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The Role of Venous Excess Ultrasound Score in Optimizing Acute Heart Failure Diagnosis and Prognosis

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Abstract

Acute heart failure (AHF) is a critical condition with significant morbidity and mortality, necessitating timely and accurate diagnosis for effective management.

The Venous Excess Ultrasound (VExUS) score has emerged as a non-invasive diagnostic tool, aimed at evaluating venous congestion through ultrasound. This scoring system integrates assessments of the inferior vena cava, hepatic veins, portal veins, and renal venous flow to quantify congestion severity. By providing a real-time assessment of venous pressure, the VExUS score has shown potential in optimizing early diagnosis of AHF and predicting outcomes and overall prognosis.

Recent studies suggest that incorporating the VExUS score into clinical practice can enhance patient stratification and guide tailored therapeutic interventions, reducing the need for invasive procedures like right heart catheterization. However, further large-scale studies are required to fully validate its role in predicting long-term outcomes and establishing its place in standard heart failure protocols.

We aimed to review the current evidence on the utility of the VExUS score in improving AHF diagnosis and its potential as a prognostic marker, highlighting its technical aspects, clinical implications and future research directions.

Keywords: Acute heart failure, Venous excess ultrasound score, Diagnosis

1. Introduction

Heart failure (HF) has become a major public health problem, affecting 1 %−12 % of the adult population based on available data from the United States and Europe [1]. Despite progress in reducing HF-related mortality, hospitalisation for HF remains very common (nearly 1 million hospitalizations occur each year) [1] and readmission rates continue to rise [2]. HF is a clinical syndrome characterized by typical symptoms (e.g. breathlessness, ankle swelling and fatigue) that may be accompanied by signs (e.g. elevated jugular venous pressure, pulmonary crackles and peripheral oedema) caused by a structural and/or functional cardiac abnormality, resulting in a reduced cardiac output and/or elevated intracardiac pressures at rest or during stress [3]. Acute heart failure (AHF) is defined as rapid onset or acute worsening of symptoms and signs of heart failure resulting in a need for urgent therapy [4]. Neurohormonal activation, venous congestion, endothelial dysfunction, myocardial injury and renal dysfunction are central to the pathophysiology of AHF [5,6]. We are interested here in venous congestion which has a major effect on the clinical presentation in most patients with AHF [5] and is a relevant determinant of multiorgan dysfunction occurring in this situation. In fact, assessment of congestion has always been an important cornerstone in the management of patients with HF, whether acute or chronic. In clinical practice, achieving a balance is challenging, as it

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requires avoiding under-treatment, which could result in residual congestion, or over-treatment, which might worsen kidney function and lead to a more severe prognosis. Many tools have been developed for this purpose, such as NT-proBNP levels or lung ultrasound. However, none of these have been tailored to assess venous congestion, which has long been neglected compared to the arterial side. The need for accurate, non-invasive and real-time diagnostic and monitoring tools is paramount in this complex clinical situation. A helpful clinical tool has been recently developed to this end: The venous excess ultrasound score. It is a semi-quantitative grading score, recently developed by Beaubien-Souligny et al. [7]. The authors conducted a post-hoc analysis of data collected during a prospective cohort study at a tertiary cardiac surgery center including non-critically ill patients 18 years and older undergoing cardiac surgery. Point-of-care ultrasound (POCUS) was used to evaluate venous congestion and to predict acute kidney injury (AKI) after cardiac surgery. All patients received repeated POCUS assessments the day before surgery, upon ICU admission after surgery, and daily from postoperative days 1–3. Each ultrasound examination included Doppler evaluation of the hepatic vein, portal vein, intra-renal veins, and inferior vena cava (IVC). This methodology allowed the researchers to create a standardized, easily applicable tool for the rapid evaluation of systemic venous congestion. Statistical methods were used to validate the system's accuracy and reproducibility, ensuring that it could reliably assist clinicians in identifying and quantifying venous congestion.

The study's findings have been extended to a wide range of patients, particularly those with conditions prone to systemic venous congestion or fluid imbalance like heart failure patients.

It is therefore essential to recognise the technical aspects of this grading system and its importance in the evaluation and prognosis of patients with acute heart failure.

1.1. Definition

The Venous Excess Ultrasound Score (VExUS) is a noninvasive, point-of-care ultrasound assessment designed to evaluate venous congestion in the liver and kidneys. The score is based on the understanding that venous congestion in these organs can lead to hypoperfusion, resulting in organ dysfunction, which ultimately increases morbidity and mortality [8].

List of abbreviations

2D	Two-dimensional
AHF	Acute heart failure
AKI	Acute kidney injury
CD	Color Doppler
CI	Collapsibility index
Cm	Centimeter
CRS	Cardiorenal syndrome
D	Diastolic
ECG	Electrocardiogram
HF	Heart failure
HV	Hepatic vein
IVC	Inferior vena cava
PI	Pulsatility index
PV	Portal vein
PWD	Pulsed wave doppler
RAP	Right atrial pressure
RH	Right heart catheterisation
RV	Renal vein
S	Systolic
V max	Maximum velocity
V min	Minimum velocity
VExUS	Venous excess ultrasound

1.2. Components of the VExUS score: key elements in evaluating venous congestion

1. Inferior Vena Cava (IVC) diameter and collapsibility.
2. Hepatic Vein (HV) Doppler Flow.
3. Portal Vein (PV) Doppler Flow.
4. Renal Vein (RV) Doppler Flow.

1.3. Technical aspects of the VExUS score [7,9–11]:

1.3.1. Preparation of the patient

The examination of the patient is carried out in the supine position. It can be performed using any type of echography equipment, whether in an echocardiography laboratory, an emergency department or an intensive care unit. A standard cardiac probe or a curvilinear (abdominal) transducer can be equally used. The electrocardiogram should be recorded simultaneously to identify the different parts of the cardiac cycle [12].

1.3.2. Inferior vena cava (IVC) assessement

The diameter of the IVC is measured rather in the subcostal view (Sub-xyphoid) or in the lateral transhepatic windows at 1.0-cm from its junction with the right atrium using two-dimensional (2D) doppler or TM mode. The normal IVC maximal diameter is < 2.1 cm. Therefore, systemic congestion is very unlikely in this situation and no further investigation is requested. When its diameter exceeds 2.1 cm, venous congestion is suspected. The next step is to perform a Doppler evaluation of the abdominal veins to grade it (Fig. 1).

1.3.3. Evaluation of the venous flow in hepatic, portal, and renal veins

1.3.3.1. Hepatic vein (HV) assessement

- **Technique:**

The sus-hepatic vein flow is evaluated in the subxyphoid or lateral mid-axillary transhepatic windows.

Either the middle hepatic vein (in the subxiphoid area) or the right hepatic vein (from a lateral angle) is usually accessible echographically.

Color Doppler (CD) of the HV will normally appear "blue" as the blood moves away from the transducer.

The pulsed-wave Doppler (PWD) evaluation is performed during quiet breathing or during end-expiratory, at 1.0 cm before HV connects with the IVC, and classified according to the wave form pattern. Nevertheless, there is a lack of clarity regarding the correct positioning of the PWD. Further research is needed to investigate the impact of small variations and to better understand how much variability is acceptable.

A simultaneous electrocardiographic (ECG) tracing is essential, as we already mentioned, to precisely identify the components of the hepatic venous waveform with A, S, and D waves occurring immediately after P, R, and T waves of the ECG waveforms, respectively.

- **Interpretation:**

➢ **Normal findings:**

The systolic S wave is negative and corresponds to the antegrade movement of the blood into the HV due to atrial relaxation. The diastolic D wave is negative and corresponds to antegrade flow caused by tricuspid valve opening. The A wave is positive and corresponds to the atrial contraction (Fig. 2).

➢ **Abnormal findings:**

Mild abnormality: With elevation of the right atrial pressure (RAP), S wave becomes smaller than the D wave.

Major abnormality: With significant increase in RAP, S wave becomes reversed.

1.3.3.2. Portal vein (PV) assessement

- **Technique:**

The PV can often be visualized by slightly tilting the transducer upwards from the mid-axillary transhepatic window.

On 2D mode PV is characterized by its hyperechoic walls.

Color doppler generally appear as 'Red' as the blood moves towards the transducer.

Assessment of PV is performed with PWD using a 20 cm/s baseline velocity.

- **Interpretation:**

➢ **Normal findings:**

The portal vein flow pulsatility index (PI) is assessed with PWD. The maximum velocity (Vmax) and minimum velocity (Vmin) of the portal vein are measured, allowing the calculation of portal PI with the following formula:

$$PI = (Vmax - Vmin) / (Vmax)$$

In the absence of congestion, no or minimal variations (PI < 30 %) are assessed in PV flow (Fig. 3).

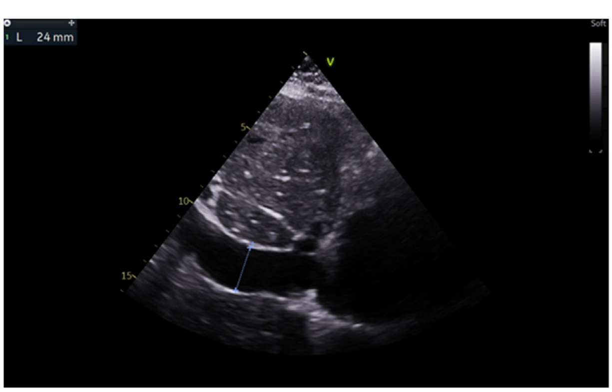

Fig. 1. 2D image of the inferior vena cava, showing evaluation of its size (>2.1 cm).

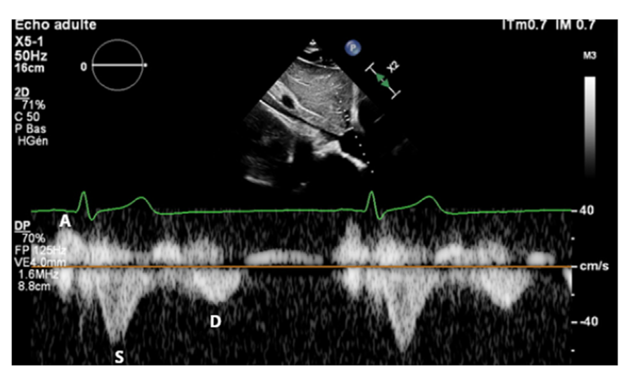

Fig. 2. PW doppler of the sus-hepatic vein before it connects with the IVC, showing two negative waves corresponding to the S and D wave with anormal S > D proportion.

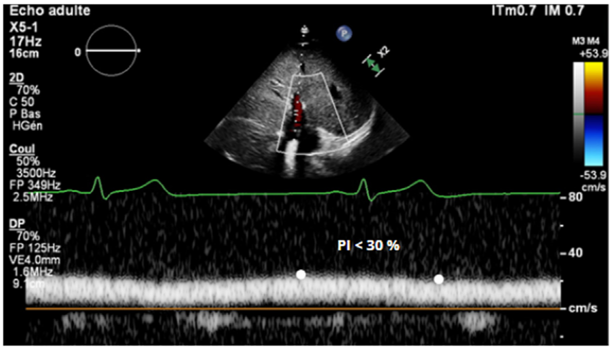

Fig. 3. PW doppler of the portal vein at the hepatic hilum, showing a continuous positive flow at a barely varying magnitude, corresponding to a normal PI.

➢ **Abnormal findings:**

Mild abnormality: PI 30–50 %.
Major abnormality: PI > 50 %.

1.3.4. *Renal vessels assessement*

• **Technique:**

The kidney is scanned in the lateral mid-axillary window at the 10th intercostal space. The interlobar veins (located between the renal medullary pyramids) are assessed.

A reduction of the Nyquist limit to <20 cm/s [10] and an increase of the color enhancement may help to visualize the renal vessels.

Because the arteries and veins travel in an anti-parallel manner along the same anatomic path, it is possible to assess both the arterial and venous flow patterns within a single PW Doppler gate.

• **Interpretation:**

➢ **Normal findings:**

Normally, the renal intralobar veins flow in PWD is monophasic and appears below baseline as the blood moves away from the transducer. While the renal arterial flow appears above the baseline and is pulsatile (Fig. 4).

➢ **Abnormal findings:**

Mild abnormality: As RAP pressure rises, the renal venous flow becomes pulsatile, initially discontinued biphasic, displaying distinct systolic and diastolic waves.

Major abnormality: As RAP increases further, the S wave becomes reversed, resembling the pattern seen in the HV waveform. Therefore, only an isolated diastolic (D-only) waveform remains visible resulting in a discontinued monophasic flow.

Table 1 summarizes the different venous flow patterns.

1.4. *VExUS score grading*

We follow this with the appropriate grading, and thus congestion severity, according to the reported venous flow abnormalities (Figs. 5 and 6):

- Grade **0**: IVC diameter <2.1 cm: No congestion.
- Grade **1**: IVC diameter ≥2.1 cm + Any combination of normal or mild abnormal waveform pattern: Mild congestion.

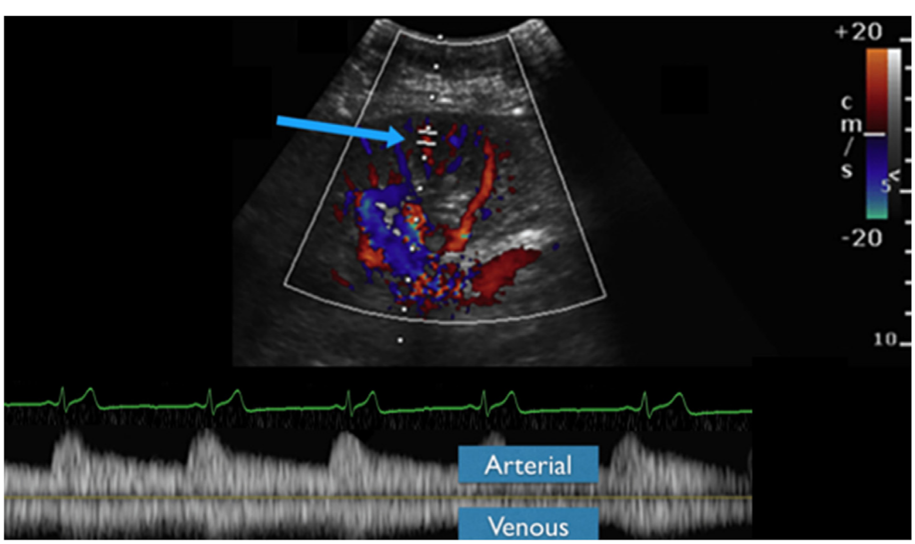

Fig. 4. PWD of the renal vein at the renal hilum, showing a continuous negative flow of minimal variation, corresponding to a normal renal vein flow pattern. The positive pulsatile flow corresponds to the renal artery flow.

REVIEW ARTICLE

Table 1. Grading venous flow pattern.

	Flow pattern	Grade
Hepatic vein	S wave > D wave	Normal
	D wave > S wave	Mild abnormality
	Reverse S wave	Major abnormality
Portal vein	Pulsatility <30 %	Normal
	Pulsatility 30 %–50 %	Mild abnormality
	Pulsatility >50 %	Major abnormality
Renal vein	Continuous	Normal
	Pulsatile with distinct S and D components	Mild abnormality
	Monophasic with a D-only pattern	Major abnormality

- Grade 2: IVC diameter ≥2.1 cm + ONE major abnormal waveform pattern: Moderate congestion.
- Grade 3: IVC diameter ≥2.1 cm + ≥ Two major abnormal waveforms pattern: Severe congestion.

1.5. Clinical application of the VExUS score in acute heart failure

Although the initial creation of the score was for the determination of patients at risk of acute

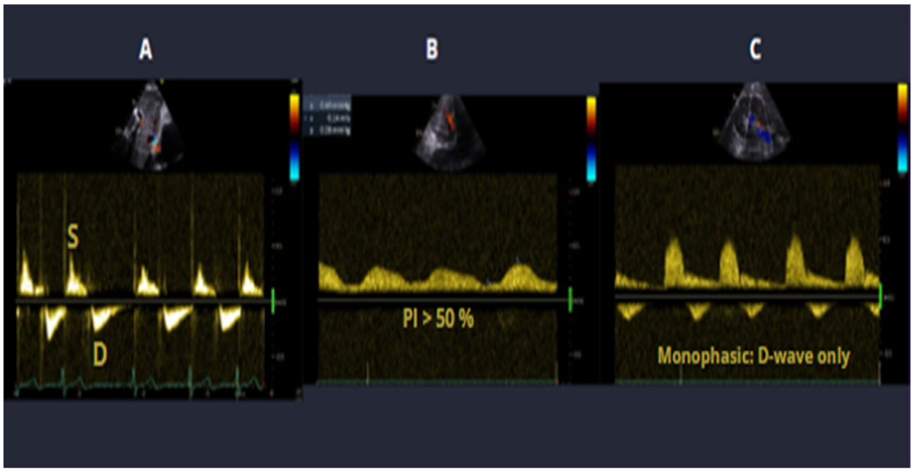

Fig. 5. Exemples of major abnormal waveforms pattern of the HV (A), PV (B) and RV (C) taken in a patient with atrial fibrillation.

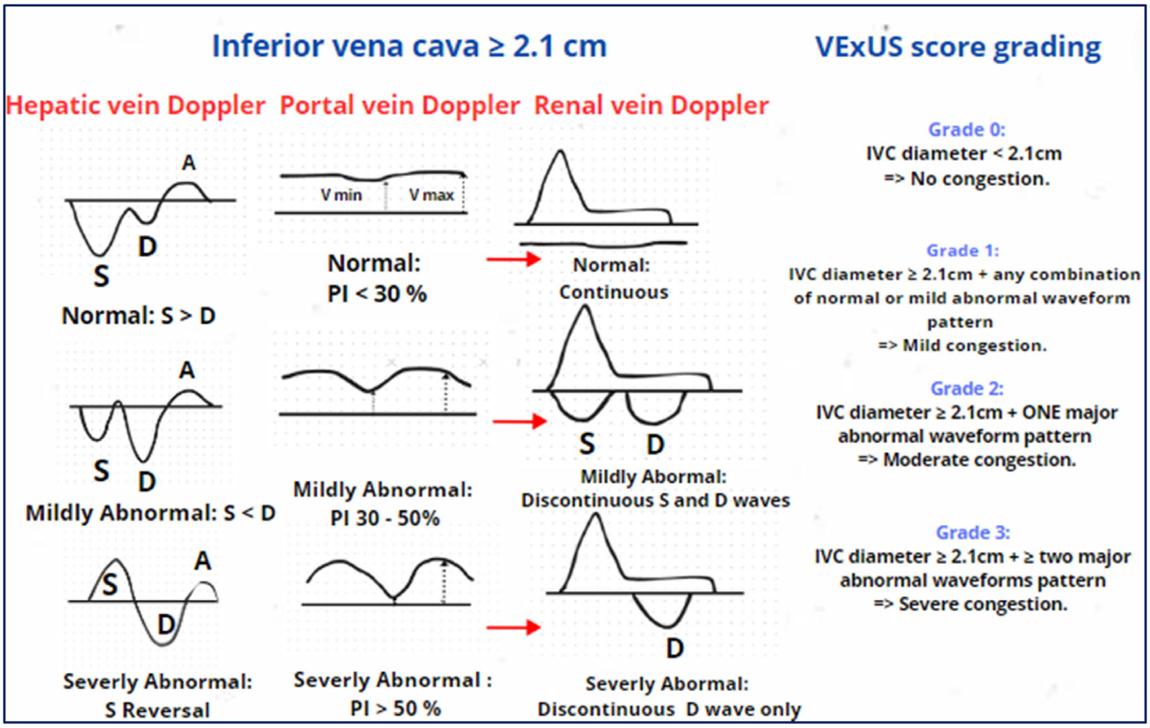

Fig. 6. Steps of the VExUS score system, with the different flow abnomalies that can be found, followed by the interpretation.

kidney injury in the post-cardiac surgery setting, establishing a significant correlation between high grade VExUS score and the risk of developing acute kidney injury (AKI), post-operatively [7,13].

VExUS has proven its value across other clinical scenarios [14] mainly in heart failure, since venous congestion has an indisputable place in its pathophysiological cycle (Table 2) and the number of studies and publications dedicated to it continues to increase lately.

1.5.1. The VExUS score in assessing acute heart failure diagnosis

AHF is a constant clinical challenge, primarily due to the complex interplay of haemodynamic abnormalities and resulting multi-organ overload.

Patients with HF, irrespective of subtype or timeframe, have a propensity for developing venous congestion through different neuro-hormonal pathways, specific to the cardio-vascular system, and independently from the possible etiologies [15].

Conventional approaches to the management of venous congestion in heart failure have long relied on clinical examination, biomarkers and evaluation of the IVC.

The VExUS score helps clinicians assess congestion and its severity in acute heart failure. It provides a more nuanced understanding of congestion than relying on IVC diameter alone. In fact, the size and inspiratory variability of the IVC, although part of the initial assessment of systemic congestion, should not be used in isolation, as their correlation with right atrial pressure measured by right heart catheterisation, is only moderate [16].

Right heart catheterisation (RHC) has been the most readily available means of venous filling pressure measurement. This technique is not always available and carries many risks. Therefore, later studies have been interested in elaborating a non-invasive technique to this end. A strong interrelation between VExUS grade and right atrial pressure measured through right heart catheterization have been found [17].

We conclude that the multi-parameter Venous Excess Ultrasound Scoring System is a feasible, safe and inexpensive tool, which can be helpful in avoiding missteps in the assessment of acute heart failure diagnosis.

1.5.2. The VExUS score in acute heart failure guiding therapy

The VExUS score helps assessing the severity of congestion in acute heart failure, guiding treatment decisions to manage fluid overload.

A prospective cohort study conducted on patients with cardiorenal syndrome (CRS) including decompensated HF (57 % of study subjects) showed a significant association between decreasing in VEXUS grade and fluid balance [18].

In fact, it enables clinicians to dynamically track venous congestion and adjust diuretic therapy, to ensure that patients receive optimal fluid removal tailored to their specific venous congestion status avoiding both over- and under-treatment [19].

It helps identify patients who are at higher risk for adverse outcomes, potentially guiding more aggressive interventions.

1.5.3. The VExUS score in assessing acute heart failure prognosis

Despite available therapy, mortality and readmission rates within 60–90 days of discharge for patients hospitalized with heart failure (HF) approach 15 % and 30 %, respectively [20].

Several research have highlighted the critical role of systemic congestion assessed by VExUS score in accurately predicting heart failure patient outcomes and prognosis [21–23].

1.5.3.1. Predicting in-hospital mortality. High VExUS scores are associated with worse outcomes in patients with acute heart failure. The higher the VExUS score, the greater the venous congestion,

Table 2. Application of VExUS score in acute heart failure.

Application	Role	Impact
Diagnosis	The VExUS score helps clinicians assess congestion and its severity in acute heart failure by the evaluation of IVC diameter and the different venous flow patterns.	It is a helpful tool in the assessment of acute heart failure diagnosis, aiding in the early detection and intervention of acute heart failure.
Guiding therapy	It enables clinicians to dynamically track venous congestion and adjust diuretic therapy.	Optimal fluid removal tailored to their specific venous congestion status avoiding both over-and under-treatment.
Prognosis	High VExUS score at the time of admission is a strong prognostic indicator, predicting mortality, HF-related deaths, and HF-related readmissions.	It provides valuable insights into the future risk of adverse events, signaling the need for adoption of aggressive management strategies to improve long-term outcomes.

indicating more severe hemodynamic compromise. In fact, a VExUS score of 3 at the initial assessment of patients with acute decompensated HF, in the emergency department, predicts in-patient mortality, HF-related death, and early readmission [21].

Patients with elevated VExUS scores tend to have higher rates of organ dysfunction, such as worsening kidney or liver function, which are key determinants of prognosis in heart failure. This is likely a result of decreased perfusion pressure associated with elevated right atrial pressure (RAP). Perfusion pressure, broadly defined as the difference between mean arterial pressure and central venous pressure, has been linked to an increased risk of organ injury when it is reduced [24].

A prospective multicentric study of Torres-Arrese M. et al. [22], followed up patients hospitalized for acute heart failure with an initial echographic evaluation of venous congestion through the use of VExUS grading, repeated throughout the hospitalization and soughtout a correlation between it and the prognosis of heart failure. They found that VExUS score and some selected venous flow abnormalities, mainly intra-renal venous Doppler assessment and portal vein pulsatility above 50 %, accurately predicted mortality.

In addition, Anastasio et al. [23] have demonstrated in a study published in May 2024, conducted on two hundred ninety patients admitted with acute HF, that a VExUS score of 3 was associated with in-hospital mortality. They concluded that the VExUS score improved the prediction of in-hospital mortality compared with other indices of venous congestion.

1.5.3.2. Predicting readmission. The VExUS score can be a valuable predictor of readmission risk in patients with acute heart failure, helping to tailor post-discharge care and reduce the likelihood of early rehospitalization.

A scientific statement by the Heart Failure Association of the European Society of Cardiology (ESC) emphasizes the importance of comprehensive care during the pre-discharge and early post-discharge phases for patients hospitalized with acute heart failure (AHF). The focus is on improving outcomes, reducing readmission rates, and enhancing patient quality of life. Effective management of fluid overload and venous congestion was one of the most parameters that should be evaluated in this part of patient care in this critical phase [25,26].

Venous congestion, as measured by the VExUS score, indicates poor volume management and elevated venous pressures. These factors often persist even after symptom resolution, increasing the risk of heart failure decompensation and, therefore, readmission.

Studies suggest that patients with higher VExUS scores at discharge have a greater likelihood of being readmitted [22].

Residual venous congestion in discharge is a major contributor to readmission of patients with heart failure [27]. In fact, a significant proportion of heart failure patients with reduced ejection fraction admitted for acute decompensated heart failure had clinical and ultrasound evidence of residual congestion at discharge. Patients with a VExUS score of 2 or 3 at discharge were at higher risk of 90-day readmission or emergency visit for acute heart failure in a recent Brazilian study [28].

Monophasic intrarenal venous flow was also a predictor of unplanned rehospitalization due to decompensated HF [22,29].

The VExUS score can be a valuable tool in guiding discharge decisions and identifying patients who may need closer post-discharge follow-up or more intensive diuretic therapy to prevent early readmission.

1.6. Pitfalls of the VExUS score: challenges in clinical practice

The VExUS score has several pitfalls that clinicians need to be aware of when using it:

- Slim subjects may have pulsatility of the PV [30], whereas, highly trained athletes [31] may have an IVC dilation chronically without an increase in the right atrial pressure. Those factors should be taken into consideration before drawing conclusions.
- The IVC may collapse in the presence of intra-abdominal hypertension despite an elevated right atrial pressure [32].
- The hepatic vein waveform is susceptible to being misinterpreted in the absence of simultaneous ECG tracing as it can be influenced by arrythmias. In the case of atrial fibrillation, even in the absence of increased RA pressure, results in loss of the A wave and a smaller S wave ($S < D$) [33].
- The value of hepatic vein Doppler is limited in the presence of significant tricuspid regurgitation, as a chronic $S < D$ or S-wave reversal may be present irrespective of the patient's fluid status [9,11]. In addition, an abnormal hepatic venous Doppler signal may be observed in the absence of tricuspid regurgitation in RV dysfunction due to the absence of annular motion.

- When evaluating portal vein pulsatility, variations in the amplitude of the PV waveform, such as those caused by the movement of the Doppler sample volume in and out of the vessel or respiratory variations, can sometimes create the appearance of pulsatility, particularly when ECG monitoring is not available, leading to a misinterpretation.
- Patients with liver disease, baseline abnormalities in hepatic and portal vein waveforms can be attributed to local structural alterations like in cirrhosis [34,35] or fatty infiltration.
- Renal images are generally considered the most technically challenging. They are difficult to acquire because of the small vessels. Breath holding helps if the patient can cooperate [10,11].
- Ultrasound information should always be used in a clinical context and integrated with other bedside information (clinical, laboratory and imaging).

1.7. Limitations of the VExUS score: understanding its constraints in clinical assessment

The VExUS score, although useful for assessing venous congestion, has some limitations:

- Operator Dependency: Accurate interpretation of the VExUS score relies heavily on the skill and experience of the operator performing the ultrasound. Although a recent study showed that it has a high inter-observer and intra-observer reliability [12], further investigation is needed in the future.
- Limited Validation: The VExUS score has not been extensively validated across diverse patient populations, including those with different types of heart failure.
- Lack of Standardization: There is currently no universal protocol for applying and interpreting the VExUS score, which can result in variations across different healthcare settings.
- Focus on Right-Sided Congestion: The VExUS score primarily assesses right-sided heart congestion and may not fully capture left-sided heart failure, limiting its comprehensiveness in all heart failure patients.

2. Conclusion

Venous congestion is an undeniable part of heart failure pathophysiology. The integration of the VExUS score system with clinical assessment could have great impact on the prognosis of patients.

It has the potential to become a valuable tool at the clinician's disposal to more accurately frame the delicate care of patients with heart failure, in the short and long term.

All first-line clinicians involved in daily fluid balance management decisions should be interested in the rapid evolution of knowledge about VExUS assessment.

Although it has gained popularity recently, its usefulness in guiding therapy or predicting outcomes remains debatable.

Prospective trials are needed to confirm the score's validity, to evaluate its utility in predicting specific outcomes, such as acute kidney injury (AKI), readmissions, heart failure diagnosis, and other related conditions ensuring its broader applicability and effectiveness.

Author contribution

Conception and design of Study: AS, RS. Literature review: AS, RS, MI. Acquisition of data: AS, RS, MI. Analysis and interpretation of data: AS, RS. Research investigation and analysis: RS, MI. Data collection: RS, MI. Drafting of manuscript: AS, RS. Revising and editing the manuscript critically for important intellectual contents: AS, ZL. Data preparation and presentation: AS, RS. Supervision of the research: AS, ZL. Research coordination and management: AS.

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Ethical information

This article is a review and does not involve original research on human participants or animals. Therefore, ethical approval was not required.

Conflict of interest

None declared.

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REVIEW ARTICLE

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