Editorial

Integrated Multiorgan Ultrasound for Assessment of Congestion in Heart Failure

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Introduction

Heart Failure (HF) is a complex clinical syndrome in which fluid overload and congestion play a central role in symptoms, hospitalization, and mortality. Traditional methods for assessing congestion, such as clinical examination and natriuretic peptide levels, often lack sensitivity and provide limited information about the distribution and severity of fluid accumulation.[1]

Traditional bedside methods, such as auscultation for lung crepitations, chest radiography to detect overt pulmonary oedema, and palpation to grade pitting oedema, can help identify congestion. However, these approaches often only detect congestion after it is well established. In modern practice, echocardiography and focused ultrasound allow clinicians to identify congestion much earlier when applied systematically and evidence-based protocols. Echocardiography provides valuable information regarding Ejection Fraction (EF) and structural abnormalities that contribute to heart failure and fluid overload. Lung ultrasound, particularly the BLUE protocol with a B profile, can reveal early pulmonary congestion long before clinical signs become apparent, allowing timely intervention.[2,3]

Beyond the lungs, targeted ultrasound of the venous system using VExUS can detect elevated venous pressures even before pitting oedema develops. This broader ultrasound-based assessment gives physicians a more sensitive and comprehensive assessment of a patient's congestive status.[4]

Integrated multiorgan ultrasound has emerged as a powerful, non-invasive tool that allows clinicians to visualise congestion across several key organs, including the lungs, heart, venous system, and kidneys. By combining findings from several ultrasound windows, this approach offers a more accurate and dynamic assessment of haemodynamic status than single-organ imaging alone. Consequently, integrated ultrasound has the potential to guide personalised therapy, optimize decongestion strategies, and reduce the risk of hospital readmission in patients with HF.

Keywords

Ultrasonography; Heart Failure; Echocardiography

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Lung Ultrasound

In heart failure, lung ultrasound enables early detection of pulmonary congestion, which presents as interstitial oedema resulting from elevated left ventricular filling pressures. Since pulmonary congestion is both a major driver of hospitalisation and a central feature of heart failure pathophysiology, lung ultrasound serves as an essential tool for diagnosis, ongoing monitoring, and therapeutic decision-making in congestive heart failure.

Patients are typically scanned across eight regions, with two anterior and two lateral zones on each side of the chest. Posterior views are generally not included unless there is a specific need to assess for pleural effusion. Positioning the probe at the level of the pleural line reveals the pleural line as a bright horizontal structure that moves with respiration, a finding known as lung sliding. Interstitial pulmonary oedema appears as bright vertical B-lines that arise from the pleural line and move in harmony with it. An increasing number of B-lines not only indicates a reduction in air content within the lung tissue but also identifies those at increased risk of subsequent heart failure readmission.[1,5]

Cardiac Ultrasound

Transthoracic echocardiography is a cornerstone of non-invasive diagnosis and management in patients with clinical Heart Failure. Intracardiac filling pressures, chamber function, prognosis, and expected clinical outcomes can all be assessed using spectral Doppler.[6] In addition, echocardiography enables assessment of mitral inflow patterns, mitral annular motion, and prompt identification of valvular abnormalities.[7] It is an essential tool for classifying patients with HF into those with preserved ejection fraction (> 50%) and those with reduced ejection fraction (45-50 %), which is a critical distinction for guiding management.[8]

Systemic Venous Congestion Ultrasound

Systemic venous congestion is a defining feature of heart failure, yet it is frequently under-recognised despite its major contribution to fluid overload and its strong links with morbidity and mortality in critically ill patients. Evidence shows that excessive fluid administration can increase the risk of acute kidney injury.[9] As venous pressures rise, the arteriovenous pressure gradient narrows, which reduces organ perfusion. Persistent elevations in capillary hydrostatic pressure, combined with endothelial barrier dysfunction, lead to interstitial oedema. Increasing systemic venous pressure further lowers organ perfusion pressure, placing encapsulated organs such as the brain and kidneys at particular risk of damage.[10]

Traditional haemodynamic monitoring has largely centred on maintaining adequate cardiac output and mean arterial pressure through fluid administration and the use of vasopressors or inotropes.[11] Although the importance of preventing, identifying, and treating congestion is increasingly recognised, the true prevalence of systemic venous congestion in ICU patients remains uncertain. Central venous pressure measurement is invasive, susceptible to error even in experienced clinicians, and carries inherent procedural risks.[12] Other approaches to assessing fluid responsiveness, including interpretation of the Frank-Starling curve, evaluation of peripheral oedema, and monitoring weight changes, have significant limitations and do not reliably reflect systemic venous pressure.[13-15]

The absence of a clear definition or reliable method for assessing venous congestion has posed major challenges, but several ultrasound-based parameters have now been established. Assessment of the hepatic portal pulsatility index, renal venous flow patterns, and inferior vena cava diameter allows clinicians to quantify and grade the severity of systemic venous congestion. The Venous Excess Ultrasound (VExUS) grading system applies colour Doppler and pulsed wave Doppler to visualise venous anatomy and evaluate blood flow patterns, providing a structured approach to identifying significant venous congestion.[16]

Preparation

With the patient lying supine, the inferior vena cava (IVC) and the hepatic, portal, and renal veins can be assessed using either a phased array transducer (2- 7.5 MHz) or a curvilinear transducer (2-5 MHz). The hepatic and portal veins are typically evaluated using standard cardiac or abdominal ultrasound approaches. Optimal imaging of the renal vessels often requires lowering the Nyquist limit by 10 to 15 cm/s and increasing the colour gain to enhance visualisation.

VExUS Protocol:

IVC Assessment

The first step in the VExUS assessment is the estimation of right atrial pressure through evaluation of the inferior vena cava (IVC) in spontaneously breathing patients. Using a subxiphoid view, the probe is positioned to obtain a long-axis image of the IVC about 2 cm below its junction with the right atrium. An IVC diameter under 2 cm usually indicates the absence of significant venous congestion and corresponds to a score of 0. In contrast, an IVC diameter greater than 2 cm suggests elevated right atrial pressure and possible venous congestion, prompting further evaluation of the hepatic veins.[17]

However, this method has important limitations, particularly in mechanically ventilated patients, in whom the relationship between right atrial pressure and IVC dilation is weak.[18] Several additional factors can influence IVC measurements, including baseline dilation in endurance athletes, differences in body surface area that may require adjusted thresholds, and instances in which elevated abdominal pressure leads to a small IVC despite high right atrial pressure. Taniguchi *et al.,* reported an optimal IVC cutoff of 1.7 cm for Asian patients with smaller body surface areas.[19] To accurately distinguish the IVC from the abdominal aorta, clinicians should look for the aorta's bright hyperechoic wall and its characteristic pulsatile movement, which corresponds to the cardiac cycle.

Hepatic Vein Assessment

If a subxiphoid view is not attainable, a right lateral sonographic window can be used to evaluate all components of the VExUS exam, particularly the thin-walled hepatic veins draining into the IVC. The three hepatic veins (right, middle, and left) can be assessed for their Doppler flow patterns. Although any of these vessels may be used, the right and middle hepatic veins are usually the easiest to visualise. The left hepatic vein is often more difficult to assess because bowel or stomach gas may obscure the view. When the probe is positioned over a hepatic vein, colour Doppler typically displays a blue signal as blood flows away from the transducer. Pulsed-wave Doppler then reveals a waveform resembling right atrial pressure at the point where the hepatic vein enters the IVC. This waveform reflects the right heart's ability to accommodate venous return and contributes to the evaluation of venous congestion.

Hepatic vein Doppler waveforms normally show two antegrade waves: the systolic (S) wave and the diastolic (D) wave, both of which reflect changes in right atrial pressure. Under normal conditions, antegrade flow occurs twice: during ventricular systole as right atrial relaxation draws blood into the hepatic vein, and during diastole when the tricuspid valve opens. In healthy individuals, the S wave is larger than the D wave. As right atrial pressure increases, this pattern reverses, with the D wave becoming larger than the S wave, indicating mild hepatic vein abnormalities. In more advanced venous congestion, the S wave may become retrograde, signalling significant right heart dysfunction (Figure 1).

It is important to recognise that significant tricuspid regurgitation can limit the usefulness of hepatic vein Doppler assessment. Tricuspid regurgitation may cause S wave reversal even without marked venous congestion, which can lead to misinterpretation. Other conditions, such as liver cirrhosis, inferior vena cava stenosis, fatty infiltration, and hepatic lymphoma, can also blunt or distort hepatic vein waveforms, making accurate evaluation of venous congestion more difficult.[4]

Portal Vein Assessment

Placing the probe slightly upward along the right midaxillary line provides a clear view of the portal vein, which typically has a baseline velocity of about 20 cm/s. In this view, the main portal vein crosses over the IVC, while the hepatic vein drains directly into it. When colour Doppler is applied over the hyperechoic walls of the portal vein, red flow should appear, indicating blood moving toward the transducer.

In the absence of systemic venous congestion, both colour and pulsed-wave Doppler usually show minimal phasic variation or a largely monophasic waveform, as seen in Figure 2. When right atrial pressure rises, this pressure can be transmitted to the portal vein, producing portal vein pulsatility, which is a key marker of venous congestion. Pulsatility can be quantified using the Portal Vein Pulsatility Index: ((Vmax − Vmin) / Vmax) × 100, where Vmax and Vmin represent the maximum and minimum velocity during a cardiac cycle. Marked portal vein pulsatility indicates advanced right heart dysfunction and is associated with poor prognosis.

In lean individuals, some degree of portal vein pulsatility may occur even without raised right atrial pressure. As with hepatic vein Doppler, conditions such as cirrhosis or fatty liver can obscure or alter portal vein waveforms, potentially reducing the accuracy of congestion assessment in affected patients.

Renal Vein Assessment

The interlobar vessels are best assessed along the posterior axillary line to obtain an optimal view. The hilar veins and peripheral arcuate veins should be avoided, as they can give misleading velocity measurements that result in overestimation or underestimation. Intrarenal venous flow offers important information about the downstream impact of elevated right atrial pressure on the encapsulated kidneys. With colour Doppler, both arterial flow in red and venous flow in blue can be visualised within the intrarenal vessels in the same imaging plane. Because these vessels are small, careful adjustment of the colour and pulsed-wave Doppler scales, along with increased gain, is essential for producing clear and reliable images. Asking the patient to briefly hold their breath can further improve visualisation.

In healthy individuals, renal interlobular venous flow appears as a monophasic waveform below the baseline on Doppler, representing blood moving away from the transducer. The arterial waveform, seen above the baseline, helps identify the phases of the cardiac cycle. As right atrial pressure rises, renal venous flow can become pulsatile, showing distinct S and D waves. In more advanced venous congestion, the S wave may reverse. However, this reversal can be obscured by the arterial waveform above the baseline, making only monophasic D waves visible (Figure 3).

Patients with congestive HF are susceptible to complications such as congestive renal failure, which contributes to the development of cardiorenal syndrome. Tricuspid regurgitation can further worsen renal congestion, resulting in a poorer long-term prognosis.[4] Notably, Martin *et al*., evaluated a modified version of the VExUS score that closely resembled the original but omitted the more technically challenging renal component. Their study suggested that this simplified approach may be more efficient in identifying elevated right atrial pressure.[20]

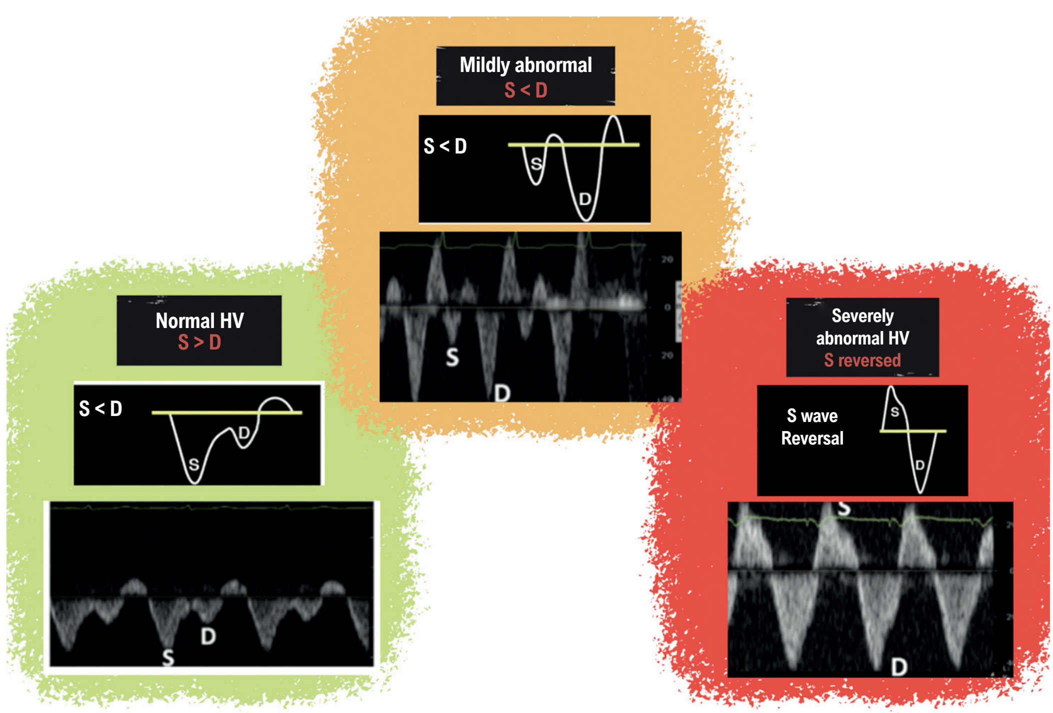

Figure 1 – *Interpretation of Hepatic Vein Doppler. Created on Canva.*

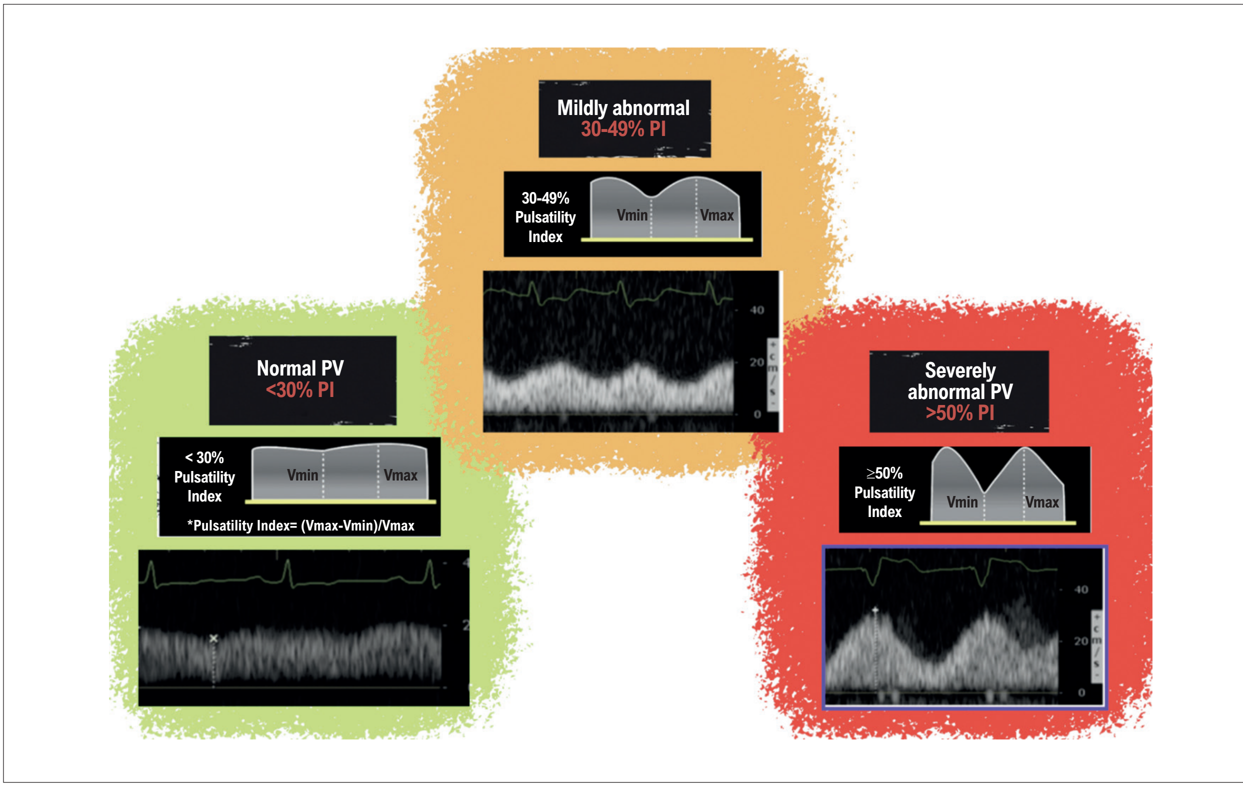

Figure 2 – *Interpretation of Portal Vein Doppler. Created on Canva.*

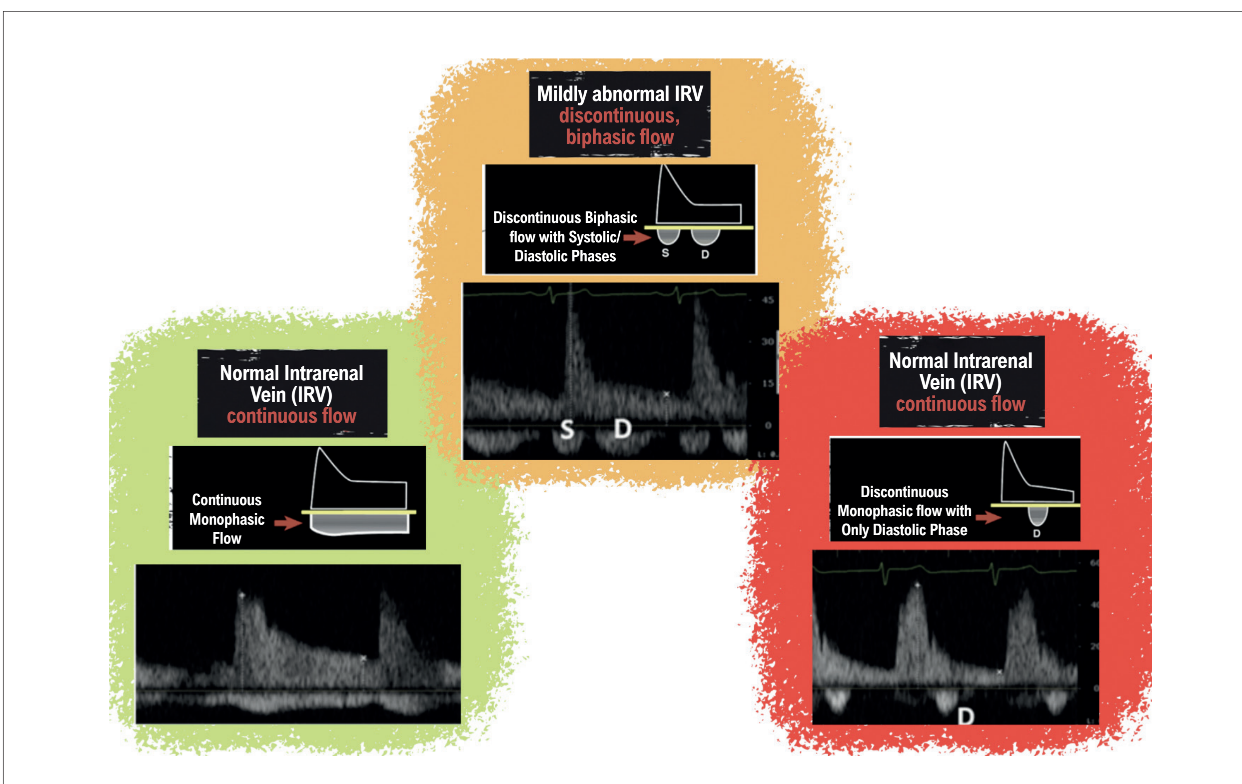

Figure 3 – *Interpretation of Intrarenal Vein Doppler. Created on Canva.*

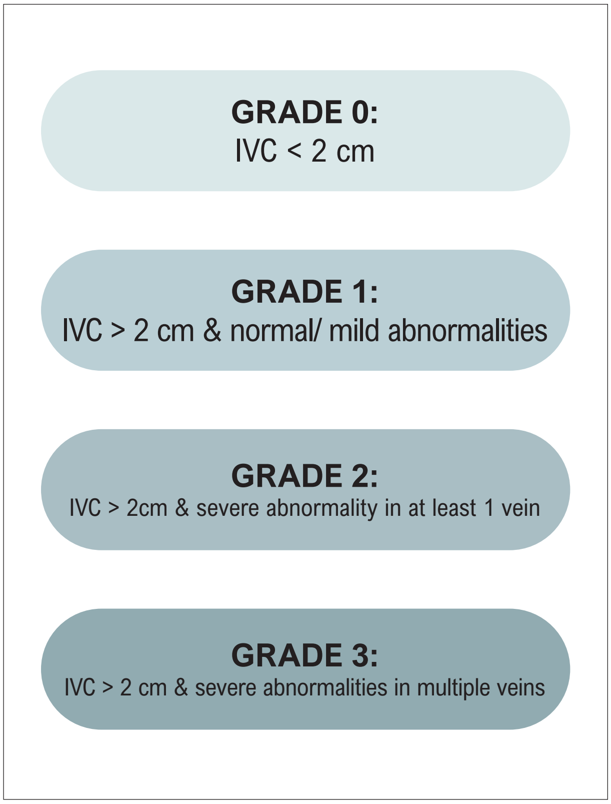

Figure 4 – *VExUS Grading scores 0-3.*

VExUS Score

The Venous Excess Ultrasound Score is a structured grading system used to determine the severity of systemic venous congestion through Doppler assessment of three key veins: the hepatic, portal, and intrarenal veins. Each vessel is evaluated for characteristic flow abnormalities that indicate rising levels of congestion, and the overall score ranges from Grade 0 to Grade 3 (Figure 4).

Grade 0 reflects no significant congestion, with normal Doppler patterns in all veins and an IVC diameter under 2 cm. Grade 1 represents mild congestion, defined by a dilated IVC and abnormal flow limited to the hepatic vein. Grade 2 indicates moderate congestion, with an IVC greater than 2 cm and abnormal waveforms in both the hepatic and portal veins. Grade 3 signifies severe congestion, characterised by a plethoric IVC and abnormal flow across the hepatic, portal, and intrarenal veins, consistent with marked right heart dysfunction.[4] A higher VExUS score correlates with more advanced congestion and is associated with poorer clinical outcomes.

Conclusion

VExUS is a valuable tool for the assessment of systemic venous congestion and should be considered within the context of a comprehensive haemodynamic evaluation. As a bedside technique, it offers a practical way to identify, monitor, and assess critically ill patients with venous

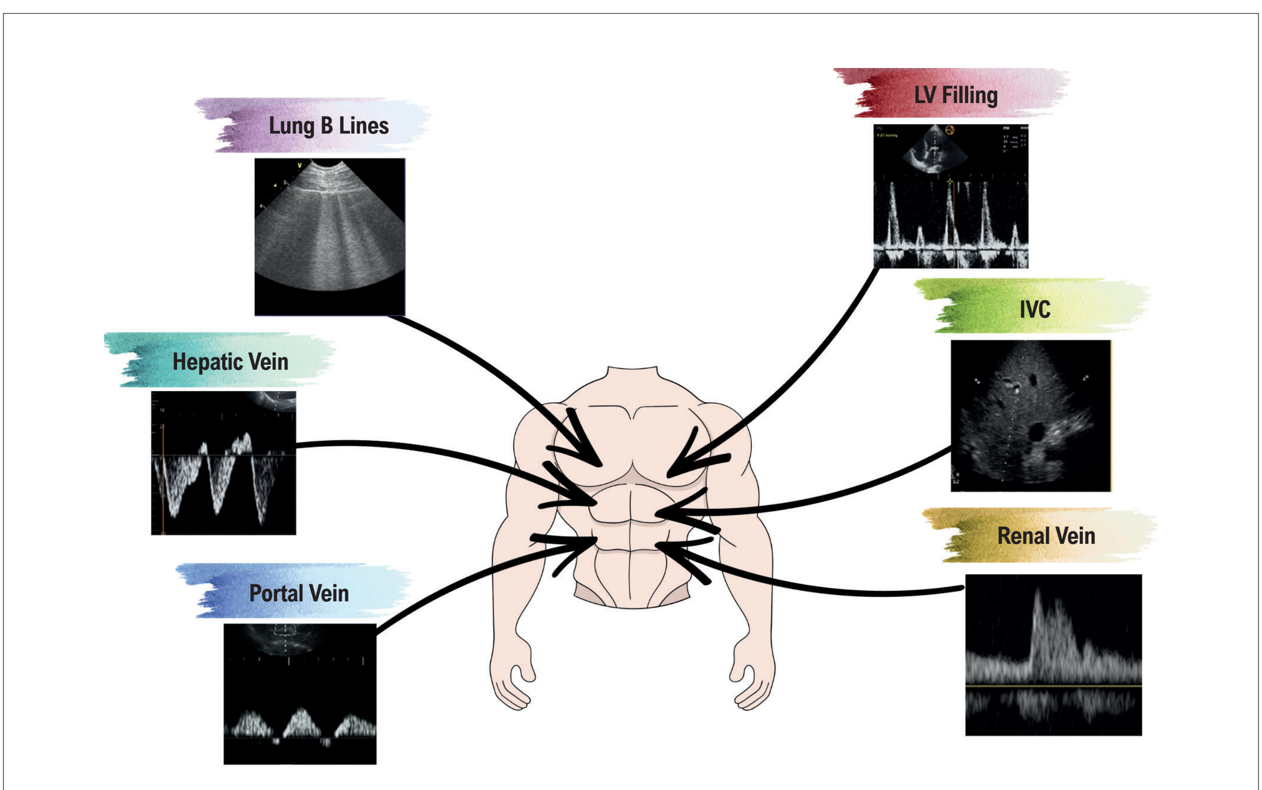

Figure 5 – *Integrated multiorgan ultrasound for the assessment of congestion in heart failure.*

congestion and to evaluate their response to treatment. Despite its value, VExUS has limitations. It cannot distinguish between right ventricular pressure overload and volume overload, so it should not be used as the sole guide for clinical decision-making. In addition, several conditions can alter VExUS waveforms, which may complicate interpretation. For a complete evaluation of congestion in heart failure, VExUS should be integrated with cardiac ultrasound to assess intracardiac pressures and ventricular function, as well as lung ultrasound to detect early pulmonary oedema (Figure 5). For these reasons, a multiparametric approach is necessary for accurate assessment, diagnosis, and management.

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