at the aortic valve level, the LA appendage can be visualized by moving the transducer slightly downward or with minimal medial angulation. In this window, the LUPV is close to the LA appendage and

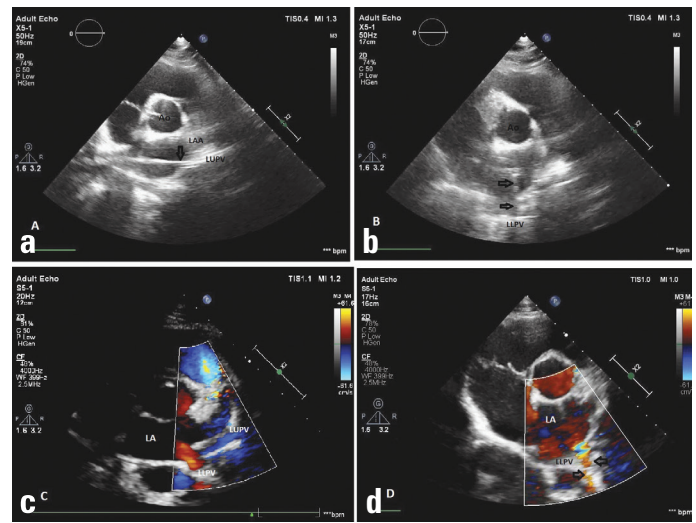


Figure 1. (a) Ablation catheter (arrow) is seen in the left upper pulmonary vein (LUPV) in parasternal short-axis view. (b) Ablation catheter (arrows) is seen in the left lower pulmonary vein (LLPV) in the same view. (c) Color flow imaging of the LUPV and LLPV. (d) Color flow imaging shows LLPV has a flow direction approaching the transducer (arrows) Ao - aortic valve; LAA - left atrial appendage; LA - left atrium

the LLPV is close to the descending aorta (Fig. 1; Video 1, 2). With color Doppler imaging, it can be demonstrated that the LUPV flow is moving in a direction away from the transducer, whereas the LLPV has a flow direction approaching the transducer (Fig. 1; Video 3).

Apical 4- and 5-chamber views

It is rarely possible to see 4 pulmonary veins together in the apical 4-chamber view. When this occurs, PVs are arranged in an order of LUPV, LLPV, RLPV, and RUPV, from left to right of the image sector (Fig. 2; Videos 4–6). Apical 4-chamber view often provides the best visualization of the RLPV (Fig. 3; Video 7). The flow of the RLPV has a course parallel to the interatrial septum and enters the LA wall at an almost perpendicular angle. Since this flow follows a path also parallel to the ultrasonic waves, the RLPV is the vein of choice for pulsed wave Doppler analysis of PV flow (Video 8). In a position between apical 4-

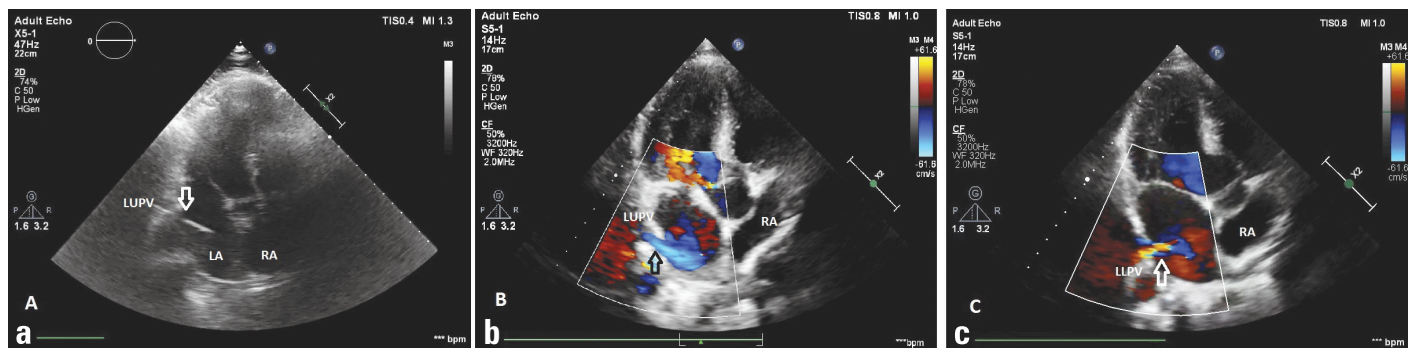


Figure 2. (a) Ablation catheter (arrow) is seen in the left upper pulmonary vein (LUPV) in apical 4-chamber view. (b) The LUPV flow has a direction moving away from the transducer (arrow). (c) The left lower pulmonary vein (LLPV) has a flow direction approaching the transducer (arrow) LA - left atrium; RA - right atrium

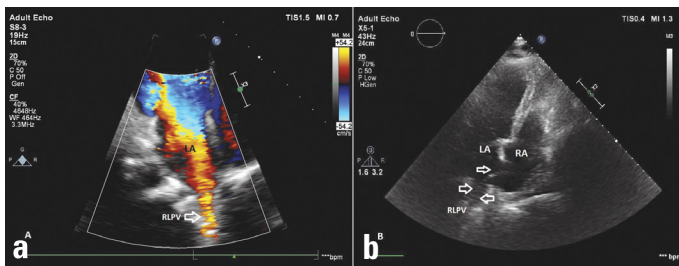


Figure 3. (a) Color flow imaging of the right lower pulmonary vein (RLPV) in apical 4-chamber view demonstrating parallel course of flow (arrow) to the interatrial septum. (b) Ablation catheter (arrow) is seen in RLPV in apical 4-chamber view

LA - left atrium; RA - right atrium

and 5-chamber views (near 5-chamber view), the RUPV enters the LA at a more oblique angle and appears closer to the right atrium (Fig. 4; Videos 9–11).

Apical 2-chamber view

In the apical 2-chamber view, the LUPV opens to the LA just below the LA appendage adjacent to the anterior wall (Fig. 5).

Suprasternal view

In suprasternal views, the LA is visible just below the long axis view of the right pulmonary artery. When the notch of the transducer is directed to the patient's right shoulder, minimal cranial tilting and lateral angulation of the transducer shows the LUPV entering the LA just below the proximal right pulmonary artery (Fig. 6; Video 12). The LLPV enters the LA from a lower level on the same side. The right-sided PVs enter the LA at a level adjacent to the distal branching point of the right pulmonary artery. Compared to the RUPV, the RLPV naturally has a lower entering level on the same side. The flow of the upper pulmonary veins moves away from the transducer, while the flow of the lower pulmonary veins has a direction approaching the transducer (Video 13, 14).

Parasternal long-axis view

In parasternal long-axis view, compared with the LUPV, the proximal segment of the LLPV has a course immediately adja-

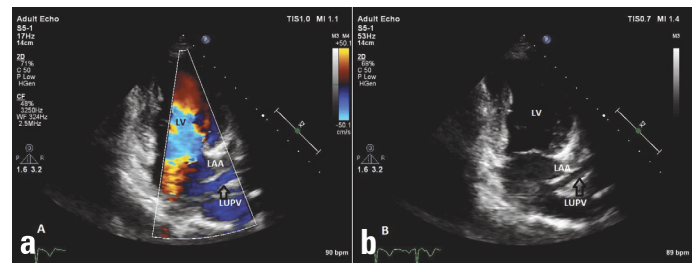


Figure 5. (a) Color flow imaging of the left upper pulmonary vein (LUPV) (arrow) in apical 2-chamber view. (b) Oblique course of the LUPV (arrow) adjacent to the left atrial appendage (LAA)

LV - left ventricle

cent to the descending aorta (Fig. 7; Video 15). Since its entry point to the LA is very close to the LUPV ostium, the flow of the LLPV is not easily distinguishable from the LUPV. In this image, the LUPV obliquely approaches the LA with a slightly left posterior to right anterior direction and shows a flow direction away from the mitral valve (Video 16).

Subcostal view

In standardized subcostal 4-chamber and near 5-chamber views, the RUPV and the RLPV can be imaged next to the interatrial septum (Video 17).

Imaging beyond the echocardiography

Although echocardiography (transthoracic and transesophageal) is the initial imaging technique of choice in the evaluation of PV anatomy and flow, anatomical imaging of PVs is best accomplished with MRI or CT (15). In particular, adolinium-enhanced MR angiography is an extremely valuable tool in the evaluation of PVs with the advantages of multiplanar capability and lack of ionizing radiation. MR angiography should be the preferred imaging technique after an inconclusive echocardiography. Disadvantages of MRI include long image acquisition time, frequent need for sedation, susceptibility to metal-related artifact, and high cost (16). CT also depicts PV anatomy excellently. Newer multi-detector CT scanners especially establish very rapid imaging with multiplanar reformatting capabilities; however, the use of ionizing radiation and

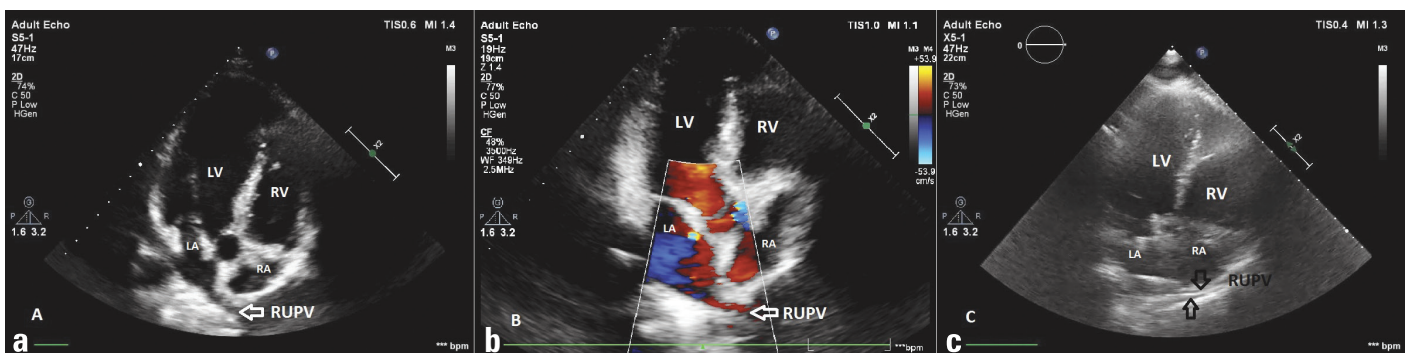


Figure 4. (a) In apical near 5-chamber view the right upper pulmonary vein (RUPV) enters the left atrium (LA) at a more oblique angle (arrow). (b) Color flow imaging of the RUPV in apical near 5-chamber view. (c) Ablation catheter (arrows) is seen in the RUPV in apical near 5-chamber view

LA - left atrium; LV - left ventricle; RA - right atrium; RV - right ventricle

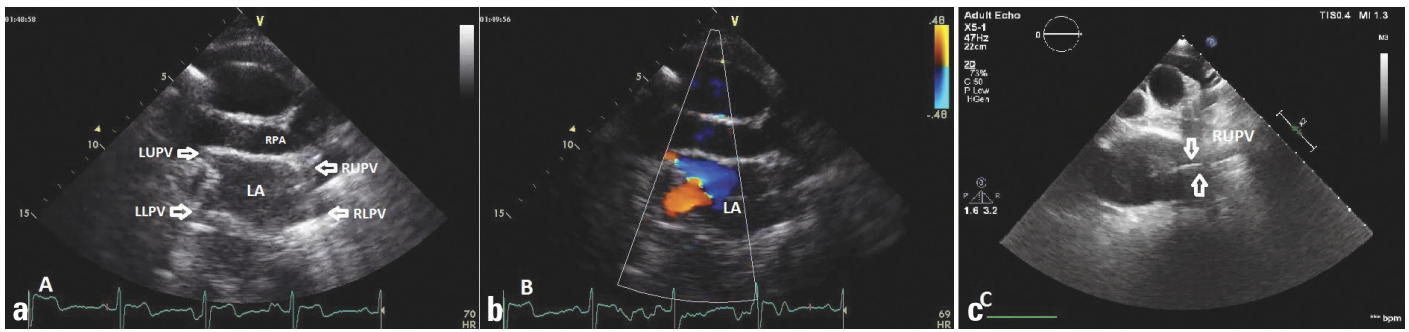


Figure 6. (a) “Crab view” of pulmonary veins in suprasternal imaging. (b) Color flow imaging of the left upper pulmonary vein (LUPV) and left lower pulmonary vein (LLPV). (c) Ablation catheter (arrows) is seen in the right upper pulmonary vein (RUPV) in suprasternal view
LA - left atrium; RLPV - right lower pulmonary vein; RPA - right pulmonary artery

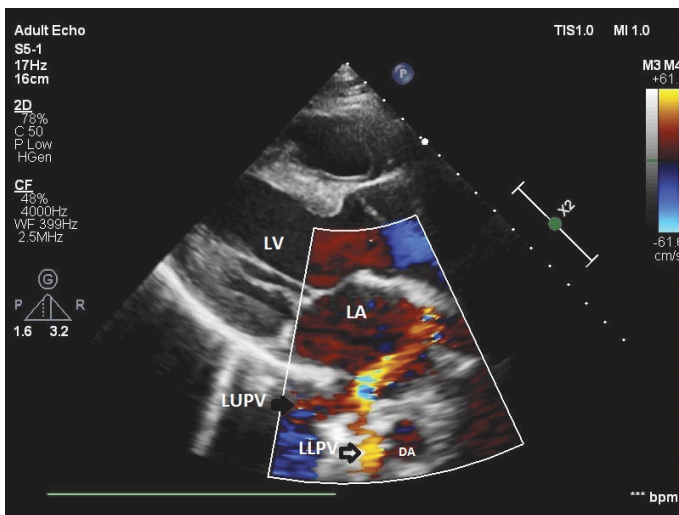


Figure 7. In parasternal long-axis view, the left upper pulmonary vein (LUPV) has a flow direction away from the mitral valve (black arrow) and the left lower pulmonary vein (LLPV) is adjacent to the descending aorta (arrow)
DA - descending aorta; LA - left atrium; LV - left ventricle

iodinated contrast material precludes CT as an initial imaging technique (17).

Conclusion

TTE is a non-invasive, easily accessible means of PV imaging. In suitable patients, each PV can be accurately visualized using TTE. To overcome the failure to diagnose abnormal pulmonary venous return, anatomical imaging of PVs must be a part of standard TTE examination. Apical views are the best for right-sided PVs, whereas the left-sided PVs are best displayed in the parasternal views. The RLPV has the most convenient flow direction for Doppler analysis.

Video 1. Parasternal short-axis view. The left upper pulmonary vein is close to the left atrial appendage and the left lower pulmonary vein is close to the descending aorta.

Video 2. Parasternal short-axis view. Ablation catheter is in the left lower pulmonary vein.

Video 3. Parasternal short-axis view, color Doppler imaging. The left upper pulmonary vein flow has a direction moving away from the transducer, whereas the left lower pulmonary vein has a flow direction approaching the transducer.

Video 4. Apical 4-chamber view. Ablation catheter is in the left upper pulmonary vein.

Video 5. Apical 4-chamber view. Color flow imaging of the left upper pulmonary vein.

Video 6. Apical 4-chamber view. Color flow imaging of the left lower pulmonary vein.

Video 7. Apical 4-chamber view. Ablation catheter is in the right lower pulmonary vein.

Video 8. Apical 4-chamber view. Color flow imaging of the right lower pulmonary vein. The right lower pulmonary vein has a flow course parallel to the interatrial septum.

Video 9. Apical near 5-chamber view. Ablation catheter is in the right upper pulmonary vein.

Video 10. Apical near 5-chamber view showing the right upper pulmonary vein.

Video 11. Apical near 5-chamber view, color Doppler imaging. Oblique entrance of the right upper pulmonary vein to the left atrium is seen.

Video 12. Suprasternal “crab view” of the pulmonary veins. Right pulmonary veins are on the right side of the image sector.

Video 13, 14. Suprasternal “crab view” of the pulmonary veins, color Doppler imaging. The flow of the upper pulmonary veins has a direction moving away from the transducer, while the flow of the lower pulmonary veins has a direction approaching the transducer.

Video 15. Parasternal long-axis view showing the left upper and lower pulmonary veins. The left lower pulmonary vein is closer to the descending aorta.

Video 16. Color flow imaging of the left upper and lower pulmonary veins in the parasternal long-axis view.

Video 17. Color flow imaging of the right lower pulmonary vein in the subcostal view.

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