

My Approach to Evaluate Systemic Venous Congestion: VExUS Protocol

Angelo Antunes Salgado,^{1,2,3} Marcos Paulo Lacerda Bernardo,^{1,4} Fernando Melo Netto^{5,6}

Universidade do Estado do Rio de Janeiro,¹ Rio de Janeiro, RJ – Brazil

Instituto Nacional de Cardiologia,² Rio de Janeiro, RJ – Brazil

Hospital Pro-Cardiaco,³ Rio de Janeiro, RJ – Brazil

Centro de Diagnóstico Avançado (CDA),⁴ Teresópolis, RJ – Brazil

Hospital Sure-Libanês Brasília,⁵ Brasília, DF – Brazil

Hospital DF Star,⁶ Brasília, DF – Brazil

Abstract

The use of non-invasive tools for analyzing systemic venous congestion in critically ill patients in the intensive care unit has been gaining increasing popularity for diagnosis, estimating the severity of congestion, and providing prognostic estimates. Patients with systemic congestion are more likely to develop renal dysfunction compared to those without congestion. In this review, the authors demonstrate how to perform systemic congestion analysis, its potential limitations, and its practical and objective applicability.

Introduction

The systemic venous congestion evaluation in outpatients and critical care patients is subject to several limitations. Clinical analysis of volume overload, the evaluation of the diameter and phasicity of the inferior vena cava (IVC), as well as measurement of central venous pressure by invasive methods, are not always dependable in representing the patient's real volume status. This pressure can be distorted by different factors, such as high pulmonary artery pressure, right ventricular dysfunction, valve dysfunction, inadequate patient position, use of invasive ventilation or non-invasive positive airway pressure (CPAP), and partial obstruction of the catheter, among others. As a result, the development of more reliable methods, preferably non-invasive, fast, low-cost, practical and which better inform patients of their real volume status, is extremely essential for clinical management and prognostic definition.

In 2020, the Canadian group led by Dr. William Beaubien-Souligny and Dr. Philippe Rola¹ created a systemic venous congestion grading system for the non-invasive assessment of volemia, using the evaluation of the diameter of the IVC

and the flows of the suprahepatic vein, portal vein and renal interlobar vein. Through a system of flow characteristics, it could be shown whether the patient had no congestion (grade zero), mild congestion (grade 1), moderate congestion (grade 2) or severe congestion (grade 3), with an important impact on clinical treatment and prognosis. This non-invasive model for analyzing systemic congestion was named VExUS (Venous Excess Ultrasound).

Physiology of Systemic Congestion

Critically ill patients who are developing organ dysfunction may be experiencing low flow to the organ (systemic arterial hypotension model) or venous congestion (right heart dysfunction model). Understanding what causes the organ to fail is extremely important, as treatment is differentiated. Patients with renal failure and elevated nitrogenous wastes due to hypotension will benefit from volume infusion and vasopressors. In contrast, patients with renal congestion (and, therefore, edema in the organ, causing its dysfunction) will benefit from the use of diuretics.

In patients with systemic volume overload, this process of dysfunction occurs not only at the renal level but throughout the body. It can also cause congestive hepatopathy and congestive enteropathy, among other things, worsening the patient's prognosis if there is no rapid resolution of the condition.^{2,3}

VExUS can be used as an important tool for grading systemic congestion secondary to increased central venous pressure.⁴

VExUS Technical Considerations

- Apnea: Respiratory apnea should be performed whenever possible throughout the VExUS protocol in order to obtain perfect flows. This detail is particularly important when obtaining renal interlobar vein flows due to their small diameter and accentuated "leakage" of the image during the respiratory cycle. Obtaining apnea is not always possible in unstable patients.
- Electrocardiogram (ECG): A clear and clean electrocardiographic signal is essential for differentiating the waves of the suprahepatic vein, particularly in defining the S and D waves.
- Use of transducers: the sectorial transducer is used to obtain the image of the IVC. However, both the

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Mailing Address: Angelo Antunes Salgado •

Universidade do Estado do Rio de Janeiro. Avenida 28 de Setembro, 77.

Postal Code: 20550-900. Rio de Janeiro, RJ – Brazil

E-mail: angeloasalgado@gmail.com

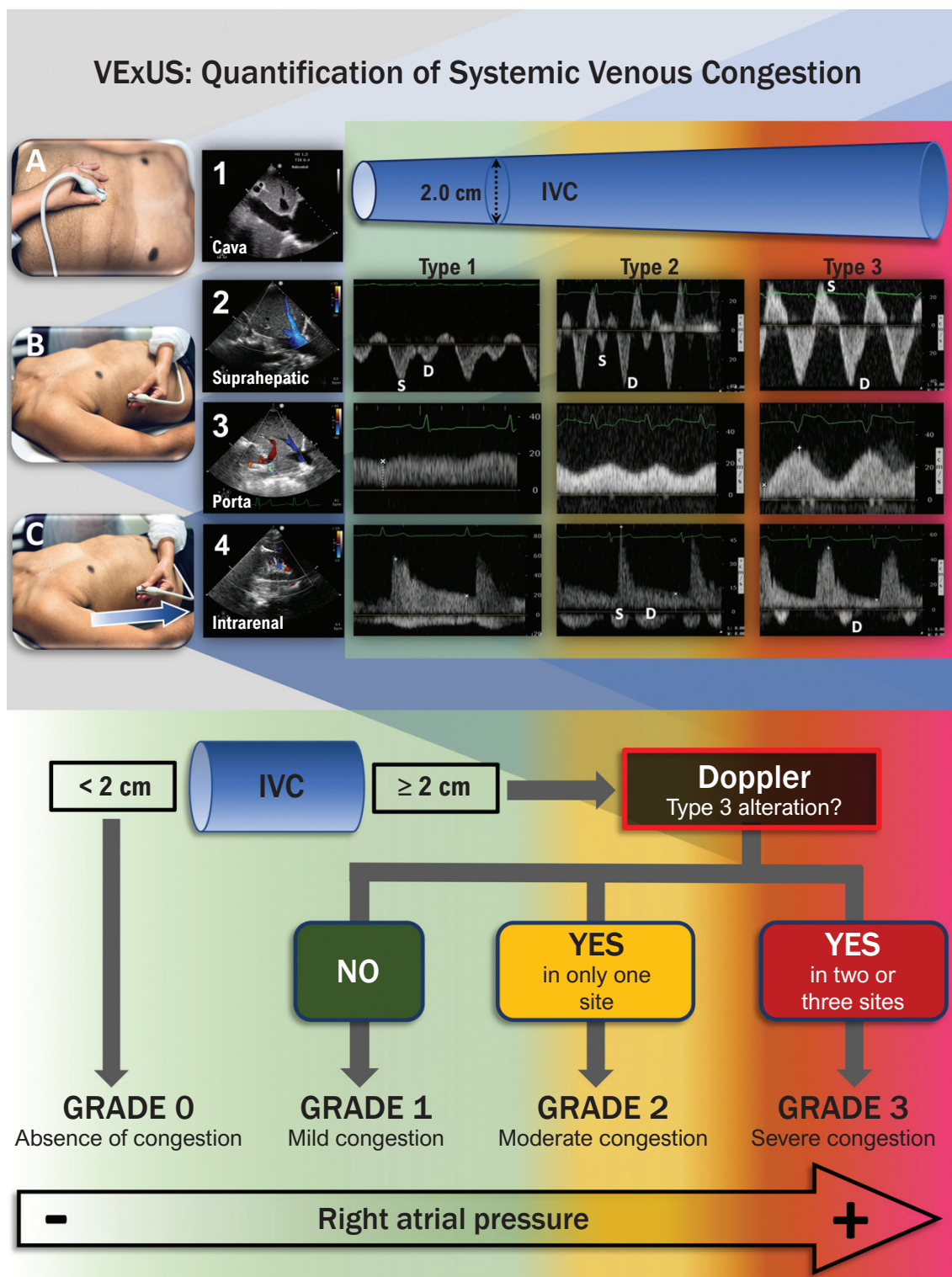
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Central Illustration: My Approach to Evaluate Systemic Venous Congestion: VExUS Protocol



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IVC: inferior vena cava.

sectorial and convex transducers can be used to analyze visceral flows.

- Flow velocities: As these are veins with low-velocity flow, it is important to reduce the filter and adjust the color scale to identify the vessels better or to select presets that already use a lower velocity scale (Example: renal arteries preset).

VExUS Components

In order to carry out the VExUS, a flowchart must be followed, which will allow the degree of venous congestion to be estimated from patients with no congestion (grade 0) to severe congestion (grade 3). The first factor to evaluate is the IVC. If it has a diameter of 2 cm or more, there may be some degree of congestion and the suprahepatic, portal and renal interlobar veins should be evaluated. In this regard, five steps are followed:

Step 1: Evaluation of the IVC

During the VExUS evaluation, the initial analysis of the IVC becomes the primary factor in defining between patients who do not have congestion (grade zero) and those in whom congestion may be present (congestion grades 1, 2 or 3).

IVC analysis will preferably be carried out subcostally, with the index pointed at 12 o'clock, with a longitudinal view of the IVC flowing into the right atrium. For patients unable to use the subcostal window, IVC analysis can be performed through the transhepatic window, especially in patients with drains in the subcostal region, with the index at 12 o'clock, through the middle axillary line (Figure 1).

With the patient in expiratory apnea, the IVC is measured 2 cm before it flows into the right atrium. The size of the IVC will serve as a reference for whether or not to proceed with the VExUS flowchart. If the size of the IVC is less than 2 cm, it is considered that there is no systemic congestion, and the VExUS is graded 0 (no congestion). If the size is equal to or greater than 2 cm, there may be evidence of congestion, and the analysis of the other components (suprahepatic vein, portal vein and renal interlobar vein) should be continued.

Pitfalls: one of the problems with IVC analysis is that it is not standardized for the patient's body surface. Short individuals are expected to have IVCs with smaller diameters than taller individuals, which limits the adoption of a single size for analysis. In addition, athletes and young people may have IVCs with increased diameters, without there necessarily being systemic hypervolemia. The isolated evaluation of the IVC for the diagnosis of volume status is subject to different problems since patients on ventilation prostheses can have increased IVC diameters without necessarily having significant congestion.

Step 2: Evaluation of the Suprahepatic Vein

The suprahepatic vein is analyzed using pulsed Doppler and can be performed subcostally or transhepatically (Figure 1). The speed of the color Doppler should be readjusted to 30-40 cm/s to visualize better the flow of the vessel, which is generally of low velocity, preferably selecting the most vertical vein for better analysis. It is extremely important to use the

ECG to correctly identify the phases of the cardiac cycle and the corresponding venous waves.

In patients in sinus rhythm, the suprahepatic vein shows four classic curves on pulsed Doppler:⁵ **S wave**, present immediately after the R wave on the ECG, with a negative and dominant pattern, which occurs due to right atrial relaxation and pulling of the tricuspid annulus towards the cardiac apex during ventricular systole; **V wave**, which may be absent, generally has a positive pattern and occurs when the tricuspid annulus returns to its initial diastolic position; **D wave**, which is associated with the T wave of the ECG and has a negative pattern, being less wide than the S wave, occurs due to the opening of the tricuspid valve and passive inflow of blood from the right atrium to the right ventricle, and **A wave**, associated with the P wave of the ECG, with a positive pattern, occurs due to atrial contractility and retrograde flow of blood to the suprahepatic vein (Table 1, Central Illustration).

Pitfalls: The waves of the suprahepatic veins can show alterations during various pathological states. The A wave can be absent in patients with arrhythmias, especially during atrial fibrillation or flutter. However, this does not hinder the analysis of the VExUS, since the S and D waves are little affected. S waves may have reduced or even inverted amplitudes (positive character) in patients with severe tricuspid regurgitation since the S wave occurs physiologically during ventricular systole. The presence of tricuspid reflux causes systemic congestion, which should not be confused with volume overload. In the presence of severe tricuspid regurgitation, the grading of VExUS (absolute value) will be impaired. Nevertheless, the evaluation of portal vein and renal interlobar vein flows will be less compromised. It can be used to understand the degree of systemic congestion, especially during patient follow-up. In addition, in cases of severe functional tricuspid regurgitation, there is an improvement in the evolution of VExUS and tricuspid regurgitation itself as congestion decreases.

Step 3: Evaluation of the Portal Vein

Pulsed Doppler analysis of the portal vein can be performed with a sectorial or convex transducer. The portal vein is best visualized through the transhepatic window, with the index at 12 o'clock, but it can also be seen subcostally (Figure 1). As this is a vessel with a low-velocity flow, the color Doppler speed must be adjusted to 20-30 cm/s.

The portal vein, unlike the suprahepatic vein, has thicker walls and an upward flow (reddish on the color scale) with a continuous or slightly pulsating pattern since it is isolated from the systemic circulation by the hepatic sinusoids.

The suprahepatic veins, on the other hand, have no visible walls and a bluish flow on color Doppler, heading towards the IVC.

With the gradual increase in systemic venous pressure due to the congestive process, dilation of the sinusoidal vessels occurs, transmitting systemic venous pulsatility to the portal system. The greater the systemic congestion, the greater the sinusoidal dilation and, therefore, the pulsatility transmitted (Table 2, Central Illustration).

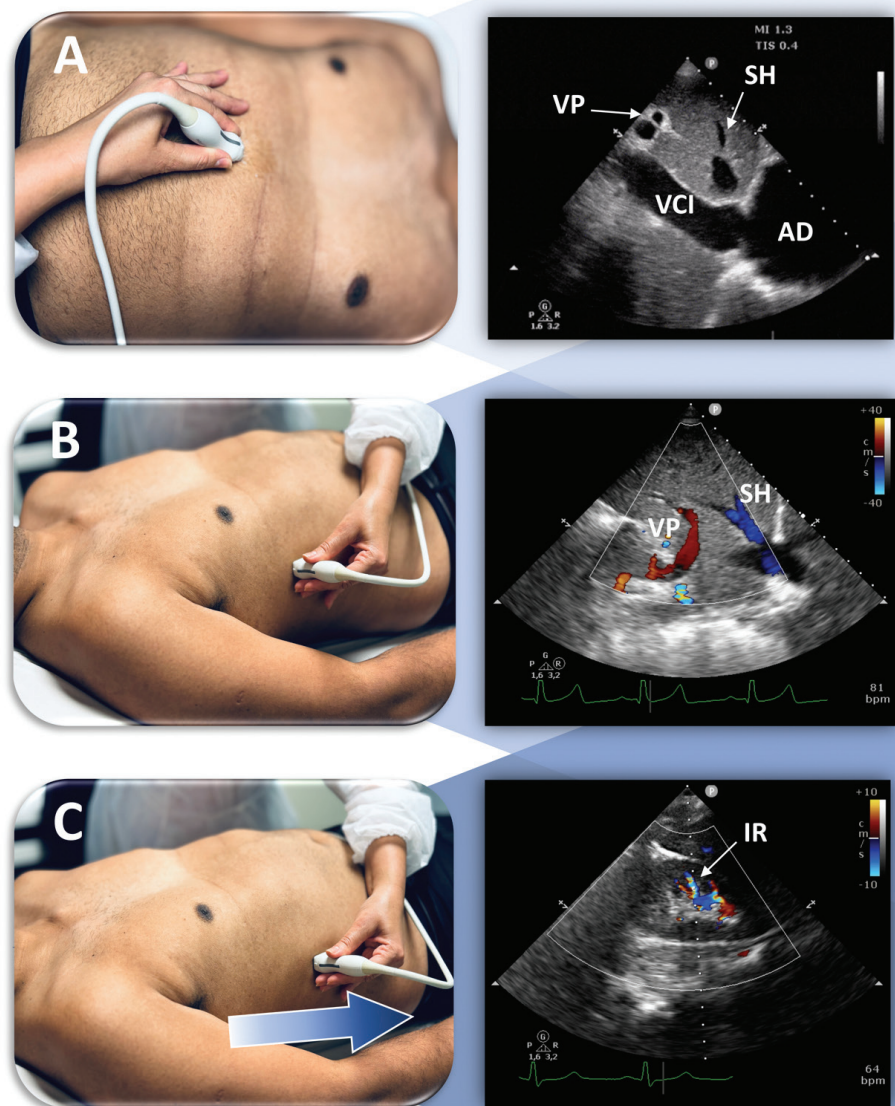


Figure 1 – Image acquisition points for evaluating the VExUS. A – Subcostal projection, with the index at 12 o'clock, pointed at the patient's head: longitudinal visualization of the IVC draining into the RA. Sometimes, in this same projection, it is possible to visualize the suprahepatic vein (which drains into the IVC) and the portal vein (hyperrefrangent walls). B – Middle axillary line projection, with the index at 12 o'clock, pointed towards the patient's head: visualization of the suprahepatic vein (blue flow on color Doppler, hepatofugal, towards the IVC) and the portal vein (red flow on color Doppler, hepatopetal, towards the liver). C – Middle axillary line projection (slightly lower than projection B), with index at 12 o'clock, pointed towards the patient's head: visualization of the renal interlobar vein in the cortical region (flow obtained by reducing the color Doppler scale). PV: portal vein; SH: suprahepatic vein; IVC: inferior vena cava; RA: right atrium; RI: renal interlobar vein.

The cyclical oscillation of the portal vein flow (percentage oscillation of the portal vein flow, considering its maximum and minimum value) will give the pulsatility fraction, which is calculated by the formula: $\text{peak speed} - \text{minimum speed} / \text{peak speed} \times 100$.

Pitfalls: In patients with liver disease, especially cirrhotic ones, due to the greater resistance of the hepatic sinusoids, even in situations of significant congestion, there will be no transmission

of pulsatility, limiting the use of VExUS in this population. Young, healthy patients without any comorbidities can have portal vein pulsatility of more than 50%, without meaning congestion.⁶

Step 4: Evaluation of the Renal Interlobar Vein

Because it is encapsulated, the kidney does not transmit the pulsatility of the central veins, resulting in a generally

continuous venous flow. However, as systemic congestion progresses, the kidney becomes edematous, and the flow pattern becomes biphasic or, in more severe cases, monophasic (Table 3, Central Illustration).

When grading the VExUS, analysis of the renal interlobar vein is extremely important, as it is the vein most closely correlated with progression to renal failure in patients with marked systemic congestion, compared to alterations observed in the suprahepatic vein or portal vein.^{7,8}

Due to the proximity of the artery/vein, the flow of the parenchymal arteries is visualized above the baseline, and the venous flow is visualized below it.

To analyze the interlobar vein, it is necessary to record the flow in the renal cortical area, reducing the color Doppler speed scale to 20 cm/s in order to better visualize the flow (Figure 1).

Pitfalls: In nephropathic patients, especially those with end-stage renal disease and already on dialysis, interlobar vein flows may be altered, limiting the use of this parameter in the VExUS analysis due to the pathological alteration of the renal parenchyma.

Another frequent cause of error is confusion between the renal vein, located in the region of the renal hilum, and the interlobar veins, located in the cortical region, since the renal vein has the characteristics of a central vein and, therefore, has a physiologically pulsatile flow.

Step 5: Integrate the Data and Grade VExUS

Once the flow types have been obtained, the data is integrated, and the degree of congestion is established (Central Illustration). Congestion is then graded as:

Grade 0 – No congestion: IVC with a diameter of less than 2 cm.

Grade 1 – Mild congestion: IVC with a diameter equal to or greater than 2 cm and without type 3 alterations, with the possibility of type 1 or 2 alterations.

Grade 2 – Moderate congestion: IVC with a diameter equal to or greater than 2 cm and with a type 3 alteration.

Grade 3 – Severe congestion: IVC with a diameter equal to or greater than 2 cm and with at least two type 3 alterations.

Using VExUS in Clinical Practice

Systemic congestion: VExUS can be used to diagnose, quantify and help treat patients with systemic congestion. By grading how congested an individual is, it can be established whether there is a need to suspend, reduce or intensify the use of diuretics.⁹ Patients with heart failure, with elevated creatinine levels due to renal failure as a result of systemic congestion, will benefit from more aggressive doses of diuretics, with a reduction in renal edema and subsequent improvement in nephron function.¹⁰ Therefore, in this patient model, with VExUS, we can define the cause of the nephropathy: whether it is due to low output due to relative

Table 1 – Flow Patterns in the Suprahepatic Vein

Normal pattern – Type 1	the amplitude of the S wave is greater than that of the D wave.
Slightly abnormal pattern – Type 2	the amplitude of the S wave is smaller than that of the D wave since atrial emptying will occur predominantly in diastole.
Severely abnormal pattern – Type 3	inversion of the S wave, which acquires a positive pattern, while the D wave maintains its negative pattern.

Table 2 – Flow Patterns in the Portal Vein

Normal pattern – Type 1	the hepatic sinusoids are preserved, with a flow oscillation of less than 30%.
Slightly abnormal pattern – Type 2	there is dilation of the sinusoidal vessels with a flow oscillation of between 31 and 50%.
Severely abnormal pattern – Type 3	the dilation of the sinusoidal vessels is extremely marked, with significant transmission of the systemic venous pulsation to the portal vein, with an oscillation higher than 50%.

Table 3 – Flow Patterns in the Renal Interlobar Vein

Normal pattern – Type 1	continuous venous flow throughout the cardiac cycle.
Slightly abnormal pattern – Type 2	bi-phasicity of venous flow, with 1 systolic peak and 1 diastolic peak.
Severely abnormal pattern – Type 3	monophasicity of interlobar venous flow, with only 1 peak, usually diastolic.

hypotension (the need to use vasopressors and inotropes) or whether it is due to systemic congestion (the need to use of diuretics).

Fluid-tolerance: another use for VExUS is to evaluate volume status and systemic venous congestion to help with volume resuscitation therapies. Too much volume administration can cause venous hypertension and organ dysfunction due to edema. Fluid responsiveness consists of an increase in stroke volume or cardiac output of at least 10% after fluid administration. Patients who have a low VExUS score (0 or 1) are usually fluid-responsive, but this is not always the case, and sometimes even patients with a low score can be intolerant of fluids. For practical purposes, during volume replacement, left ventricular outflow tract (LVOT) flow can be evaluated to estimate stroke volume, and VExUS can be performed to evaluate fluid tolerance. Regardless of the increase in cardiac output with fluid administration, VExUS helps us to determine how much this additional volume may be causing systemic congestion.¹¹ Future proposals are being put forward to define whether patients with VT above 18 cm would fall into the “hot” pattern and below 18 cm into the “cold” pattern, VExUS 0 or 1 into the “dry”

pattern, and VExUS 2 or 3 into the “wet” pattern of heart failure (Figure 2).¹²

Conclusion

VExUS is a recent tool that can help evaluate systemic venous congestion and tolerance to fluid therapy. As it is an easy-to-perform test, it can be incorporated into the daily use of POCUS, with an important diagnostic, prognostic and therapeutic impact.

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Writing of the manuscript: Salgado AA; critical revision of the manuscript for intellectual content: Salgado AA, Bernardo MPL, Netto FM; figure production: Netto FM.

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Ethics Approval and Consent to Participate

This article does not contain any studies with human participants or animals performed by any of the authors.

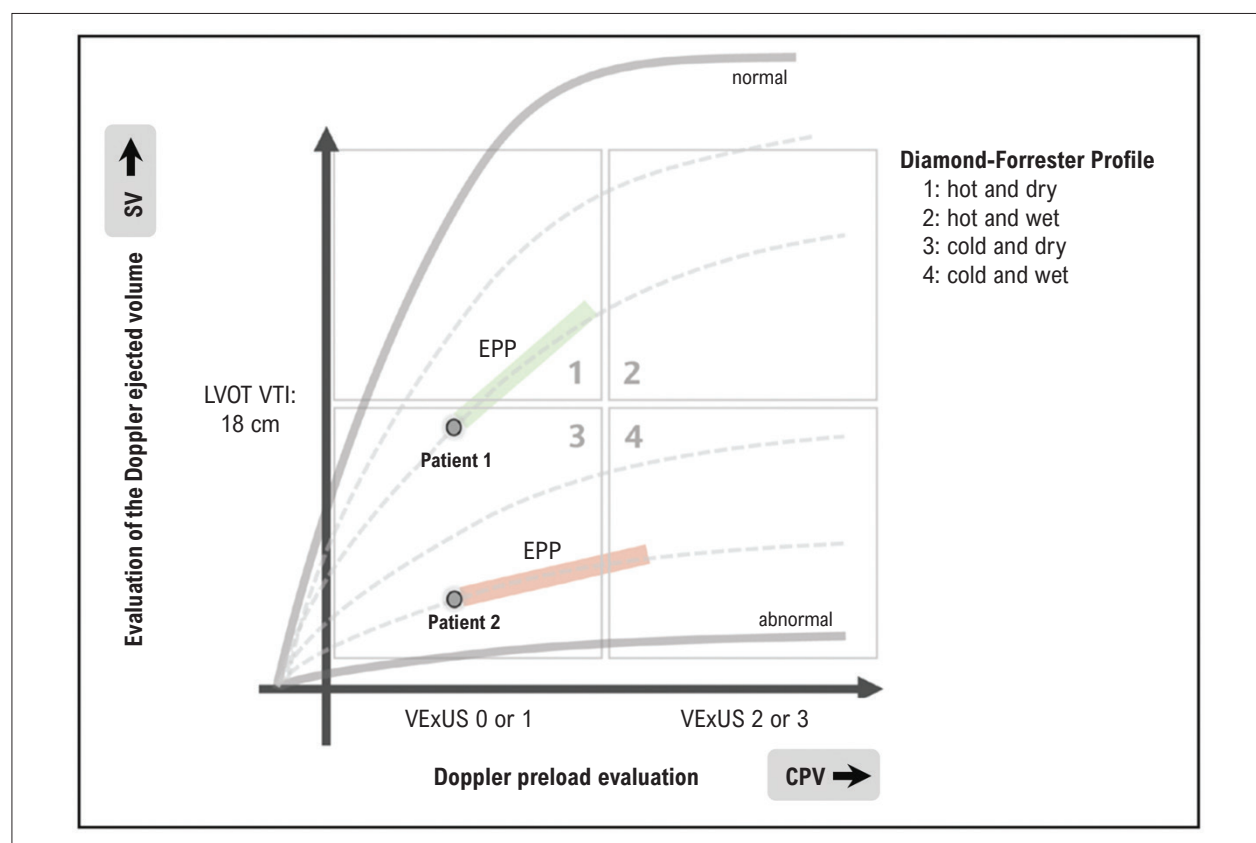


Figure 2 – Proposed combination of Frank-Starling curves with Diamond-Forrester profiles. In place of preload, the VExUS score is on the X-axis. In place of stroke volume, the LVOT VTI is on the Y-axis. Two patients with profile 3 are retreated. For patient 1, the increase in preload (after a passive leg-raising maneuver) moves the patient up the Frank-Starling curve. For patient 2, the increase in preload shows little change in LVOT and a large increase in venous congestion markers (VExUS). SV: stroke volume (ejected volume); LVOT VTI: flow in the left ventricular outflow tract's integral (velocity x time); CVP: central venous pressure; VExUS: venous excess ultrasound; EPP: passive leg elevation. Adapted from Kenny et al.¹²

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