# Fluid tolerance in septic shock: Femoral vein pulsatility versus VExUS score in a cross-sectional study

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**Background.** Excessive fluid resuscitation in patients with septic shock is associated with acute organ injury and increased mortality. Accurate assessment of fluid tolerance is therefore essential. Right cardiac chamber fluid tolerance can be evaluated by estimating the right atrial pressure using central venous catheters, inferior vena cava (IVC) measurements, Venous Excess Ultrasound (VExUS) scores and femoral vein pulsatility (FVP).

**Objectives.** To assess the correlation between FVP and VExUS score in evaluating fluid intolerance and venous congestion in patients with septic shock; the correlation of FVP and VExUS score with central venous pressure (CVP); and to evaluate the effect of positive pressure ventilation on the relationship between FVP and VExUS score.

**Methods.** In this observational cross-sectional study, 80 participants were assessed for fluid tolerance using VExUS scores and FVP. CVP, maximum and minimum IVC diameters and IVC dynamicity were regarded as the gold standard and used as reference.

**Results.** FVP showed moderate agreement with VExUS score (Kappa=0.55; $p$<0.001). Both FVP and VExUS score demonstrated the ability to predict CVP values ≥17 cm$H_2O$ with overall accuracies of 70% and 77.5%, respectively ($p$<0.001). A CVP ≥17.5 cm$H_2O$ predicted severely congested femoral veins with a sensitivity of 70% and specificity of 90%, whereas a CVP ≥18.5 cm$H_2O$ predicted VExUS grade 3 with a sensitivity of 66.7% and specificity of 83.3%. Maximum IVC diameter accurately predicted abnormal femoral vein Doppler findings, with an overall accuracy of 82.5%.

**Conclusion.** A pulsatile femoral vein pattern indicates fluid intolerance in patients with septic shock, providing an additional marker for assessing fluid status. Doppler assessment of the femoral vein offers advantages of easier anatomical accessibility and a shorter learning curve compared with other methods.

**Keywords:** venous congestion, VExUS score, femoral vein pulsatility, central venous pressure, inferior vena cava, fluid management, monitoring, septic shock

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**Contribution of study**
This study evaluated a simple rapid tool (femoral vein pulsability) in assessing volume state and fluid tolerance in septic patients in comparison with VExsus.

In patients with septic shock, fluid therapy remains a cornerstone of management to restore and maintain tissue perfusion, as recommended by the 2024 Surviving Sepsis Campaign guidelines.[1] However, many studies have correlated excessive fluid resuscitation with increased rates of acute organ injury, prolonged duration of positive pressure ventilation (PPV) and increased mortality.[2] Consequently, finding accurate methods of assessing fluid status in critically ill patients is essential.

Fluid administration in critically ill patients is guided by the concepts of fluid responsiveness and fluid tolerance. Fluid responsiveness is defined as the ability of the left ventricle to increase stroke volume in response to preload augmentation, whereas fluid tolerance represents the body's capacity to tolerate intravenous fluids without developing venous congestion or organ dysfunction.[3] Fluid tolerance is assessed by evaluating cardiac chamber filling pressures.[4] Right atrial pressure (RAP) may be measured invasively through the insertion of a Swan-Ganz catheter or central venous catheter (CVC).[5] Echocardiographic assessment of the inferior vena cava (IVC) respiratory dynamicity is another simple, reproducible tool to estimate RAP.[6] The Venous Excess Ultrasound (VExUS) score is a recently validated protocol comprising assessment of the IVC, hepatic, portal and renal veins to reflect RAP.[7] However, the requirement for experienced operators, time-consuming methodology and difficult anatomical accessibility pose limitations to the acceptance of the VExUS score in critical care settings.[8]

Femoral vein pulsatility (FVP) is an emerging tool for predicting volume overload and has been shown to correlate with RAP.[9-11] This study aimed to compared FVP with VExUS score in assessing fluid tolerance in patients with septic shock.

## Methods

This observational cross-sectional study was conducted over a 7-month period from October 2023 to May 2024. All patients with septic shock admitted to the Critical Care Department of Cairo University Hospitals during this period were consecutively enrolled, provided they met the inclusion criteria and none of the exclusion criteria.

Eligible patients were identified according to the definition of septic shock provided by the Third International Consensus for Sepsis and Septic Shock.[12] Both patients with a first episode of septic shock and those with recurrent episodes were included. Each participant was assessed once during their intensive care unit (ICU) stay.

The study was approved by the Ethical Research Committee of the Faculty of Medicine, Cairo University (ref. no. MS-458-2023), and written non-opposition consent was obtained.

Exclusion criteria included patients with an inadequate ultrasonographic window, raised intrathoracic or intra-abdominal pressure or those who were mechanically ventilated with positive end-expiratory pressure ≥8 cm$H_2O$ or tidal volume <6 mL/kg. Patients with portal hypertension, stage 4 or 5 chronic kidney disease or moderate to severe tricuspid regurgitation were also excluded. In addition, patients with septic shock who had IVC thrombosis or deep venous thrombosis of the lower limbs were not enrolled.

All enrolled participants were evaluated during their ICU stay in the same setting. Measurements included central venous pressures (CVP), VExUS scores and FVP. Sonographic recordings were performed using a GE Vivid iq portable ultrasound machine (GE Healthcare, Chalfont St Giles, UK).

## Variables of interest

**CVP.** A water manometer was connected to internal jugular or subclavian CVCs. The manometer was aligned with the phlebostatic axis while patients were in the dorsal decubitus position. CVP was recorded at end-expiration. A CVP ≥17 cm$H_2O$ was regarded as volume overload, as supported in the literature.[8,13-15]

**VExUS score.** A 1.8 - 6.0 MHz curvilinear probe was used to assess VExUS score with the patient in the dorsal decubitus position. All pulsed-wave Doppler (PW Doppler) measurements were obtained at end-expiration with an angle of insonation <45° and optimised Doppler scale settings. The VExUS score was assessed according to the protocol described by Beaubien-Souligny *et al.*[7] (VExUS score prototype C). Scores ranged from grade 0 (absence of congestion) to grades 1 - 3, suggesting venous congestion.

**FVP.** With the patient in the dorsal decubitus position, a 2.4 - 10.0 MHz linear array probe was placed 2 - 3 cm below the midpoint of the inguinal ligament with an angle of insonation <45°. PW Doppler was used to record the waveforms over a single respiratory or ventilatory cycle. The following waveform patterns were defined:

(*i*) Normal pattern: Antegrade uninterrupted flow pattern with respiratory variation (Fig. 1).

(*ii*) Mild congestion: Triphasic pulsatile pattern representing the jugular venous pressure waveform (Fig. 2).

(*iii*) Severe congestion: Bidirectional pattern with flow reversal exceeding one-third of the antegrade flow (Fig. 3).[12]

## Statistical methods

Data were coded and analysed using IBM SPSS Statistics version 28 (IBM Corp., USA). Quantitative data were summarised as mean and standard deviation (SD) or median with minimum and maximum values, as appropriate. Categorical data were summarised as frequencies and percentages. Categorical data were compared using either the $\chi^2$ or Fisher's exact test. Standard diagnostic indices included sensitivity, specificity, positive predictive value, negative predictive value and diagnostic efficacy. Receiver operating characteristic (ROC) curves were constructed, and the area under the curve (AUC) was calculated to detect the optimal cut-off values of CVP for detecting abnormal VExUS scores and femoral vein Doppler findings. A $p$-value <0.05 was regarded as statistically significant.

## Objectives

The primary objective was to assess the correlation between FVP and VExUS score in evaluating fluid tolerance and venous congestion in patients with septic shock,

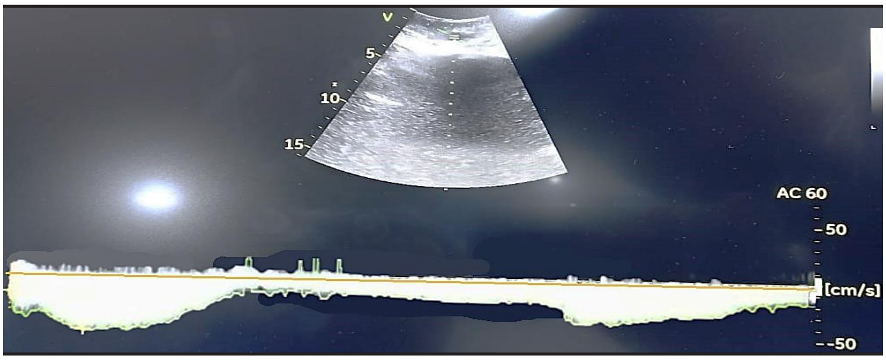


*Fig. 1. PW Doppler assessment of CFV waves in short axis view showing a normal venous waveform with an uninterrupted flow pattern with respiratory dynamicity (CFW = common femoral vein).*

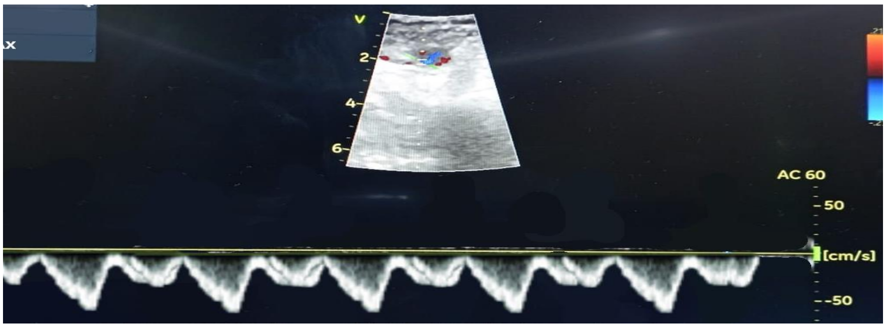


*Fig. 2. PW Doppler assessment of CFV waves in short axis view showing a mildly congested vein with a pulsatile pattern with systolic and diastolic waves (CFW = common femoral vein).*

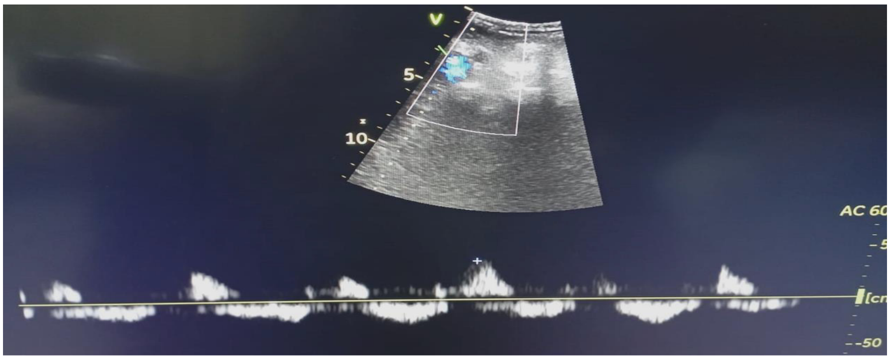

*Fig. 3. PW Doppler assessment of CFV waves in short axis view showing a severely congested vein with bidirectional pattern with flow reversal more than one-third the antegrade flow (CFW = common femoral vein).*

including both spontaneously breathing patients and those receiving invasive or non-invasive PPV.

Secondary objectives included assessing the correlation of FVP and VExUS score with CVP, and evaluating the effect of PPV on the relationship between FVP and VExUS score.

## Results

A total of 113 patients with septic shock were screened for eligibility. After the exclusion of 33 patients, 80 were enrolled in the study, of whom 55% were male. The mean (SD) age was 60.18 (17.52) years. All patients were receiving vasopressor treatment, and 40% were receiving PPV.

### Primary objective: FVP v. VExUS score

Among patients with a VExUS score of 0, 73.9% showed a normal FVP, whereas 82.4% of patients with VExUS scores suggestive of congestion (grades 1 - 3) showed abnormal FVP.

FVP demonstrated moderate agreement with the VExUS score in both spontaneously breathing patients and those receiving invasive or non-invasive PPV, with a Kappa value of 0.55 and an overall agreement of 77.5% (Table 1).

### Secondary objectives

Both FVP and VExUS scores showed significant correlation with CVP values ($p$<0.001).

#### CVP v. FVP

Abnormal FVP (suggestive of mild or severe congestion) was associated with a mean (SD) CVP of 15.20 (5.01) cm$H_2O$. FVP demonstrated the ability to predict whether CVP values were above or below 17 cm$H_2O$ with an overall accuracy of 70% (AUC 0.870; $p$<0.001) (Table 2). A normal FVP predicted a CVP of ≤9.5 cm$H_2O$ (AUC 0.775; $p$<0.001) with a sensitivity of 70% and specificity of 75%. A severely congested FVP predicted a CVP of ≥17.5 cm$H_2O$ (AUC 0.895; $p$<0.001) with a sensitivity of 70% and specificity of 90%.

#### CVP v. VExUS

VExUS scores suggestive of congestion (grades 1 - 3) were associated with a mean (SD) CVP of 16.06 (4.95) cm$H_2O$. The VExUS score predicted whether the CVP values were above or below 17 cm$H_2O$ with an overall accuracy of 77.5% (AUC 0.891; $p$<0.001) (Table 3). Abnormal VExUS scores were detected in all patients with a CVP ≥17 cm$H_2O$, whereas 71.9% of patients with a normal VExUS score (grade 0) had a CVP <17 cm$H_2O$. A grade 2 VExUS score predicted a CVP ≥13.5 cm$H_2O$ with a sensitivity of 66.7% and specificity of 60%, and a grade 3 VExUS score predicted a CVP ≥18.5 cm$H_2O$ with a sensitivity of 66.7% and specificity of 83.3%.

#### IVC and VExUS score

VExUS score grades showed a strong association with various IVC measurements, as shown in Supplementary Table 1.

#### IVC and FVP

FVP was also significantly correlated with the ultrasonographic measurements of the IVC, as shown in Supplementary Table 2.

## Discussion

The aim of this study was to assess the correlation between VExUS score and FVP in estimating venous congestion and fluid tolerance in patients with septic shock. Few studies have explored this association. Our findings revealed that the common femoral vein (CFV) pulsatility

**Table 1. VExUS score v. FVP**

| | | VExUS total | | |
|---|---|---|---|---|
| | | **Normal $n$(%)** | **Abnormal $n$(%)** | **$p$-value** |
| Femoral vein pulsatility | Normal flow | 34 (73.9) | 6 (17.6) | <0.001 |
| | Abnormal flow | 12 (26.1) | 28 (82.4) | |

VExUS = Venous Excess Ultrasound; FVP = femoral vein pulsatility.

**Table 2. Overall accuracy of both FVP and VExUS score to predict if CVP ≥17 cm$H_2O$**

| | FVP | | VExUS score | |
|---|---|---|---|---|
| **Statistic** | **Value** | **95% CI** | **Value** | **95% CI** |
| Sensitivity | 100% | 79.41 - 100 | 100% | 79.41 - 100 |
| Specificity | 62.5% | 49.51 - 74.3 | 71.88% | 59.24 - 82.4 |
| Positive predictive value | 40% | 32.70 - 47.77 | 47.06% | 37.53 - 56.8 |
| Negative predictive value | 100% | 91.19 - 100 | 100% | 92.29 - 100 |
| Accuracy | 70% | 58.72 - 79.74 | 77.5% | 66.79 - 86.09 |

FVP = femoral vein pulsatility; VExUS = Venous Excess Ultrasound; CVP = central venous pressure; CI = confidence interval.

**Table 3. CVP thresholds for predicting VExUS score grades and FVP**

| Grades of congestion of VExUS score and FVP | CVP thresholds for VExUS grades | CVP thresholds for FVP |
|---|---|---|
| Normal flow | <10.5 cm$H_2O$<br>Sensitivity 88.2%; specificity 78.3% | <9.5 cm$H_2O$<br>Sensitivity 85%; specificity 75% |
| Moderate congestion | >13.5 - 18.5 cm$H_2O$<br>Sensitivity 66.7%; specificity 60% | - |
| Severe congestion | >18.5 cm$H_2O$<br>Sensitivity 66.7%; specificity 60% | >17.5 cm$H_2O$<br>Sensitivity 70%; specificity 90% |

CVP = central venous pressure; VExUS = Venous Excess Ultrasound; FVP = femoral vein pulsatility.

demonstrated moderate agreement with VExUS score (Kappa=0.55). This may be explained by the anatomical relationship between the CFV – particularly the right CFV – and the IVC and right atrium, whereby flow derangements may be noted along this axis.[9]

In agreement with our results, Bhardwaj *et al.*[13] similarly concluded that the accuracy of VExUS scores and FVP in estimating volume overload was 80.37% and 74.7%, respectively, in a cohort of post-cardiac surgical ICU patients. The level of agreement between FVP and VExUS score in that study was also moderate (Kappa=0.62).

Andrei *et al.*[16] conducted a study involving 108 ICU patients, of whom 14% had septic shock and approximately 60% were mechanically ventilated. Similar to our findings, they also demonstrated a statistically significant association between FVP and VExUS score in estimating volume overload ($p$=0.001), with an odds ratio of 2.1 (95% confidence interval (CI) 1.4 - 3.4).

Our results demonstrated that FVP can reliably predict elevated CVP ≥17cm$H_2O$ with a sensitivity of 100% and specificity of 62.5%. In addition, a normal FVP predicted a CVP ≤9.5 cm$H_2O$ with a sensitivity of 70% and specificity of 75%, while a severely congested FVP predicted a CVP ≥17.5 cm$H_2O$ with a sensitivity of 70% and specificity of 90%.

The stronger association between FVP and VExUS score compared with CVP values may be due to the anatomical and physiological continuity between the CFV and the IVC, the latter being a key component of the VExUS scoring system.

Cozcolluela *et al.*[17] also demonstrated a statistically significant correlation between FVP and CVP. In their study, FVP predicted a CVP >8 cm$H_2O$ with a specificity of 82.39%, accuracy of 75% and sensitivity of 59.7%.

In our study, the higher predictability and sensitivity of FVP for elevated CVP values may be attributed to the higher CVP cut-off threshold (≥17 cm$H_2O$), which likely reduced the number of false-negative cases. Furthermore, assessing CVP and FVP within the same setting may have been a contributing factor.

Similarly, Alimoğlu *et al.*[18] reported that the sensitivity of FVP for estimating a RAP ≥10.88 cm$H_2O$ was 70%, with a specificity of 92%, positive predictive value of 92% and negative predictive value of 70%.

To our knowledge, our study was the first to demonstrate that a CVP ≥13.5 cm$H_2O$ predicted a grade 2 VExUS score with a sensitivity of 66.7% and specificity of 60%, while a CVP ≥18.5 cm$H_2O$ predicted a grade 3 VExUS score with a sensitivity of 66.7% and specificity of 83.3%.

The statistically significant association between VExUS score and CVP observed in our study is consistent with the findings of Beaubien-Souligny *et al.*,[7] in which the VExUS model demonstrated a statistical correlation with CVP ($p$=0.004).

In concordance with our findings, Muñoz *et al.*[19] reported a statistically significant association ($p$=0.047) between abnormal VExUS score (grades 1 - 3) and elevated CVP (≥16 cm$H_2O$) in a cohort of critically ill mechanically ventilated patients receiving intravenous vasopressors.

## Conclusion

Our findings conclude that FVP demonstrates moderate agreement with VExUS score. In addition, given its ease of use and anatomical accessibility, Doppler assessment of the femoral vein may represent a promising tool for the evaluation of fluid tolerance and status in critically ill patients with septic shock. However, the ability of FVP to predict lower CVP values – potentially important for preventing fluid accumulation syndrome – requires further investigation. Further studies are needed to refine methods for assessing fluid tolerance in critically ill patients.

## Limitations

This study did not evaluate right ventricular function or its potential influence on the correlation between VExUS score and FVP.

In addition, CVP was used as one of the gold reference standards for assessing venous congestion. This approach has recognised limitations and potential confounding factors. Nevertheless, CVP remains one of the most commonly used informative clinical measures for assessing fluid tolerance and status in critically ill patients.

The use of CFV pulsatility as a method for assessing volume status also has several pitfalls and limitations.

Many critically ill patients encountered daily by intensivists in routine clinical practice may meet one or more of the exclusion criteria outlined in the methods section, which limits the applicability of femoral vein Doppler assessment in such settings and may render it inaccurate.

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**Conflicts of interest.** None.

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