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Correlation between venous excess ultrasound and acute kidney injury in patients with sepsis: A pilot study

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Abstract:

OBJECTIVES: Venous congestion is increasingly recognized as a contributor to acute kidney injury (AKI) in critically ill patients. The venous excess ultrasound (VExUS) score has been proposed to assess systemic venous congestion, but its role in emergency department (ED) sepsis remains underexplored. This pilot study investigated the association between VExUS scores, development of AKI, and other outcomes in septic ED patients.

METHODS: This was a prospective observational pilot study conducted from July 2023 to December 2023 in a university-affiliated tertiary ED. Adult patients with sepsis and an inferior vena cava diameter ≥2 cm after initial resuscitation were enrolled. VExUS was assessed at enrolment. The primary outcome was AKI within 72 h based on the Kidney Disease Improving Global Outcomes criteria. Secondary outcomes included mortality, organ dysfunction scores, and other outcomes. Associations were analyzed using Kendall's tau-b correlation and group comparisons with Mann–Whitney *U*-test.

RESULTS: Thirty-one patients were included, mean age 64.2 years. VExUS scores were Grade 1 in 64.5%, Grade 2 in 25.8%, and Grade 3 in 9.7%. Median VExUS scores did not differ between patients with and without AKI (2.0 [2.0–3.0] vs. 2.0 [2.0–3.0], $P = 0.729$), died and survived at 28 days (2.0 [2.0–2.25] vs. 2.0 [2.0–3.0], $P = 0.419$) or 60 days (2.0 [2.0–3.0] vs. 2.0 [2.0–3.0], $P = 0.693$). VExUS showed moderate correlations with creatinine ($\tau = 0.392$, $P = 0.004$), sequential organ failure assessment ($\tau = 0.267$, $P = 0.041$), and inotrope requirements ($\tau = 0.299$, $P = 0.041$).

CONCLUSION: In septic ED patients, VExUS was not associated with AKI or mortality but correlated with markers of organ dysfunction.

Keywords:

Acute kidney injury, Doppler ultrasound, mortality, multiple organ dysfunction syndrome, sepsis, venous congestion

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Introduction

Hemodynamic optimization is a cornerstone of sepsis resuscitation, focusing on maintaining adequate cardiac output and arterial blood pressure through fluid administration, vasopressors, and inotropes.[1] However, this approach often overlooks the complex interplay between cardiac function, venous capacitance, and organ perfusion pressure. Patients with sepsis often have coexisting conditions, such as right ventricular dysfunction, pulmonary hypertension, or inherent fluid overload, which may elevate venous pressure and impede organ perfusion.[2] Achieving optimal hemodynamic status necessitates a balance between optimising cardiac output and preventing overzealous fluid administration;[3] thus, the importance

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Box-ED Section

What is already known about this topic?

- Venous congestion is a recognised contributor to organ dysfunction in critical illness
- The Venous Excess Ultrasound score (VExUS) is a noninvasive method for assessing systemic venous congestion.

Why is this study important to readers?

- The utility of VExUS in patients with sepsis remains uncertain
- Understanding its role in this population may guide fluid management to mitigate the risk of AKI.

How was the study conducted?

- This was a single-center, prospective observational study involving adult patients with sepsis and an inferior vena cava diameter ≥2 cm.

What are the key findings?

- VExUS was not associated with acute kidney injury or mortality in patients with sepsis, but it did correlate with serum creatinine levels.

of considering both fluid responsiveness and fluid tolerance during sepsis resuscitation.[4-6] Elevated venous pressures impair organ perfusion and have been linked to adverse outcomes such as acute kidney injury (AKI) and cardiopulmonary complications.[7]

Point-of-care ultrasound (POCUS) is a valuable tool for assessing fluid status and venous congestion by evaluating the inferior vena cava (IVC) size and collapsibility.[8] However, this method has several limitations, including variations due to ventilator settings, intrinsic inspiratory efforts, cardiac conditions, and intra-abdominal pressure.[9] The venous excess ultrasound (VExUS) score addresses these limitations by incorporating Doppler indices from multiple venous territories, offering a more comprehensive evaluation of systemic congestion.[10] It integrates hepatic, portal, and intrarenal venous Doppler patterns with IVC measurements to offer a structured, noninvasive approach to grading venous congestion.[10] Higher VExUS grades have been associated with an increased risk of AKI, reduced renal perfusion, and multi-organ dysfunction in various critical care settings.[11-13]

VExUS was originally assessed in postoperative cardiac surgery patients,[14] and most studies on the application of VExUS primarily focus on perioperative and intensive care unit (ICU) populations.[10,11,14-17] Since its introduction, VExUS has been used to guide targeted fluid removal in cardiorenal syndrome, diagnosing subtypes of hyponatremia, predicting postoperative AKI, evaluating right ventricular dysfunction, and guiding decongestive therapy in heart failure.[10,14,15]

Emergency department (ED) patients, however, differ in hemodynamic physiology, illness trajectory, and resuscitation priorities, which may influence the applicability and clinical utility of VExUS in this setting. Sepsis represents an ideal clinical model to evaluate VExUS in the ED, as these patients are highly susceptible to venous congestion due to fluid resuscitation, vasoplegia, and vasopressor use. Understanding the relationship between VExUS and organ dysfunction in this population may inform fluid strategies and identify patients at risk of AKI. This prospective observational cohort study aims to investigate the association between VExUS scores and the development of AKI, along with other clinical outcomes in patients with sepsis presenting to the ED.

Methods

Study design and time period

This was a prospective observational study conducted at the ED of Universiti Malaya Medical Centre, Kuala Lumpur, Malaysia, from July 1, 2023 to December 31, 2023. Ethics approval to conduct this study was obtained from the institutional Medical Research Ethics Committee (MREC ID NO: 202269-11306) on June 27, 2022. Informed consent was obtained prior to recruitment.

Population

Adult patients presenting to the ED with a diagnosis of sepsis were screened for eligibility. Sepsis was defined based on the Third International Consensus Definitions for Sepsis and Septic Shock (Sepsis-3), as suspected or confirmed infection with a Sequential Organ Failure Assessment (SOFA) score of ≥2.[18] Patients were recruited if they exhibited an IVC diameter of ≥2 cm following the administration of 10–20 ml/kg of fluid bolus, in accordance with the original VExUS protocol by Beaubien-Souligny *et al*., where ≥2 cm is considered the entry threshold for assessing systemic venous congestion.[2] Exclusion criteria included conditions that could compromise ultrasound evaluation, such as pneumoperitoneum, subcutaneous emphysema, or significant abdominal wall thickness. In addition, patients experiencing obstructive, neurogenic, or cardiogenic shock, and those with a "do not resuscitate' order were excluded from the study.

Standard care for patients

All sepsis patients received isotonic crystalloid fluid boluses, based on clinical and POCUS assessments by the treating clinicians who were not involved in the study. POCUS assessment included bedside echocardiography for left ventricular ejection fraction, IVC diameter and collapsibility, and lung ultrasound for the presence of B lines. Fluid resuscitation was administered at a slower

rate, and vasopressors were initiated when the IVC measured ≥2 cm and lung ultrasound showed B lines. All patients received empirical antibiotics. Diuretics were administered if patients were deemed to be fluid overloaded.

Intervention

Upon patient recruitment, POCUS was performed using a GE Logiq P7 ultrasound system (GE Healthcare, Chicago, IL, USA) by a single trained investigator who was not involved in patient care. The investigator received competency training in VExUS image acquisition and interpretation under the supervision of a qualified critical care and emergency ultrasound fellow. The phased array probe was used for qualitative estimation of left ventricular ejection fraction, and the curvilinear probe was used for lung ultrasound and VExUS assessment. VExUS was performed according to the protocol by Beaubien-Souligny *et al*., incorporating IVC size and Doppler assessments of hepatic, portal, and renal veins [Figure 1].[14] The ultrasound operator was not blinded to baseline clinical status but was blinded to eventual patient outcomes, as VExUS assessments were performed prior to outcome determination.

Measurements

Patient demographic data (age and gender), clinical data (comorbidities, vital signs, diagnosis), and fluid balance within 24 h, laboratory data (hematological indices, serum electrolytes, renal and liver functions, coagulation profile, arterial blood gases, lactate, and C-reactive protein) were obtained from the electronic medical record. Left ventricular ejection fraction was reported as "normal," "mild dysfunction," "moderate dysfunction," and "severe dysfunction" according to Lam and Solomon[19] Lung ultrasound score was estimated based on the system by Gargani where the findings were classified as "absent" for ≤5 B lines, "mild" for 6–15 B lines, "moderate" for 16–30 B lines, and "severe" for >30 B lines.[20] VExUS was graded as grade 1, 2 (mild congestion), and 3 (severe congestion) according to the VExUS C grading system by Beaubien-Souligny *et al*.[2]

Outcome measures

The primary outcome measure was the development of AKI based on the kidney disease improving global outcomes (KDIGO) criteria. These criteria involve assessing the elevation of creatinine relative to the patient's baseline or monitoring urine output over 12–24 h.[21] Baseline creatinine levels were extracted from the electronic medical record, using values recorded within 6 months prior to presentation. If no baseline creatinine was available, a normal baseline was assumed if the patient had a normal creatinine level at presentation. In cases where creatinine was elevated, patients were assigned a KDIGO stage based on urine output. Other outcome measures were 28-and 60-day mortality, duration of ventilation, and hospital length of stay, SOFA score (at presentation and 72 h), and Acute Physiology and Chronic Health Evaluation (APACHE) II score (at presentation).

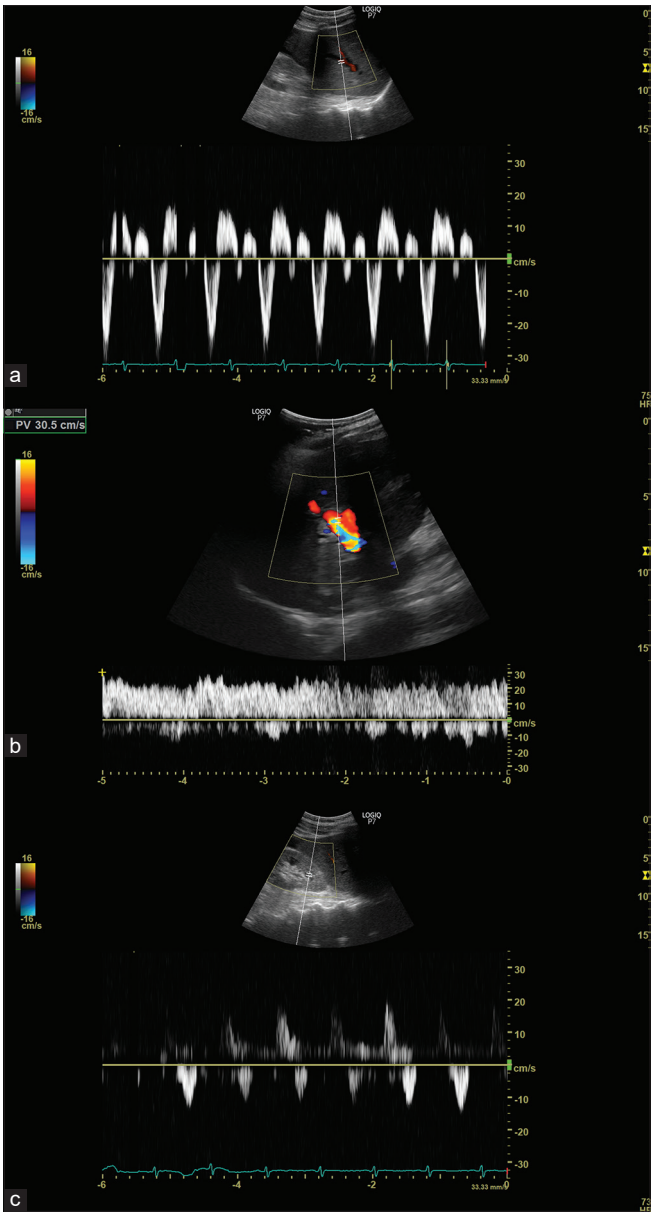

Figure 1: Doppler images obtained from a patient using the venous excess ultrasound protocol showing (a) mildly abnormal hepatic vein, (b) normal portal vein, and (c) mildly abnormal renal vein

Data analysis

Data were analyzed using IBM SPSS Statistics 29 (IBM Corp., Armonk, NY, USA). There were no missing data, as this was a prospective study. Normality of continuous variables was assessed with the Shapiro–Wilk test. Demographic data were presented as descriptive statistics. Parametric data were reported as means and

standard deviations, while nonparametric data were reported as medians and interquartile ranges (IQR). Categorical variables were presented as frequencies and percentages. Kendall's tau-b correlation coefficient was used to assess the strength and direction of association between the VExUS score and measured variables. This test was selected because VExUS scores are ordinal in nature, reflecting increasing severity of venous congestion, and because most of the measured variables were confirmed to be nonparametric using the Shapiro–Wilk test. One-sided tests were applied where we had *a priori* hypotheses that higher VExUS scores would correlate positively with worse markers of organ dysfunction.[11-13] Mann–Whitney *U*-test was used to compare VExUS scores between patients with and without AKI, and according to mortality status at 28 and 60 days.

Sample size

As no prior studies have examined the association between VExUS and AKI in patients with sepsis, this was designed as a pilot study. A target sample size of 31 patients was selected to assess feasibility and explore preliminary associations between VExUS scores, AKI, and other clinical outcomes.

Results

Out of 145 patients with sepsis, 114 patients were excluded due to an IVC diameter ≤2 cm (n = 104) and suboptimal ultrasonographic view (n = 10). This resulted in a final enrolment of 31 patients during the study period. Patient's demographic and clinical data are summarized in Table 1. The mean age was 64.2 ± 12.5 years, with a male predominance (51.6%). The most common infection sources were community-acquired pneumonia (58.1%) and urinary tract infections (22.6%). Diabetes mellitus (77.4%) and hypertension (80.6%) were the most prevalent comorbidities, with frequent use of antihypertensives (83.9%) and oral hypoglycaemics (64.5%). On admission, the median SOFA score was 5.0 (IQR 3.0–7.0), mean APACHE II score 15.6 ± 5.6, and median PaO_2/FiO_2 ratio 235.5 ± 81.9. Median creatinine was elevated at presentation, and inflammatory markers were raised. Kidney injury per KDIGO criteria was present in 77.4% of patients, though none required renal replacement therapy. Table 2 illustrates the laboratory and outcome data. At 24 h, patients had a mean fluid deficit of 497.5 ± 1370.2 ml. The median ventilator-free days was 7 (IQR 3–11), and hospital stay was 8 days (IQR 6–13). Mortality was 19.4% at 28 days and 32.3% at 60 days.

The POCUS findings in this study are reported in Table 3. Ejection fraction was preserved in 32.3% of the patients. Upon recruitment, 93.5% patients had B-lines, including 32.3% having severe B-lines. Pleural effusion was also prevalent, affecting 51.6% of the patients. VExUS score was Grade 1 in 20 patients (64.5%), Grade 2 in 8 patients (25.8%), and Grade 3 in 3 patients (9.7%). Abnormal flows in the hepatic, portal, and renal systems were seen in 64.5%, 54.8% and 74.2% of patients, respectively.

Table 4 presents the correlation between VExUS and various clinical parameters and patient outcomes. Correlations were assessed using Kendall's tau-b. There was no correlation between VExUS and KDIGO (τ = 0.225, P = 0.079). A moderate positive correlation was observed between VExUS and creatinine levels on presentation (τ = 0.392, P = 0.004), at 24 (τ = 0.338, P = 0.015), 48 (τ = 0.297, P = 0.025), and 72 h (τ = 0.273,

Table 1: Demographic and clinical data

Variables	Values (n=31), n (%)
Mean age, years (SD)	64.2 (12.5)
Male	16 (51.6)
Source of infection	
Community-acquired pneumonia	18 (58.1)
Urosepsis	7 (22.6)
Acute gastroenteritis	1 (3.2)
Cellulitis	2 (6.5)
Catheter-related bloodstream infection	3 (9.7)
Co-morbidities	
Diabetes	24 (77.4)
Hypertension	25 (80.6)
Heart disease	12 (38.7)
Kidney failure	14 (45.2)
Chronic lung disease	5 (16.1)
Stroke	5 (16.1)
Baseline medications	
Diuretics	12 (38.7)
Antihypertensives	26 (83.9)
Oral hypoglycemics	20 (64.5)
Vital signs on arrival	
Mean MAP, mmHg (SD)	97.6 (19.6)
Mean heart rate, beats per min (SD)	99.1 (25.0)
Mean respiratory rate, per min (SD)	27.7 (5.8)
Median temperature, °C (IQR)	36.7 (36.4–37.8)
Median oxygen saturation, % (IQR)	96.0 (90.0–100.0)
Median Glasgow coma scale (IQR)	15 (15–15)
Treatment in emergency department	
Oxygen therapy	
None	1 (3.2)
Oxygen supplement	15 (48.4)
Non-invasive ventilation	13 (41.9)
Invasive ventilation	2 (6.5)
Noradrenaline	
None	20 (64.5)
<0.5 µg/kg/h	9 (29.0)
≥0.5 µg/kg/h	2 (6.5)
Diuretics	24 (77.4)
Steroids	5 (16.1)
Antibiotics	31 (100)

SD=Standard deviation, IQR=Interquartile range, MAP=Mean arterial pressure

Table 2: Laboratory and outcome data

Variables	Values (*n*=31)
Laboratory parameters	
Mean hemoglobin, g/dL (SD)	10.4 (2.3)
Median white cell count, $\times10^9$/L (IQR)	12.2 (9.2–19.3)
Mean platelets, $\times10^9$/L (SD)	251.7 (136.6)
Median urea, mmol/L (IQR)	11.8 (7.2–19.7)
Median creatinine µmol/L (IQR)	
On presentation	191.0 (107.0–583.0)
Day 1	168.0 (80.0–432.5)
Day 2	162.0 (67.5–466.0)
Day 3	163.5 (71.8–462.0)
Median bilirubin, µmol/L (IQR)	11.0 (6.0–22.0)
Median aspartate transaminase (IQR)	41.0 (21.0–87.0)
Median alanine transaminase (IQR)	24.0 (15.0–50.0)
Mean albumin, g/L (SD)	28.5 (6.1)
Median C-reactive protein (IQR)	70.8 (21.7–163.7)
Mean lactate, mmol/L (SD)	2.7 (1.9)
Median pH (IQR)	7.40 (7.34–7.48)
Median PaO_2, mmHg (IQR)	97.6 (74.1–143.3)
Median $PaCO_2$, mmHg (IQR)	30.0 (24.0–34.5)
Median bicarbonate, mmol/L (IQR)	21.2 (16.5–24.0)
Mean base excess, mmol/L (SD)	–4.6 (9.00)
Mean PaO_2/FiO_2 ratio	235.5 (81.9)
KDIGO score, *n* (%)	
No AKI	8 (25.8)
Stage 1	8 (25.8)
Stage 2	3 (9.7)
Stage 3	6 (19.4)
ESRF	6 (19.4)
Median input, ml (IQR)	365 (160–791)
Median output, ml (IQR)	895 (300–1540)
Mean fluid balance, ml (SD)	–771.6 (1567.3)
Mean SOFA score at presentation (SD)	5.0 (2.9)
Median SOFA score at 72 h (IQR)	3.0 (1.8–5.0)
Mean APACHEII score (SD)	15.6 (5.6)
Median ventilator-free days, days (IQR)	7 (3–11)
Mortality, *n* (%)	
28-day mortality	6 (19.4)
60-day mortality	10 (32.3)
Median length-of-hospital stay, days (IQR)	8 (6–13)

SD: Standard deviation, IQR: Interquartile range, MAP: Mean arterial pressure, PaO_2: Partial pressure arterial oxygen, $PaCO_2$: Partial pressure arterial carbon dioxide, KDIGO: Kidney disease improving global outcomes, AKI: Acute kidney injury, SOFA: Sequential organ failure assessment, APACHE: Acute physiology and chronic health evaluation

$P = 0.033$). In addition, there was a moderate positive correlation between VExUS and SOFA score on presentation ($\tau = 0.267$, $P = 0.041$) as well as inotropic support requirement ($\tau = 0.299$, $P = 0.041$).

There were no statistically significant differences in median VExUS scores between patients with and without AKI, 2.0 (2.0–3.0) vs. 2.0 (2.0–3.0), $P = 0.729$. Similarly, median VExUS scores did not differ significantly between patients who died and those who survived at 28 days, 2.0 (2.0–2.25) vs. 2.0 (2.0–3.0), $P = 0.419$, nor at 60 days, 2.0 (2.0–3.0) vs. 2.0 (2.0–3.0), $P = 0.693$.

Table 3: Point-of-care ultrasound findings

Findings	*n* (%)
Ejection fraction	
Normal	10 (32.3)
Mild dysfunction	13 (41.9)
Moderate dysfunction	3 (9.7)
Severe dysfunction	5 (16.1)
Presence of pericardial effusion	2 (6.5)
B-lines	
Absent	2 (6.5)
Mild	10 (32.3)
Moderate	9 (29.0)
Severe	10 (32.3)
Presence of pleural effusion	16 (51.6)
IVC variability	
No variability	28 (90.3)
<50% collapsible	3 (9.7)
Hepatic vein Doppler	
Normal	11 (35.5)
Mildly abnormal	12 (38.7)
Severe abnormal	8 (25.8)
Portal vein Doppler	
Normal	14 (45.2)
Mildly abnormal	16 (51.6)
Severe abnormal	1 (3.2)
Renal vein Doppler	
Normal	8 (25.8)
Mildly abnormal	18 (58.1)
Severe abnormal	5 (16.1)
VExUS, *n* (%)	
Grade 1	20 (64.5)
Grade 2	8 (25.8)
Grade 3	3 (9.7)

IVC: Inferior vena cava, VExUS: Venous excess ultrasound

Discussion

To our knowledge, this is the first study investigating VExUS in predicting clinical outcomes in patients with sepsis presenting to the ED. This study did not find an association between VExUS and AKI, aligning with some previous research while contrasting with others.[11,13-16,22,23] The multifaceted pathogenesis of AKI in sepsis, such as microcirculatory dysfunction, cellular metabolic reprogramming, dysregulated inflammatory responses, with venous congestion being a possible contributing factor, added complexity to VExUS interpretation.[2,22,23] Despite no correlation with AKI, VExUS exhibited a moderate association with creatinine levels in the first 72 h. This suggests that venous congestion in our study population is more prevalent in patients with inherent kidney dysfunction, similar to the review by Deschamps *et al*.[24] Interestingly, Klompmaker *et al*. reported that VExUS grade ≥2 was associated with MAKE-30, a composite measure of adverse kidney outcomes, suggesting that VExUS may still capture broader haemodynamic stress even when not directly predictive of AKI.[25]

Table 4: Correlation between venous excess ultrasound and clinical parameters

Parameters	Correlation coefficient, τ	*P*
Lung		
PaO_2/FiO_2 ratio	0.030[a]	0.420
Oxygen requirement	−0.197[a]	0.219
Ventilation requirement	0.196[a]	0.254
B-line presence	0.108[a]	0.255
Heart		
Inotropic support requirement	0.299[a]	0.041
Ejection fraction	0.102[a]	0.533
Liver		
Alanine transaminase	0.048[a]	0.373
Aspartate transferase	0.045[a]	0.381
Alkaline phosphatase	0.270[a]	0.033
International normalized ratio	0.258[a]	0.053
Kidney		
KDIGO score	0.225[a]	0.079
Creatinine on presentation	0.392[a]	0.004
Creatinine at 24 h	0.338[a]	0.015
Creatinine at 48 h	0.297[a]	0.025
Creatinine at 72 h	0.273[a]	0.033
Composite scores		
SOFA on presentation	0.267[a]	0.041
δ SOFA score	0.115[b]	0.467
APACHE II on presentation	0.229[a]	0.064
δ APACHE II	0.075[b]	0.626
Length-of-stay	0.064[a]	0.335
Ventilator-free days	0.190[a]	0.104

[a]One-tailed, [b]Two-tailed. Correlation coefficient, τ, was analysed with Kendall's tau-b. VExUS: Venous excess ultrasound, KDIGO: Kidney disease improving global outcomes, SOFA: Sequential organ failure assessment, APACHE=Acute physiology and chronic health evaluation

A key consideration when comparing our findings to previous studies is the inclusion criteria for IVC diameter. Prior studies included patients with an IVC diameter of <2 cm, whereas our study focused solely on patients with an IVC diameter of ≥2 cm.[15,22] This threshold was chosen based on the original VExUS study, where it was considered the "entry point" for assessment. This decision, while methodologically sound, limits generalisability and underscores the need for future studies to evaluate VExUS performance in patients with IVC <2 cm to determine whether this exclusion impacts diagnostic accuracy. In addition, while the VExUS score is a valuable tool for assessing venous congestion, its applicability in patients with sepsis may be limited due to vasoplegia resulting from glycocalyx shedding, which contributes to acute circulatory failure.[26,27] This circulatory dysfunction may alter venous flow patterns, potentially affecting VExUS interpretation. Furthermore, vasopressor administration, by inducing peripheral vasoconstriction and increasing venous return, may inadvertently influence venous Doppler flow patterns, further complicating assessment.[26] The use of standardized image acquisition protocols and experienced operators, however, can partially mitigate these confounding effects and may enhance reproducibility in future studies. Notably, Elfeky *et al*. demonstrated that repeated VExUS assessments in septic shock patients improved the detection of evolving venous congestion and strengthened the association between higher VExUS scores and adverse outcomes.[28] This highlights that a single-time VExUS measurement, as used in our study, may underestimate dynamic hemodynamic changes in sepsis and warrants further evaluation in future studies.

The majority of patients in this study had a VExUS score of 1, which likely reflects the practice of judicious fluid administration, resulting in less frequent occurrences of fluid overload.[29] This approach, which relies on hemodynamic monitoring with clinical and POCUS assessments, may explain the reduced incidence of venous congestion in our population. Furthermore, a significant proportion of patients (77.4%) received diuretics, leading to a significant negative fluid balance within the first 24 h of presentation. As fluid removal during dialysis was associated with improved VExUS scores, these practices could potentially obscure the true relationship between venous congestion identified by VExUS.[30]

In this study, we found that VExUS scores have a moderate positive correlation with SOFA scores, dose of inotropes, and alkaline phosphatase levels in patients with sepsis. These findings suggest that higher VExUS scores are associated with greater overall organ dysfunction, including renal, cardiovascular, and hepatic dysfunction.[31] This correlation suggests that the VExUS score may serve as a valuable noninvasive tool for evaluating and monitoring the severity of organ dysfunction in patients with sepsis. Integrating VExUS alongside other POCUS parameters and clinical scores may serve as an adjunctive tool in the ED to support bedside decision-making, particularly in identifying patients at higher risk of early organ dysfunction and in guiding fluid administration or diuretic use. While previous studies have reported inconsistent findings regarding the association between VExUS scores and mortality, our study found no correlation between VExUS scores and 28-day or 60-day mortality. Further research is needed to confirm these findings and to explore their broader clinical implications.[22,23]

Limitations

This pilot study has several limitations. First, the single-center design restricts the generalizability of our findings, as septic shock patients are managed in diverse settings across institutions, with potentially different admission practices, particularly regarding ICU utilization. Second, the convenience sampling method employed, limited sample size, and low

prevalence of high VExUS scores (only three patients with grade 3) may have restricted the statistical power to detect significant associations. Third, the absence of a control group without sepsis or with lower risk for venous congestion limits contextual interpretation of our findings, and future studies should incorporate an appropriate comparator arm. Fourth, all VExUS assessments were performed by a single, trained operator, ensuring procedural consistency but preventing assessment of interobserver reliability. The operator was also not blinded to clinical status or outcomes, although scans were completed prior to outcome ascertainment, which mitigates bias risk. Fifthly, VExUS was only performed once due to practical constraints in the fast-paced and time-sensitive ED setting. Given the dynamic nature of venous congestion, repeated assessments might better reflect evolving hemodynamic changes and improve predictive accuracy. Sixthly, excluding patients with IVC diameters <2 cm may limit the applicability of our findings to hypovolemic septic populations. Finally, given the small sample size, we did not perform full multivariate modeling, as this would have been statistically underpowered and potentially misleading. This approach aligns with the pilot nature of the study and the intent to inform larger, adequately powered investigations. Despite these limitations, this pilot study provides valuable insights for designing future studies with larger, multicenter samples to definitively assess the utility of VExUS for fluid management in patients with septic shock.

Conclusion

In this pilot study of septic ED patients, high-grade venous congestion was uncommon, and initial VExUS grading was not predictive of AKI or mortality. Nevertheless, the moderate correlations between VExUS, creatinine, SOFA scores, and inotrope use suggest that VExUS may provide complementary information on multi-organ dysfunction. Future multicenter studies with larger sample sizes and serial VExUS assessments are warranted to assess the role of VExUS in guiding fluid management for patients with sepsis.

Author contribution statement

MHH: conceptualization, data curation, formal analysis, investigation, methodology, project administration, resources, visualization, writing original draft. MNA: formal analysis, methodology, project administration, resources, supervision, validation, writing review and editing. AB: investigation, methodology, project administration, validation, writing review and editing. AZ: resources, supervision, validation, writing original draft, review and editing. KP: conceptualization, formal analysis, funding acquisition, methodology, project administration, resources, supervision, validation, visualization, writing review and editing. KP is the guarantor and takes responsibility for the integrity of the work as a whole.

Conflicts of interest

None Declared.

Ethical approval

Ethics approval to conduct this study was obtained from the Universiti Malaya Medical Centre Medical Research Ethics Committee (MREC ID NO: 202269-11306) on 27th June 2022.

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