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REVIEW
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Venous congestion in surgical patients assessed by the Venous Excess Ultrasound Grading System (VExUS): A comprehensive review

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ABSTRACT:

Venous congestion from fluid overload is an underrecognized contributor to postoperative organ dysfunction. The Venous Excess Ultrasound Grading System (VExUS) is a non-invasive Doppler-based tool for assessing systemic venous congestion at the bedside. This review outlines the physiological basis, step-by-step protocol, and current clinical evidence for VExUS use in surgical patients. While it shows potential for guiding fluid management, results across studies are mixed, and several clinical limitations affect interpretation. VExUS is feasible and promising, but further multicenter research is needed to establish its clinical value and integration into perioperative care.

Keywords: Ultrasonography; Doppler; Hemodynamics; Acute kidney injury; Postoperative complications

INTRODUCTION

Optimal volume management remains central to perioperative care. While hypovolemia may lead to inadequate tissue perfusion, fluid overload can result in systemic venous congestion that impairs organ function, particularly of the kidneys, liver, and lungs [1]. Conventional assessments of volume status such as physical examination findings, central venous pressure measurements, and other static parameters often lack reliability. Although dynamic indicators such as pulse pressure variation, stroke volume variation, and passive leg raising are more informative regarding preload responsiveness, these methods are relatively invasive, and the choice of assessment varies depending on individual patient conditions and the availability of monitoring equipment [2]. The Venous Excess Ultrasound grading System (VExUS) was developed to address this gap, offering a systematic approach to bedside Doppler assessment of key venous structures to evaluate congestion.

METHODS

We conducted a comprehensive search for relevant literature using databases including PubMed, Embase, and Google Scholar. The search focused on studies published between 2018 and 2025 to capture the development and clinical application of the VExUS system. Keywords included "VExUS," "Venous Excess Ultrasound," "venous congestion," and "perioperative care". We included prospective and retrospective observational studies, case reports, and previous reviews involving surgical and critically ill populations.

CLINICAL EVIDENCE SUPPORTING VEXUS IN SURGICAL PATIENTS

Several studies have explored the role of VExUS in the perioperative and critical care settings, particularly in surgical populations.

Beaubien-Souligny et al. (2020) demonstrated in a prospective study involving postoperative cardiac surgical patients that a VExUS grade of 3 was significantly associated with the development of acute kidney injury (hazard ratio 3.69, 95% CI 1.65–8.24, p = 0.001). This study validated the clinical use of the VExUS grading system [3].

In contrast, Andrei et al. (2021) evaluated 145 intensive care unit patients, including surgical cases, and found no significant association between VExUS grading and the occurrence of acute kidney injury or 28-day mortality. Nonetheless, they did observe that approximately 20 percent of patients had moderate to severe venous congestion [4].

Magin et al. (2022) conducted a prospective pilot study to evaluate the feasibility of using VExUS for perioperative fluid assessment in noncardiac surgeries. VExUS scans were successful in 91% of cases, with postoperative venous congestion rising to 44% in the PACU and 49% at 24 hours. No significant correlation was found between VExUS grade and 30-day complications or acute kidney injury [5].

In a separate case report, Singh and Carvalho (2021) described the successful use of VExUS to guide perioperative fluid management in a patient with dilated cardiomyopathy. The application of VExUS in this case facilitated individualized decongestion therapy and improved surgical safety [6].

More recently, Gupta et al. (2023) conducted a systematic review summarizing available evidence from perioperative and critical care studies. The review found that moderate to severe venous congestion is frequently observed in surgical patients and that higher VExUS scores have shown a clinical association with an increased risk of AKI in several observational studies, though causality remains to be established. Additionally, VExUS grading correlated strongly with central venous pressure (CVP) and intra-renal venous Doppler signals, suggesting its reliability as a surrogate marker of systemic congestion [7].

To streamline clinical use, Martin et al. (2023) evaluated a simplified or "modified" VExUS protocol, which excluded renal Doppler. This modified version demonstrated good diagnostic performance (AUC 0.85–0.87) for detecting right atrial pressure ≥12 mmHg in patients undergoing right heart catheterization. The findings support the utility of a simplified VExUS approach for rapid bedside assessments, particularly in time-sensitive perioperative settings [8].

KEY MESSAGES:

- VExUS is a feasible, non-invasive bedside tool for assessing systemic venous congestion in surgical patients, offering more reliable insights than traditional static volume markers.
- Higher VExUS grades are associated with increased risk of postoperative complications, particularly acute kidney injury (AKI), although evidence remains mixed across study populations.
- Integration of VExUS into perioperative fluid management may improve individualized volume strategies, but further multicenter studies are needed to validate clinical thresholds and standardize protocols.

In the context of goal-directed hemodynamic therapy (GDHT), a recent study from 2024 incorporated VExUS into an Enhanced Recovery After Surgery (ERAS) protocol for colorectal surgery. This study reported no postoperative venous congestion when VExUS-guided fluid management was used intraoperatively, demonstrating its potential role in optimizing perioperative fluid strategies and reducing complications related to fluid overload [9].

Finally, a mini-review by Chin et al. (2025) emphasized the broadening clinical role of VExUS in perioperative and critical care. The review supports its use in individualized volume management, especially in patients with limited fluid tolerance, and advocates for integration into multimodal fluid assessment protocols [10].

Collectively, these findings suggest that while VExUS is highly feasible in postoperative care and may be associated with clinical outcomes, the conflicting results observed across clinical studies regarding the predictive value of VExUS for postoperative complications may be largely attributed to the heterogeneity of the surgical populations studied. For instance, while severe venous congestion was strongly associated with AKI in patients following cardiac surgery, similar associations were not consistently found in general ICU cohorts or non-cardiac surgical patients. This discrepancy may stem from differences in baseline patient risks, such as pre-existing right ventricular dysfunction, or variations in the physiological stress associated with different surgical types. Additionally, the timing of VExUS assessments ranging from the immediate postoperative period in the PACU to 24 hours postoperatively likely contributes to the variability in reported congestion prevalence and its impact on clinical outcomes.

PHYSIOLOGICAL BASIS OF VEXUS

Venous congestion arises from elevated right atrial pressure that is transmitted retrogradely through the systemic venous circulation. This leads to increased hydrostatic pressure in organ-specific venous territories and subsequent impairment of microcirculatory flow. The hepatic veins are directly affected by changes in right atrial pressure. The portal vein is influenced by hepatic sinusoidal congestion [11].

The intrarenal veins are particularly sensitive to increases in venous pressure and are often associated with impaired renal perfusion. Together, these venous systems provide a comprehensive physiological framework for the VExUS assessment.

LIMITATIONS OF THE VEXUS ASSESSMENT

Despite its promise as a non-invasive tool for assessing venous congestion, the Venous Excess Ultrasound Grading System (VExUS) has several limitations [12] that may affect interpretation accuracy across various clinical scenarios:

1. **Arteriovenous malformations (AVMs):** In patients with arteriovenous malformations, the portal vein may exhibit pulsatile flow on Doppler ultrasound even in the absence of fluid overload [13]. This may result in a falsely elevated VExUS grade and misclassification of the patient's true volume status.
2. **Chronic liver disease (cirrhosis and NAFLD):** Patients with liver cirrhosis or non-alcoholic fatty liver disease (NAFLD) may show preserved or near-normal portal venous waveforms on VExUS despite significant systemic venous congestion. This discrepancy is likely due to attenuated transmission of right atrial pressure through fibrotic or steatotic hepatic sinusoids, which blunts the expected Doppler waveform abnormalities [11].
3. **Parenchymal renal disease:** In the presence of intrinsic parenchymal renal disease, intrarenal venous Doppler waveforms may be altered independently of systemic venous pressure [14]. As such, renal waveform interpretation in VExUS can be confounded, reducing diagnostic reliability in this population.
4. **Severe tricuspid regurgitation:** Patients with severe tricuspid regurgitation may exhibit minimal or no changes in hepatic venous Doppler waveforms due to high right atrial compliance [15]. This can mask elevated right atrial pressures and lead to underestimation of venous congestion severity when relying solely on hepatic vein assessment.

These considerations highlight the need for contextual interpretation of VExUS findings and underscore the importance of integrating clinical, echocardiographic, and hemodynamic data for accurate fluid status assessment.

DETAILED PROTOCOL FOR VEXUS EXAMINATION

1. **Equipment and probe selection**

The Venous Excess Ultrasound Grading System (VExUS) examination requires a high-quality ultrasound machine equipped with color Doppler and pulsed-wave (PW) Doppler capabilities. These modalities are essential for evaluating venous blood flow patterns in key vessels including the hepatic veins, portal vein, and intrarenal veins.

For optimal image acquisition, the use of a phased-array transducer is generally recommended. Phased-array probes are particularly suited for imaging deep abdominal structures due to their small footprint and ability to navigate between rib spaces. This makes them ideal for assessing hepatic and portal venous flow. Alternatively, a curvilinear transducer may be employed, especially when broader field-of-view is desired. Curvilinear probes provide enhanced lateral resolution and are beneficial when assessing renal parenchymal vessels or when the patient body habitus permits easier access. The addition of electrocardiographic (ECG) gating is optional but can enhance Doppler waveform interpretation by synchronizing waveforms with the cardiac cycle, improving diagnostic precision [16].

2. **Patient positioning**

The patient should be positioned in a supine or semi-recumbent posture with the head elevated between 0 and 30 degrees. Minimal respiratory movement during image acquisition is desirable to optimize Doppler signal quality [3].

3. **Step-by-Step examination**

Step 1: Inferior vena cava (IVC) assessment

The IVC is visualized in a subxiphoid long-axis view, approximately 2 cm distal to the cavo-atrial junction[16]. When the sub-xiphoid window was not appropriate the probe was moved laterally to the right side of the body, over the liver, until an adequate view was achieved. The maximal diameter during the respiratory cycle was measured. If the IVC diameter is equal to or exceeds 2.0 cm, the likelihood of elevated right atrial pressure increases, and further Doppler assessment should be performed (Figure 1).

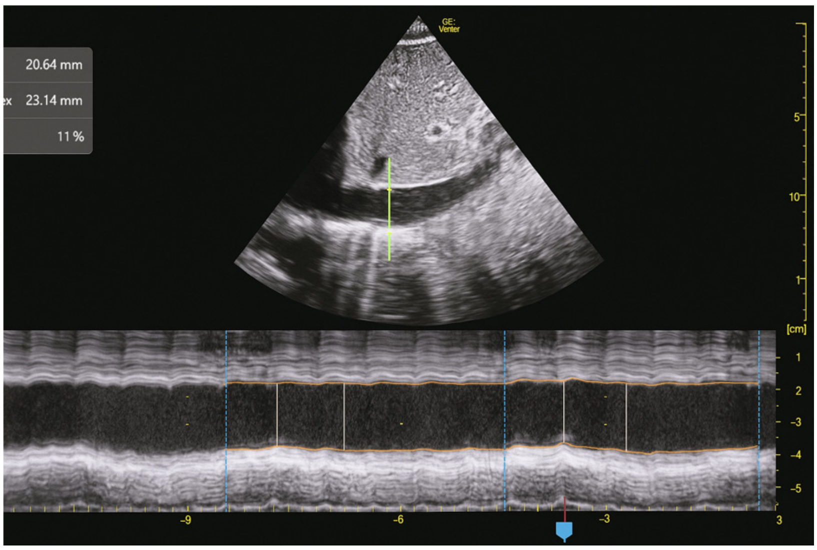

Figure 1. IVC at longitudinal view from a sub-xiphoid position.

Step 2: Hepatic vein doppler

The hepatic vein is imaged through a right mid-axillary or subcostal approach. Pulsed-wave Doppler should be aligned parallel to venous flow. A normal waveform is characterized by a dominant systolic wave (S wave) greater than the diastolic wave (D wave). Mild abnormalities are indicated by a reversal in wave dominance, where the diastolic wave exceeds the systolic wave, though flow remains hepatofugal. Severe abnormalities are identified by a reversed systolic wave, indicating hepatopetal flow and significant congestion [17] (Figure 2).

Step 3: Portal Vein Doppler

The portal vein is identified using a right subcostal or posterior axillary approach with color Doppler. Pulsed-wave Doppler is applied to evaluate pulsatility, which is quantified using the pulsatility fraction formula:

$$\text{Pulsatility Fraction} = \frac{V_{\max} - V_{\min}}{V_{\max}} \times 100\%$$

A pulsatility fraction below 30 percent is considered normal. Values between 30 and 49 percent suggest mild congestion, while values of 50 percent or higher are consistent with severe congestion [16] (Figure 3).

Step 4: Intrarenal Vein Doppler

The intrarenal veins are examined in a longitudinal plane via a posterior axillary approach. Color Doppler is used to identify interlobar arteries and veins, followed by pulsed-wave Doppler interrogation. A continuous monophasic waveform is considered normal. Biphasic waveforms with distinct systolic and diastolic components indicate mild congestion. A monophasic diastolic-only waveform or intermittent venous flow pattern is consistent with severe renal congestion [3,16] (Figure 4).

4. VExUS Grading System

The VExUS system categorizes venous congestion into four grades based on IVC diameter and the presence of severe Doppler abnormalities [4].

- Grade 0: The IVC diameter is less than 2 cm with normal respiratory variation, and no further Doppler assessment is required.
- Grade 1: The IVC diameter is equal to or greater than 2 cm, but no severe Doppler abnormalities are identified in hepatic, portal, or renal veins.
- Grade 2: The IVC diameter is equal to or greater than 2 cm, and one of the three assessed venous territories shows a severe abnormality.
- Grade 3: The IVC diameter is equal to or greater than 2 cm, and at least two of the three venous territories demonstrate severe Doppler abnormalities.

CLINICAL APPLICATIONS AND FUTURE DIRECTIONS

VExUS has the potential to transform fluid management in surgical patients by identifying subclinical venous congestion, guiding decongestive therapies such as diuretics or ultrafiltration, and assisting in perioperative hemodynamic decision-making. Despite its promise, clinical

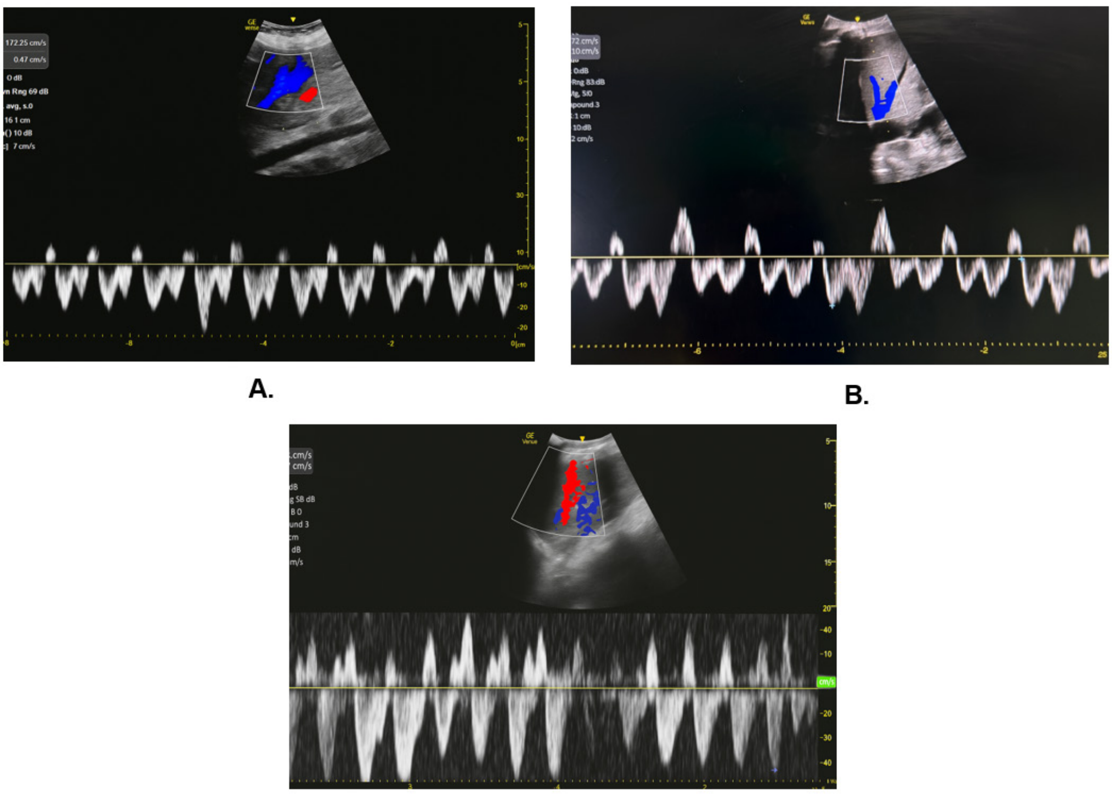

Figure 2. Hepatic vein Doppler waveform. A. Hepatic vein Doppler waveform showing normal pattern with dominant systolic (S) wave over diastolic (D) wave; B. Hepatic vein Doppler waveform showing reversal of wave dominance, with diastolic (D) wave greater than systolic (S) wave. This pattern indicates mild hepatic venous congestion; C. Hepatic vein Doppler waveform demonstrating severe venous congestion with reversed systolic (S) wave.

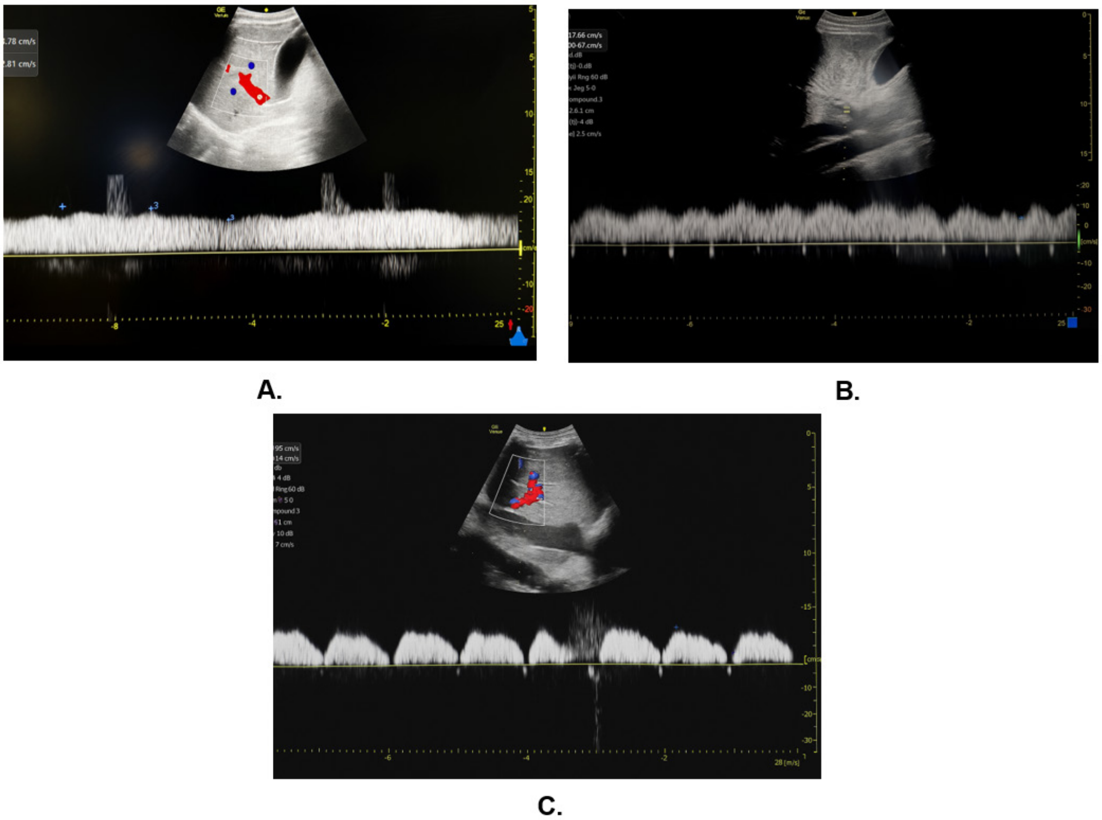

Figure 3. Portal vein Doppler waveform. A. Portal vein Doppler with <30% pulsatility indicating normal flow; B. Portal vein Doppler with 30-49% pulsatility indicating mild congestion; C. Portal vein Doppler with ≥50% pulsatility indicating severe congestion.

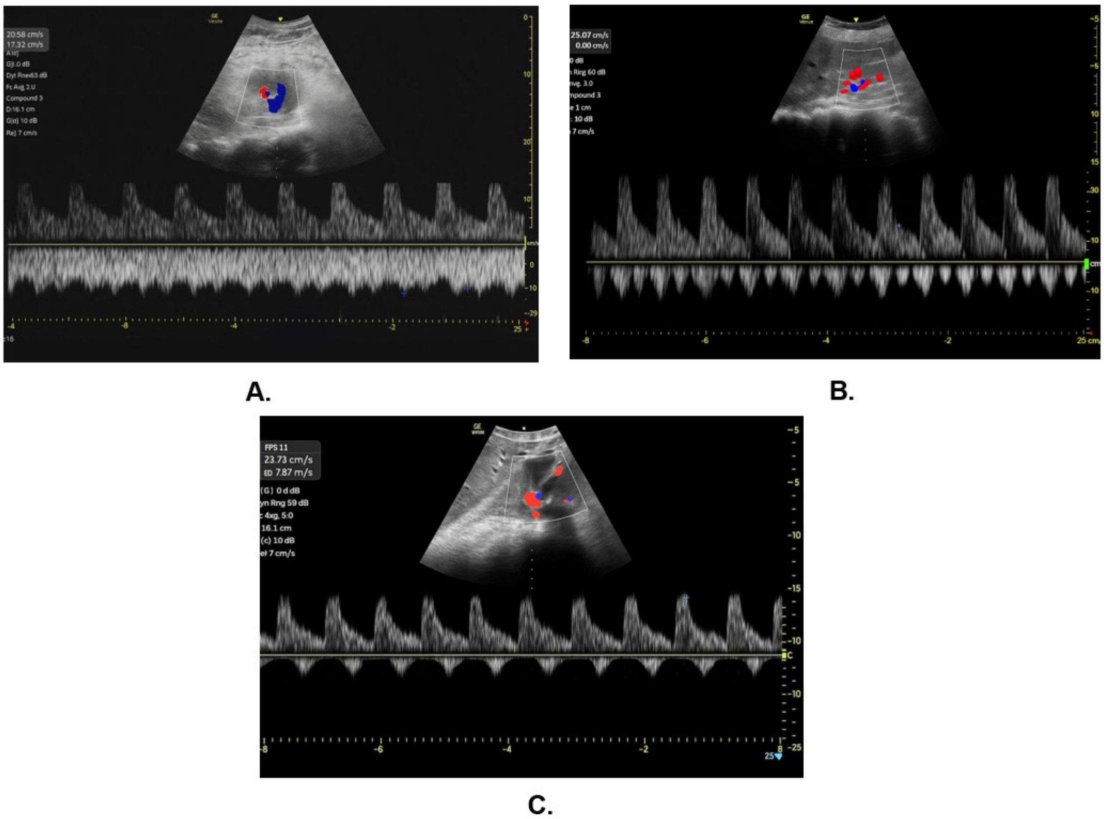

Figure 4. Intrarenal Vein Doppler waveform. A. Intrarenal vein Doppler waveform showing continuous monophasic flow, consistent with normal renal venous outflow; B. Intrarenal vein Doppler waveform showing biphasic flow pattern with distinguishable systolic and diastolic components, indicating mild renal venous congestion; C. Intrarenal vein Doppler waveform demonstrating monophasic diastolic-only flow, consistent with severe renal venous congestion.

implementation is currently limited by several factors, including the absence of standardized training protocols, undefined intervention thresholds, and limited data in specialized patient populations such as those with liver disease or pediatric patients. Future research should focus on multicenter prospective trials to establish the prognostic value of VExUS and validate therapeutic cutoff points.

To illustrate the translational value of VExUS in perioperative care, consider a scenario involving a postoperative patient with declining urine output and a positive fluid balance. While traditional markers might suggest a need for more fluid, a VExUS assessment can refine the strategy:

- **VExUS Grade 0–1 (No to Mild Congestion):** Indicates that systemic venous pressure is not significantly elevated. In this case, the clinician may continue maintenance fluid therapy or consider a cautious fluid bolus if other dynamic indicators suggest fluid responsiveness, as the risk of congestive organ injury is low.
- **VExUS Grade 2 (Moderate Congestion):** Suggests an emerging risk of venous excess. Clinicians should exercise high caution with further fluid administration. Fluid boluses should be avoided unless absolutely necessary, and the focus should shift toward achieving a neutral fluid balance.
- **VExUS Grade 3 (Severe Congestion):** Indicates a high risk of congestion-associated organ dysfunction, such as AKI. This finding should prompt immediate consideration of decongestive strategies, including the cessation of intravenous fluids and the initiation of diuretic therapy or ultrafiltration to reduce the venous congestion and improve organ perfusion.

CONCLUSION

The Venous Excess Ultrasound Grading System (VExUS) offers a paradigm shift in hemodynamic assessment by focusing on venous congestion rather than solely on volume responsiveness. In surgical patients, where precise volume control is essential, VExUS provides a reproducible and non-invasive method for evaluating the consequences of elevated venous pressures. Although early evidence supports its feasibility and potential utility, further validation through large-scale studies is necessary to guide its integration into routine surgical care.

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