

How to Easily Visualize the Superior Vena Cava in Adults? Introducing Three Transthoracic Echocardiographic Road Maps: Techniques, Dimensions and Doppler Spectral Signals

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Abstract

Background:

Although much is known about the technical aspects of inferior vena cava visualization, it is much less about its counterpart: the superior vena cava (SVC). The aims of this study therefore, were to describe in detail the different possible transthoracic SVC visualization techniques in adults and to provide a series of normal values for its dimensions and Doppler signals.

Methods:

The feasibility of SVC visualization by TTE was initially established in 40 patients with or without central venous catheters, or pacemaker wires. Subsequently, the newly found SVC visualization road maps were applied in 30 healthy adults to assess SVC dimensions, their respiratory variations and Doppler signal parameters. Dimensions were measured 3-5mm proximal (above) the RA-SVC junction at the end of both cardiac and respiratory cycles but the peak Doppler velocities were only measured at the end-held expiration. To clarify the SVC color flow, the Nyquist limit was set at 25-40 m/s.

Results:

The three new SVC visualization road maps included:

- a) Modified apical 5-chamber view (MA5CV),
- b) Modified parasternal short axis view of great vessels (MSAVGV) and
- c) Modified subcostal view (MSCV).

The 30 normal subjects included 17 males and 13 females with an age range of 24-45 years, weight of 46-77 kg, height of 158-178cm and body mass index (BMI) of 15.73-27.24 kg/m². The largest end systolic SVC dimensions at the end of the expiration and inspiration ranged from 7.7 to 14.0 mm (10.74 ± 1.7 mm) and 8.0 -14.0 mm (10.86 ± 1.53 mm) respectively, and the highest S wave velocity ranged from 0.49 - 0.65 m/s (0.57 ± 0.03 m/s).

Conclusion:

The challenge of SVC visualization by TTE is over now and it is hoped that it could become a part of routine echocardiographic assessments by everybody and everywhere.

Background

The superior vena cava (SVC) is formed by the right and left brachiocephalic (innominate) veins and receives the venous return from the upper part of the body above the diaphragm. It then passes vertically

downwards and after receiving the azygous vein it joins the upper and posterior part of the right atrium at the level of the third costal cartilage.¹

The right supraclavicular and less frequently suprasternal windows for SVC visualization have been in use for many years, but until recently the true conventional transthoracic ones were ignored, partly because of the presence of poor acoustic windows. In the most recent echocardiographic guidelines, however, the possibility of seeing SVC through most of these transthoracic windows has been brought about,² but what actually is missing, is the technical description and details of how to do it, which in addition to other reasons, has made SVC imaging to be neglected as a standard part of routine transthoracic echocardiographic evaluation.

SVC occlusion is an important clinical entity that requires urgent diagnosis and treatment. It may be caused by extravascular compression or intravascular thrombosis, mediastinal masses,³ central venous catheters,⁴ pacemaker wires^{5,6} and radiofrequency ablation for ectopic atrial tachycardia are only some of the many causes of SVC obstruction.⁷ Satisfactory visualization of SVC, therefore, could be quite helpful for proper diagnosis and selection of appropriate treatment. Here, we report the fine technical details for SVC visualization through the conventional transthoracic echocardiographic windows and some of its normal parameters.

The Starting Point:

It happened just few months ago when, while performing a routine 2DE and trying to find a proper window for apical 4-chamber study in a febrile patient, an unexpected view was noted which seemed to include the SVC. This was confirmed through left-brachial vein injection of agitated saline which showed the SVC course and right atrial (RA) filling. In addition, color flow study showed flow direction inside the SVC and this was the starting point for 2D transthoracic SVC visualization.

Since then, some 40 patients with or without central venous catheters or cardiovascular implantable electronic devices requiring echocardiographic study were carefully evaluated, trying to get expertise in SVC visualization. The result of all these trials and errors was the detection of all techniques and methodologies required for a perfect SVC visualization through the three conventional transthoracic echocardiographic windows.

Methods

Subjects

After documenting the feasibility of SVC visualization by the three conventional transthoracic echocardiographic views, the technique was applied in a group of 30 normal young adult volunteers, including 17 males and 13 females for the final assessment. Subjects were included in the study only if they fulfilled all the following criteria: a) being completely healthy and having no underlying illness or cardiovascular risk factor. b) having normal general physical examination including the cardiovascular

system. c) having a completely normal electrocardiography and conventional 2DE, and d) having proper windows for all the three conventional parasternal, apical and subcostal echocardiographic views.

All participants signed a written consent and the study protocol was approved by the local ethics committee.

Techniques

Road 1: The Modified Apical 5-Chamber View (MA5CV):

The subjects were positioned half-way between supine and left lateral decubitus. Then the transducer was placed in the 5th intercostal space at the anterior axillary line with the index mark pointing to the patient's right shoulder to obtain an apical 5-chamber view. By gentle side tilting the transducer more medially (between -40 to -80 degrees), the SVC could be visualized and studied (Figure 1A).

Road 2: The Modified Parasternal Short Axis View of Great Vessels (MSAVGV).

The participants were slightly turned to the left, somewhere between supine and left lateral decubitus position. Then the transducer was put in the 3rd intercostal space, close to the sternal border with the index mark pointing to the suprasternal notch. By mild and gentle tilting of the transducer toward the right shoulder (between -15 to -30 degrees) the SVC could be seen and assessed in this view (Figure 1B).

Road 3: The Modified Subcostal View (MSCV).

The subjects were put in supine position and were asked to flex the knees to relax the abdominal wall muscles. Then the transducer was positioned a bit lateral to the upper mid-epigastric region, with the index mark pointing to the mid-right clavicular area. By tilting the probe toward the right shoulder (between -15 to -45 degrees depending on the subject's cardiac position), the SVC was visualized (Figure 1C).

Normal SVC Parameters

SVC dimensions and Doppler parameters

The SVC dimensions were measured 3-5 mm proximal (above) the RA-SVC junction, both at the end of systole and diastole, and deep held inspiration and expiration. The pulse Doppler measurement, however, was performed only at the end of held expiration, color guided, proximal (above) the RA-SVC junction and using a 3mm sample volume size. In addition, to clarify the SVC color flow, the Nyquist limit was set at 25 to 40 cm/sec (Figs 2A-C, 3A-C & 4A-C). Also, the SVC course with final right atrial (RA) filling was shown through left-brachial vein injection of agitated saline (Fig 4D). Data are expressed as mean \pm SD.

Results

The demographic data of the studied subjects are shown in table 1 and the SVC dimensions and the Doppler parameters are shown in tables 2 and 3 respectively.

Pulse wave Doppler interrogation of SVC revealed three distinct wave forms. The largest of the three wave forms is the S-wave, which occurs during right ventricular systole and is formed by the rush of blood from the SVC into the RA. The second wave form, the D-wave, occurs during early diastole when tricuspid valve opens and rapid ventricular filling happens and finally RA contraction results in a brief flow reversal leading to the development of the third wave (Ar wave) (Figs 2C, 3C & 4C) (Video image).

Discussion

This study has provided detailed technical description for transthoracic SVC visualization in adults, through the three conventional transthoracic echocardiographic windows. It has also furnished the normal transthoracically obtained values for SVC dimensions and their respiratory variations as well as its Doppler velocity signals.

SVC visualization and its parameters can provide useful information helping the bedside diagnosis of certain cardiac and non-cardiac disorders. In majority of normal subjects, inspiration increases the magnitude of both the S and D waves, whereas, the Ar wave will decrease in size.⁸ In their quantitative analysis of SVC flow velocities, Byrd and Linden have shown that the ratio of expiratory systolic to diastolic flow velocity in the SVC was high in subjects with cardiac tamponade compared with in healthy individuals and patients with constrictive pericarditis.⁹ In patients with chronic pulmonary problems, the expiratory disappearance of the D wave or both S and D waves have been associated with the diagnosis of the chronic obstructive pulmonary disease (COPD) or the presence of combined obstructive and restrictive ventilatory disorders.¹⁰

Little is known about the echocardiographically measured SVC dimension(s). However, in their five normal subjects, Gindea et al. have proved it to be 10 ± 3 mm,¹¹ which is very similar to our findings. SVC dilation has been shown to correlate with that of the IVC as a marker of venous congestion as in patients with congestive heart failure.¹² Ghio and colleagues have also shown that in patients with congestive heart failure, SVC flow velocities can help differentiate those with normal RV hemodynamics from subjects with compensated RV dysfunction and patients with RV failure associated with raised RA pressure.¹³ Analysis of respiratory diameter variation of SVC could be helpful to assess fluid challenge in patients with acute circulatory failure. In addition, significant diminution of the SVC – S and Ar waves have been shown to be the most sensitive parameters of blood volume depletion.¹⁴ Furthermore, SVC visualization could help detect the presence of masses, thrombi and device-related vegetations since infection and thrombosis have become the most common complication of longstanding central venous catheters and implantable cardiac devices.¹⁵

Clinical Implication:

Superior vena cava (SVC) visualization has been hard to do through the classic transthoracic windows for the past several decades. The main accessible sites have been supraclavicular and suprasternal regions with the former being the most popular. Transesophageal echocardiography (TEE) has also been used to see the SVC. However, it is both invasive and expensive and it is not available everywhere.

Transthoracic echocardiography (TTE) is a simple, low-risk procedure and easily available in any hospital. If SVC visualization becomes a routine part of any daily echocardiographic procedure, it would help the implantation and/or extraction of central lines and cardiovascular implantable devices and assist the detection of SVC occlusion and other pathologies and help early diagnosis and appropriate therapeutic decision making.

What actually is missing in the literature is a simple practical and technical description of “How to visualize the SVC by TTE”. Thus we have tried to overcome this issue by introduction of the fine technical aspects of SVC visualization through the three conventional transthoracic windows.

Study limitations

Although transthoracic visualization of SVC could be a good initial non-invasive diagnostic imaging of choice, it has its own limitations since the presence of a suitable echocardiographic window is mandatory for its successful performance. This is especially true in patients with marked obesity, COPD and chest wall deformities. Cardiac MR could be a proper substitution in such difficult cases.

Conclusion

The study has provided a detailed description of SVC visualization technique through three different transthoracic windows and has furnished sets of normal values for its dimensions, their respiratory variations as well as its Doppler signal parameters. Therefore, the question of how to visualize the SVC from true transthoracic windows has been properly answered and as such has opened a semi closed SVC-related research window to the interested investigators.

Abbreviations

- SVC= Superior vena cava
- TTE= Transthoracic echocardiography
- MA5CV= Modified apical 5-chamber view
- MSAVGV= Modified parasternal short axis view of great vessels
- MSCV= Modified subcostal view

Declarations

Declaration of interest:

None

Ethics approval and consent to participate:

Have done.

Consent for publication:

Not applicable.

Availability of data and materials:

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests:

The authors declare that they have no competing interests.

Availability of data and materials:

Not applicable.

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None.

Authors' contributions:

Both authors have made substantial contributions to the conception, design of the work, the acquisition, analysis, interpretation of data, drafted the work, approved the submitted version and have agreed both to be personally accountable for the author's own contributions and to ensure that questions related to the accuracy or integrity of any part of the work, even ones in which the author was not personally involved, are appropriately investigated, resolved, and the resolution documented in the literature.

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Tables

Tables:

Table 1. Characteristics of the 30 normal participants, including 17 males and 13 females.

Parameters	Range	Mean \pm SD
Age (years)	24-45	34.90 \pm 5.32
Weight (kg)	46-77	61.06 \pm 10.30
Height (cm)	158-178	167.56 \pm 4.69
Body mass index (kg/m ²)	15.73-27.24	21.75 \pm 3.58

Table 2. SVC dimensions of 30 normal subjects obtained at the end of both cardiac and respiratory cycles.

Timing	2DE view	End held expiration		End held inspiration	
		Range(mm)	Mean \pm SD(mm)	Range(mm)	Mean \pm SD(mm)
End systole	MSCV	7.7-14.0	10.74 \pm 1.70	8.0-14.0	10.86 \pm 1.53
	MA5CV	6.6-13.9	10.33 \pm 2.19	7.0-10.9	8.61 \pm 1.08
	MSAVGV	8.0-13.2	10.43 \pm 1.78	8.0-13.2	10.43 \pm 1.78
End diastole	MSCV	4.4-7.0	5.69 \pm 0.75	4.0-8.1	6.01 \pm 1.19
	MA5CV	4.0-6.9	5.74 \pm 0.73	3.0-7.4	4.59 \pm 0.83
	MSAVGV	3.0-6.7	4.83 \pm 0.84	3.0-6.7	4.83 \pm 0.84

MSCV, Modified Subcostal View; MA5CV, Modified Apical 5-Chamber View; MSAVGV, Modified Parasternal Short Axis View of Great Vessels.

Table 3. Peak Doppler velocities of superior vena cava

View	S-wave		D-wave		Ar	
	Range (m/sec)	Mean ± SD (m/sec)	Range (m/sec)	Mean ± SD (m/sec)	Range (m/sec)	Mean ± SD (m/sec)
MSCV	0.36 - 0.67	0.53 ± 0.07	0.30-0.42	0.36 ± 0.02	0.23-0.36	0.27 ± 0.03
MA5CV	0.38 - 0.56	0.46 ± 0.03	0.33-0.41	0.37 ± 0.02	0.24-0.35	0.30 ± 0.02
MSAVGV	0.49 - 0.65	0.57 ± 0.03	0.30-0.54	0.42 ± 0.05	0.24-0.39	0.32 ± 0.04

S, D and Ar waves obtained at the end-held expiration in 30 normal subjects by the three different SVC visualization road maps. MSCV, Modified Subcostal View; MA5CV, Modified Apical 5-Chamber View; MSAVGV, Modified Parasternal Short Axis View of Great Vessels.

Figures



Figure 1

SVC visualization through the three conventional transthoracic echocardiographic windows. A. Patient in left lateral decubitus position for taking modified apical five chamber view. B. Patient mildly turned to the left between supine and left lateral position for taking the modified parasternal short axis view of great vessels. C. Patient in supine position for taking the modified subcostal view.

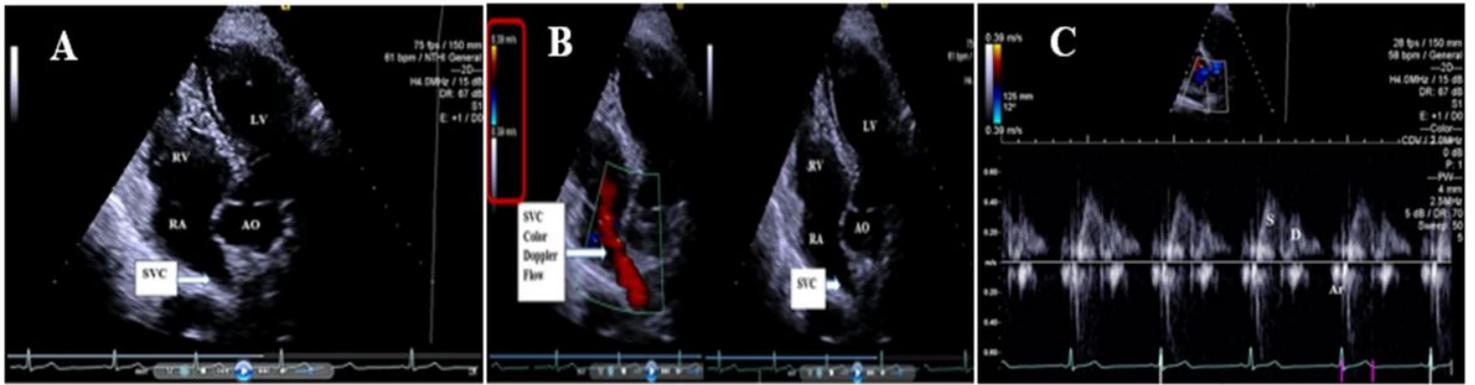


Figure 2

Modified Apical Five Chamber View A. Two dimensional modified apical five chamber view for demonstration of SVC. SVC, superior vena cava; RA, right atrium; RV, right ventricle; AO, aorta; LV, left ventricle. B. SVC Color Doppler flow (red in color; flow towards the probe) from modified apical five chamber view. Simultaneous 2D and Color Doppler Images. SVC, superior vena cava; RA, right atrium; RV, right ventricle; AO, aorta; LV, left ventricle. C. SVC Pulse Wave Doppler from modified apical five chamber view. S, systolic forward flow; D, diastolic forward flow; Ar, atrial flow reversal.

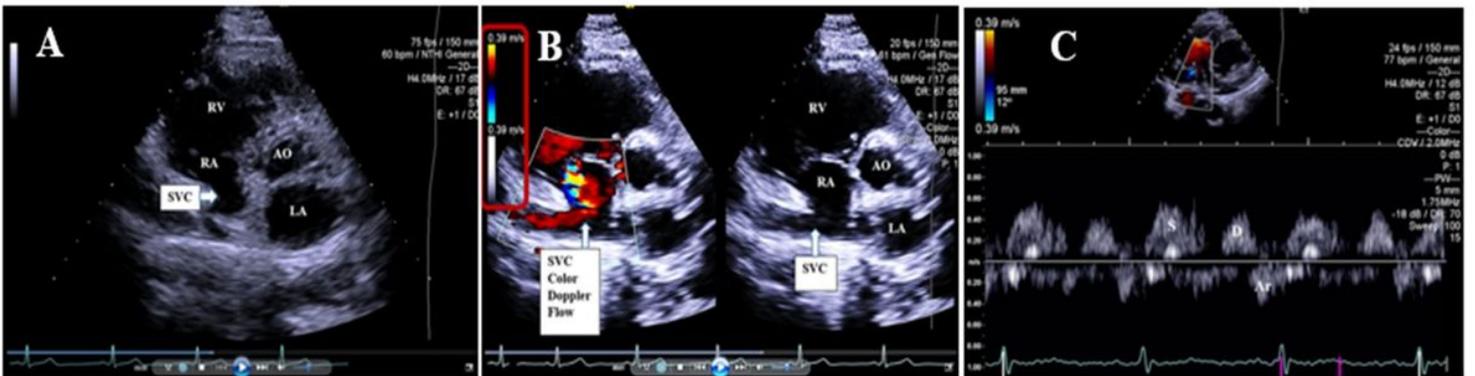


Figure 3

Modified Parasternal Short Axis View of Great Vessels A. Two dimensional modified parasternal short axis view of great vessels for SVC visualization. SVC, superior vena cava; RA, right atrium; RV, right ventricle; AO; aorta; LA, left atrium. B. SVC Color Doppler flow (red in color; flow towards the probe) from modified parasternal short axis view of great vessels. Simultaneous 2D and Color Doppler Images. SVC, superior vena cava; RA, right atrium; RV, right ventricle; AO, aorta; LA, left atrium. C. SVC Pulse Wave Doppler from modified parasternal short axis view of great vessels. S, systolic forward flow; D, diastolic forward flow; Ar, atrial flow reversal.

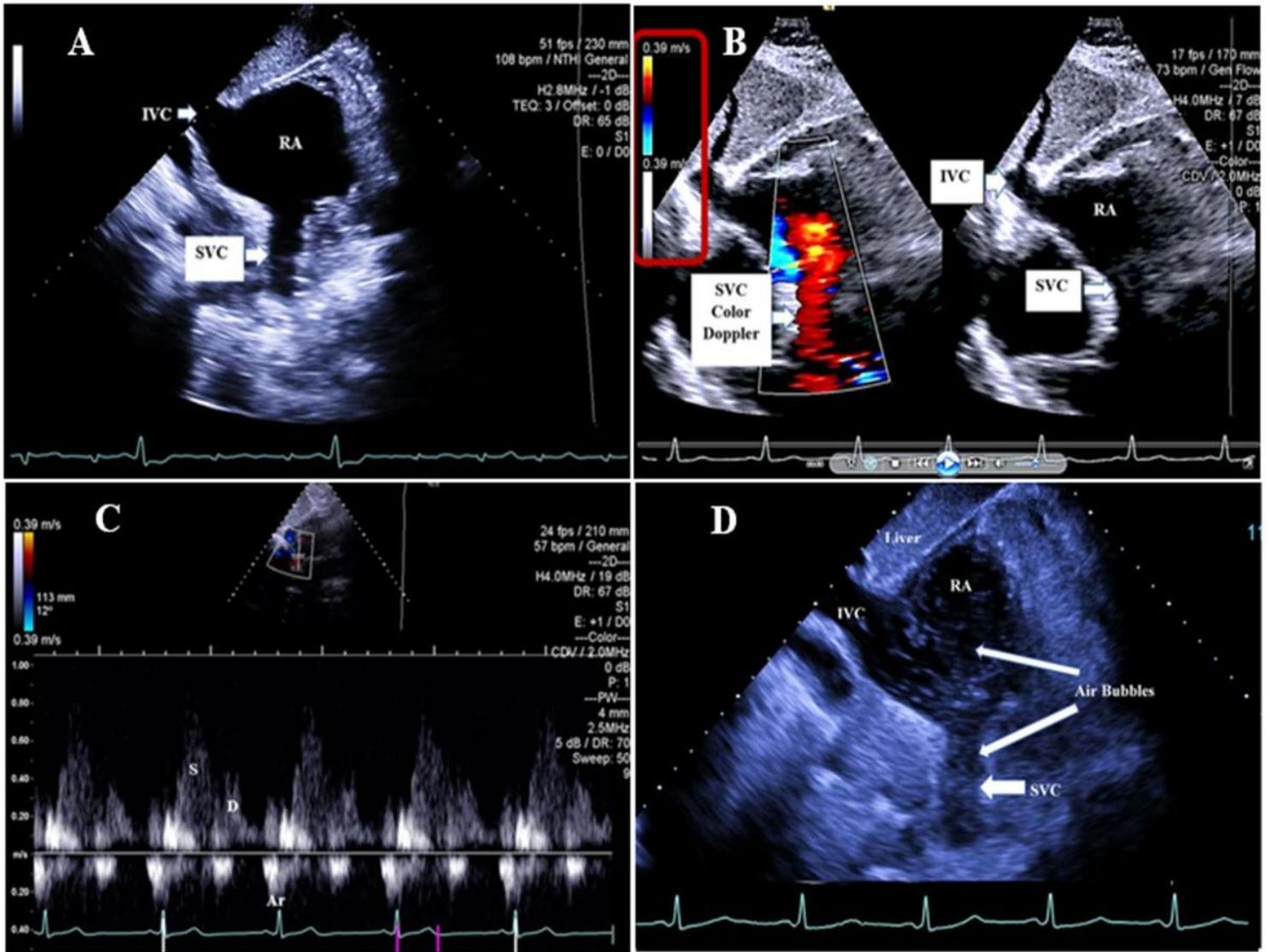


Figure 4

Modified Subcostal View A. Two dimensional modified subcostal view for demonstration of SVC. IVC, inferior vena cava; RA, right atrium; SVC, superior vena cava. B. SVC Color Doppler flow from modified subcostal view (red in color; flow towards the probe). Simultaneous 2D and Colour Doppler Images. IVC, inferior vena cava; RA, right atrium; SVC, superior vena cava. C. SVC Pulse Wave Doppler flow from modified subcostal view. S, systolic forward flow; D, diastolic forward flow; Ar, atrial flow reversal. D. Agitated saline injection through peripheral arm vein that filled SVC and partially filled RA to verify SVC course. IVC, inferior vena cava; RA, right atrium; SVC, superior vena cava.

Supplementary Files

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