



Review

Role of point-of-care ultrasound in septic shock

*El papel de la ecografía en el punto de atención en el shock séptico*Marta Torres-Arrese^a, Gonzalo García-Casasola^a, Rafael Blancas^{b,*}^a Department of Emergency Medicine, Hospital Universitario Fundación de Alcorcón, Calle Budapest 1, 28922 Alcorcón, Madrid, Spain^b Department of Critical Care, Hospital Universitario del Tajo, Avda. Amazonas Central s/n, Aranjuez, Madrid, Spain

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ABSTRACT

Sepsis and septic shock are critical medical emergencies with high rates of morbidity and mortality. Point-of-care ultrasound (POCUS) has been demonstrated to be a vital instrument in the management of these patients, facilitating dynamic haemodynamic assessment and prompting immediate clinical decision-making. POCUS has been demonstrated to facilitate early identification of shock type, assessment of fluid response, and detection of infectious foci in unstable patients. It is evident that ultrasound protocols, including RUSH and VExUS, offer a systematic approach to the assessment of perfusion, venous congestion, and fluid overload. Recent studies have validated the usefulness of parameters such as left ventricular outflow tract velocity time integral (LVOT-VTI) and inferior vena cava (IVC) collapse to predict fluid response. However, it is imperative that its limitations be considered in the clinical context. In the context of etiological diagnosis, the use of pulmonary ultrasound has been shown to be superior to radiography in terms of the detection of pneumonia and pleural effusions. Concurrently, the use of abdominal and cardiac ultrasound has been demonstrated to enhance the identification of urological infections, biliary infections, abscesses, and indications of endocarditis. Despite its dependence on the operator, the extant evidence supports the systematic use of POCUS in the comprehensive assessment of the septic patient, being crucial for targeted and personalised resuscitation. Further research is necessary to standardise its application and demonstrate its benefits in clinical outcomes.

RESUMEN

La sepsis y el *shock* séptico representan emergencias médicas críticas con alta morbilidad y mortalidad general. La ecografía de cabecera (POCUS) se ha consolidado como una herramienta esencial en su manejo, permitiendo la evaluación hemodinámica y orientando la toma de decisiones clínicas inmediatas. POCUS facilita la identificación temprana del tipo de *shock*, la evaluación de la respuesta a la administración de fluidos y la detección de focos infecciosos en pacientes inestables. Los protocolos de ultrasonido como RUSH y VExUS proporcionan enfoques estructurados para la evaluación de la perfusión, la congestión venosa y la sobrecarga de líquidos. Estudios recientes validan la utilidad de parámetros como la integral velocidad-tiempo de velocidad integral en el tracto de salida del ventrículo izquierdo (IVT-TSVI) y el colapso de la vena cava inferior (VCI) para predecir la respuesta de los líquidos, aunque sus limitaciones deben considerarse según el contexto clínico. En el diagnóstico etiológico, la ecografía pulmonar ha demostrado superioridad sobre la radiografía en la detección de neumonía y derrames pleurales, mientras que la ecografía abdominal y cardíaca puede identificar infecciones urológicas y biliares, abscesos y signos de endocarditis. A pesar de su dependencia del operador, la evidencia apoya el uso sistemático de POCUS en la evaluación integral del paciente séptico, siendo crucial para la reanimación dirigida y personalizada. Se necesitan más estudios de investigación para estandarizar su aplicación y demostrar los beneficios en los resultados clínicos.

Palabras clave:

Sepsis
POCUS (Point-of-Care Ultrasound)
Shock séptico
Valoración hemodinámica
Diagnóstico precoz

Introduction

Despite the advances in antimicrobial therapy and improved life-sustaining therapies, sepsis and septic shock remain significant causes of morbidity and mortality worldwide. Sepsis is defined as a dysreg-

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ulated host response to infection, which can result in life-threatening organ dysfunction and can progress rapidly, especially in patients with underlying comorbidities.¹ Sepsis may be accompanied by septic shock, which is characterised by profound circulatory, cellular, and metabolic abnormalities. These abnormalities necessitate the administration of vasopressor support and are concomitant with elevated lactate levels, indicative of impaired tissue perfusion. In this context, the integration of point-of-care ultrasound (POCUS) into the clinical assessment and management of sepsis has become a valuable adjunct to traditional diagnostic and therapeutic strategies.

POCUS is a non-invasive, real-time, bedside imaging modality that has been widely implemented in septic patients due to its versatility, repeatability, and ability to facilitate immediate clinical decisions. In contradistinction to conventional imaging techniques, POCUS facilitates the dynamic assessment of the patient's haemodynamic status, allows the guidance of resuscitation procedures, and allows the observation of responses to interventions at any stage of the patient's progression.² This is particularly salient in the initial management of septic shock, where timely decisions regarding volume administration, the initiation and maintenance of vasoactive drugs, and the control of sepsis have been shown to have a substantial impact on outcomes.

The use of POCUS in haemodynamic evaluation encompasses a variety of applications, including the assessment of cardiac function, intravascular repletion status, and systemic vascular resistance. The inferior vena cava (IVC) is a widely utilised surrogate for intravascular volume, and its collapsibility has been extensively studied as a predictor of fluid response. However, its interpretation requires contextual integration with ventilatory mode, intra-abdominal pressure, and right heart function.

Lung ultrasound (LUS) further contributes to the diagnostic arsenal of sepsis by identifying respiratory foci of infection, such as pneumonia, pleural effusions, or acute respiratory distress syndrome (ARDS), with sensitivity and specificity that are superior to those of conventional thoracic radiology.³

It is imperative that abdominal ultrasound is performed to identify intra-abdominal infectious foci, including biliary sepsis, intra-abdominal abscesses, and urinary tract obstruction. It has been demonstrated that POCUS can also be utilised to facilitate procedures such as percutaneous drains and vascular access.⁴

The present review has been conducted with the aim of examining the current evidence on the usefulness of point-of-care ultrasound in the diagnosis and management of sepsis and septic shock. The role of POCUS in haemodynamic monitoring, foci identification, and management of volume administration in the setting of sepsis and septic shock is considered.

Methods

A narrative review of the scientific literature on the role of point-of-care ultrasound (POCUS) in the diagnosis and management of septic shock was conducted. The literature search was conducted in the PubMed/MEDLINE, Embase and Cochrane Library databases, encompassing publications up to May 2025, with no initial restriction on the date of publication. Combinations of free terms and MeSH descriptors related to 'sepsis', 'septic shock', 'point-of-care ultrasound', 'POCUS', 'haemodynamic monitoring' and 'early diagnosis' were used.

Priority was given to original studies, systematic reviews, meta-analyses, and clinical practice guidelines that provided relevant evidence on the usefulness of POCUS in haemodynamic assessment, early detection of shock type, and identification of infectious foci. A selection of seminal articles, as referenced in recent publications and consensus papers from scientific societies, have also been included.

The selection of studies was carried out independently by the authors, considering their relevance, methodological quality and clinical relevance. No exclusion criteria were applied on the basis of language,

provided the full text was accessible. In view of the narrative character of the review, a systematic analysis of the quality or quantitative synthesis of the results was not undertaken. However, an attempt was made to integrate the most current evidence with the greatest clinical impact.

Furthermore, it is specified that the refinement of the search was achieved through the utilisation of Boolean operators (AND/OR). A further procedure entailed the screening of reference lists of key articles and consensus statements from scientific societies, with a view to identifying additional relevant studies. In the course of the discussion of the findings, an explicit distinction was sought between the various study designs (e.g. observational studies versus randomised controlled trials).

It is hereby confirmed that all disclosures and ethical statements are accurate. As this is a narrative review, formal approval from an institutional review board or protocol is not typically required for the review process. Nevertheless, the methodological approach employed is characterised by transparency.

The role of point-of-care ultrasound in the early diagnosis of septic shock

Early diagnosis is of the utmost importance in sepsis, as delays in antimicrobial therapy and source control have been shown to result in a significant increase in mortality. POCUS facilitates rapid differentiation of shock types, accelerating diagnosis and providing immediate insight into the patient's pathophysiology, as demonstrated by Jones et al.^{3,5} (see Fig. 1). Multiorgan ultrasound protocols, including the RUSH (Rapid Ultrasound in Shock) test, have exhibited high sensitivity (Sn) and specificity (Sp) in identifying shock etiologies.^{4,6} A meta-analysis by Keikha et al. reported that RUSH had an area under the receiver operating characteristic curve (AUC) of 0.98 to differentiate shock types.⁷ Specifically, the distributive shock yielded an area under the curve (AUC) of 0.97, with a high specificity [1.00 (0.97–1.00)] and a high positive likelihood ratio [51.32 (10.17–258.96)]. However, its sensitivity was lower [0.73 (0.50–0.89)] probably due to the absence of pathognomonic ultrasound findings. Notwithstanding this fact, the RUSH protocol maintains a specificity of > 90% and sensitivity of > 89% for other types of shock, thus rendering it a valuable first-line diagnostic tool. The sensitivity of the system is reduced for mixed shock, presumably due to the inherent complexity of the system. When multimodal POCUS is applied in emergency departments, it has been demonstrated to improve the recognition of undifferentiated hypotension, including septic shock.⁸ In the cohort of Volpicelli et al., POCUS-based diagnosis was accurate in 87.5% of patients.⁹

Ultrasound findings indicative of septic shock

Although septic shock is a clinical diagnosis, it can be challenging to assess in specific populations, such as the elderly, due to physiological changes and polypharmacy. The identification of the infectious source is known to increase diagnostic specificity; however, this is not always feasible. In such cases, clinicians should be able to identify "red flag" ultrasound findings that increase suspicion of septic shock (Fig. 2).

- a) It is evident that the diameter of the IVC is reduced, accompanied by significant respiratory variability, as evidenced by the presence of > 50% collapsibility with respiratory effort. This observation suggests that the effective circulating volume is low. However, this cannot exclude the possibility of distributive shock, especially in patients with septic cardiomyopathy or pre-existing heart disease, who may present with distended IVC.¹⁰
- b) Hyperdynamic left ventricle (LV): A heightened ejection velocity and diminished end-diastolic size are frequently observed in distributive shock, a condition precipitated by diminished systemic vascular resistance. In certain instances, the process of "kissing" of the ventricular walls has been observed. Objectively, an increase in the integral velocity-time left ventricular outflow tract (LVOT-VTI) of more than 18 cm has been shown to suggest distributive shock.¹¹ Conversely, in

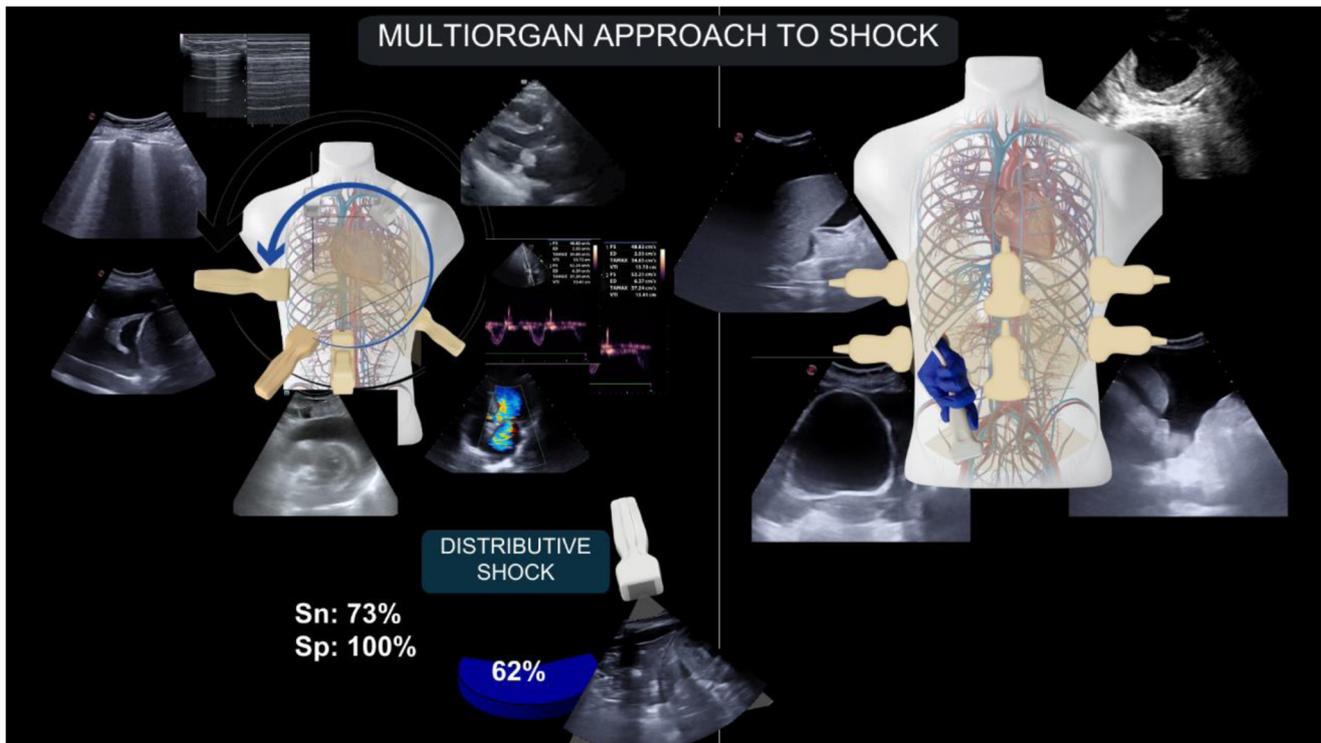


Fig. 1. Assessment of multiorgan failure with POCUS. Ultrasound examination of various organs in patients with shock. It includes chest, cardiac, abdominal, urinary tract and inferior vena cava collapsibility. This assessment has a high Sp for the diagnosis of distributive shock. Sn: sensitivity; Sp: specificity.

cases of hypovolemia, while the phenomenon of “kissing” of the walls can be observed, the LVOT-VTI remains low due to reduced preload. In the absence of underlying heart disease, echocardiographic estimates of left ventricular filling pressure are usually within normal limits, with a transmitral E -wave velocity of less than 50 cm/s and an E/e' ratio of less than 14, as assessed by pulsed Doppler and tissue Doppler, respectively. Furthermore, it is imperative to base decisions on a range of ultrasound parameters, as the presence of mixed shock with a cardiogenic component may complicate assessment.

- c) Hyperdynamic right ventricle (RV): In circumstances where conventional LVOT-VTI is not obtainable, the short-axis subxiphoid view is typically a more viable option. This view provides information about left ventricular function and allows for the assessment of the right ventricular outflow tract velocity-time integral (RVOT-VTI). A RVOT-VTI greater than 15 cm is indicative of distributive shock. Short-axis subxiphoid views have been demonstrated to be particularly useful in technically challenging cases.¹²
- d) The exclusion of other potential causes of shock is a key finding of POCUS in the context of septic shock. This is evidenced by the absence of ultrasound signs of other types of shock, when considered in conjunction with the patient's compatible clinical signs.

Understanding cardiac function in sepsis

Early assessment of cardiac function is imperative. A study reported LV and RV dysfunction in 63% and 48% of septic patients, respectively.¹³ The recognition of pre-existing cardiomyopathies and septic cardiomyopathy is paramount for the prognosis and treatment of the condition. It is imperative to note that these conditions have the potential to transform distributive shock into mixed shock, necessitating adjustments in vasopressor therapy (e.g., the administration of dobutamine or the transition to epinephrine) and a heightened level of caution regarding fluid administration. Consequently, five-view bedside echocardiography should be the primary imaging investigation. The visual estimation of LV function is generally considered adequate in experienced practitioners. In the event of the endocardial edges being

visible, the Simpson biplane method can be employed. Septic cardiomyopathy may present as global dysfunction or apical bulging (Takotsubo syndrome). In patients diagnosed with coronary artery disease, segmental abnormalities in wall movement may be indicative of ischaemia.

It is imperative to ascertain whether the right ventricle is also affected, in which case it is equally important to identify the nature of any dysfunction. A tricuspid annular plane systolic excursion (TAPSE) of less than 17 mm, RV enlargement, significant tricuspid regurgitation (TR), plethoric IVC, and elevated pulmonary pressure are suggestive parameters. Furthermore, visual evaluation of valve integrity is imperative.

The diagnosis of severe aortic stenosis should be suspected if auscultation reveals a systolic murmur radiating to the neck and the absence of the second heart sound. This suspicion can also be confirmed using two-dimensional parasternal views and a continuous-wave Doppler. Whilst a full cardiological evaluation is advised, general practitioners should estimate severity using the maximum aortic jet velocity (≥ 4.0 m/s) and mean gradient (≥ 40 mmHg). The most effective method for achieving this is to employ a five-chamber apical view, utilising a low gain, high wall filter, and a timescale of 50–100 mm/s.

Colour Doppler imaging has been found to be a useful diagnostic tool in the identification of mitral valve rupture. Furthermore, on occasion, an endocarditis valve vegetation with significant valve regurgitation may be identified.^{14,15}

Assessment of fluid response and tolerance

Resuscitation is a fundamental component of the management of sepsis in its early stages. In the context of sepsis, approximately 50% of patients exhibit a positive response to a fluid bolus, and of these, half will eventually become unresponsive after 30 min.^{16,17} Excessive fluid administration has been demonstrated to result in tissue oedema, renal organ dysfunction, and inferior outcomes, particularly in patients who do not respond to fluids.¹⁸ POCUS offers dynamic bedside tools to assess whether an additional fluid will increase cardiac output and, just as importantly, whether the patient can tolerate it.

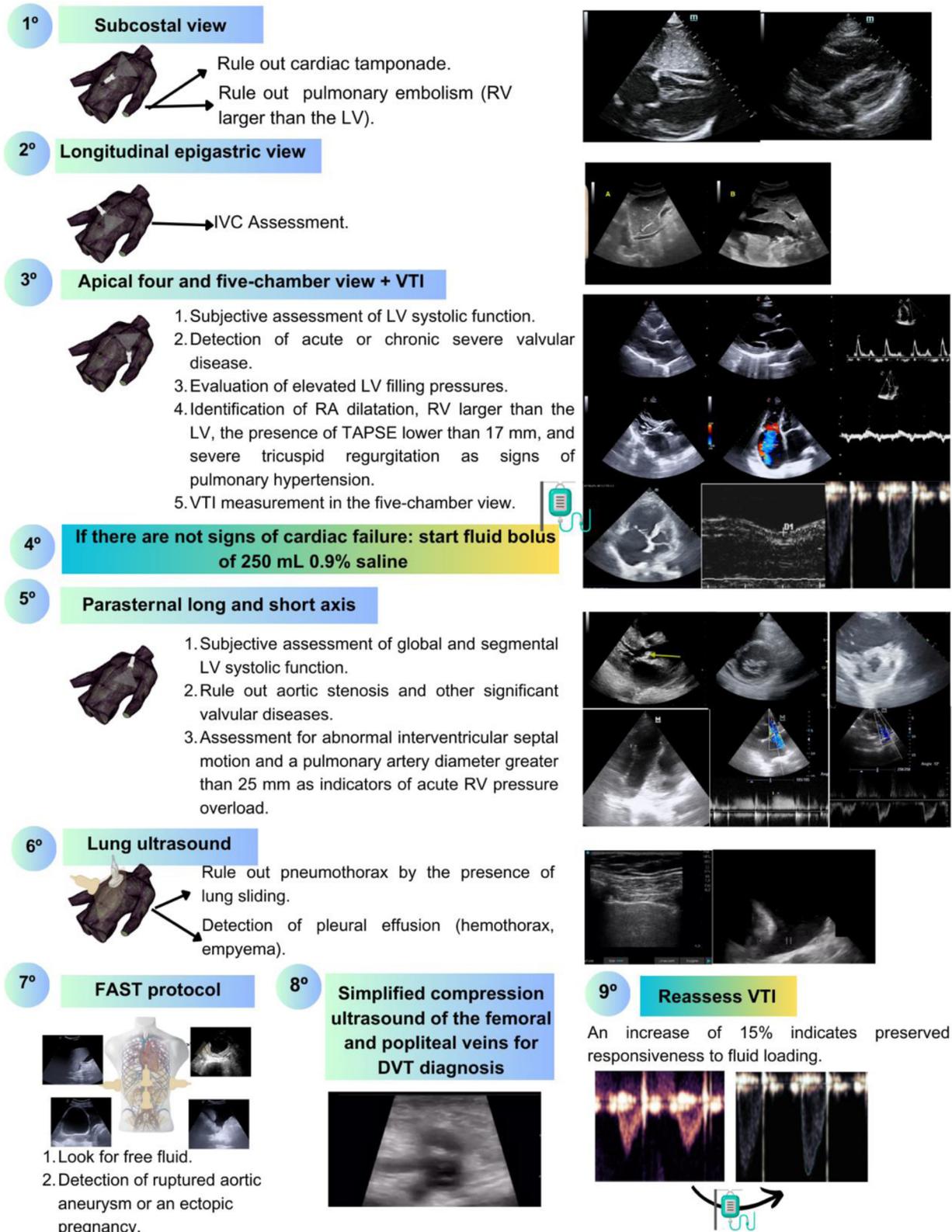


Fig. 2. Shock assessment of shock through point-of-care ultrasound. Different echocardiographic and thoracic planes to be assessed in shock by ultrasound. This scan allows assessment of pulmonary artery systolic pressure and LVOT VTI as haemodynamic parameters. LVOT: left ventricular outflow tract; VTI: velocity time integral; RA: right auricle; LA: left auricle; RV: right ventricle; LV: left ventricle; DVT: deep venous thrombosis.

The term ‘fluid response’ is defined as an increase in stroke volume greater than 10% following a fluid test.¹⁹ The utilisation of different ultrasound parameters has been demonstrated to facilitate the prediction of this phenomenon (cf. Fig. 3).

a) The fluid test (administration of 250–500 mL of bolus crystalloids) or the passive leg raise test (60–180 s of 45° elevation in a supine position, from a semi-seated position) is considered positive if cardiac output (CO), LVOT-VTI, or RVOT-VTI increases by at least 15%.

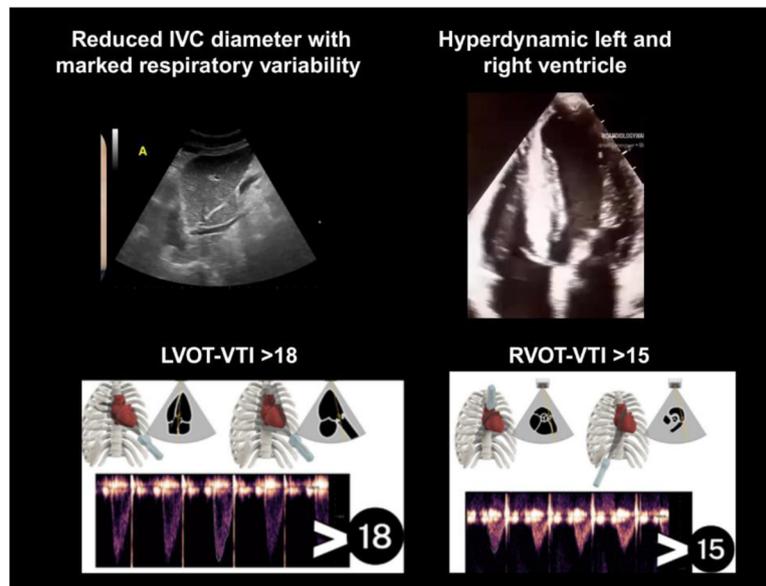


Fig. 3. Findings of distributive shock by ultrasound. The existence of distributive shock can be assessed by collapsibility of the inferior vena cava during the respiratory cycle and VTI in RVOT and LVOT. The subcostal plane may be the only one that can be explored in some cases and its transverse plane may be the one that allows this measurement. Kissing of the LV may result in poor diastolic filling of the LV. VTI: velocity time integral; LVOT: velocity time integral; RVOT: right ventricular outflow tract; LV: left ventricle.

The evaluation of the variation of the LVOT-VTI following a fluid test has a Sn of 85% and a Sp of 91%, with an area under the curve greater than 0.9 to detect fluid response.²⁰ Furthermore, the findings appear to be in alignment with those of stroke volume variation, cardiac index variation, and pulse pressure variation, as evidenced by the pulse index contour continuous CO (PiCCO).^{20–22} Ultimately, while the evaluation of CO by ultrasound can prove beneficial, it is a complex process. The calculation involves the multiplication of two variables: the stroke volume, which is the product of the LVOT area and the LVOT-VTI, and the heart rate. The accurate measurement of the internal edge-to-edge distance in the LVOT (approximately 3–10 mm from the aortic valve during mesosystole in the long parasternal axis) is imperative for this calculation. The inter-observer variability in this measurement is high and is a constant in the patient. Consequently, the simple variation of the LVOT-VTI is generally preferred.

- b) The predictive value of IVC variation for fluid response is inconsistent across studies. It is important to note that a number of factors may be responsible for these discrepancies. These include elevated intra-abdominal pressure, right ventricular dysfunction, septic cardiomyopathy, and differences in breathing pattern (spontaneous breathing versus mechanical ventilation). The variability of the data is influenced by the type of patients included in the studies, ranging from critically ill individuals on mechanical ventilation to spontaneously breathing patients in intermediate care settings, and even surgical patients. These variables have the capacity to alter the diameter of the IVC and its respiratory variation, with the potential to result in false-positive or negative findings if not interpreted within the broader haemodynamic context. In the case of mechanically ventilated patients, the term ‘ δIVC ’ is used to denote inferior vena cava compliance [$\delta IVC = ((D_{max} - D_{min})/D_{min}) \times 100$], whereas in the case of spontaneously breathing patients, the term ‘ $cIVC$ ’ is used to denote inferior vena cava collapsibility [$cIVC = ((D_{max} - D_{min})/D_{max}) \times 100$]. In the event of threshold values being suggested, consideration should be given to the variability of such values across studies. A δIVC greater than approximately 15–18% in mechanically ventilated patients (i.e. those not exhibiting spontaneous respiratory effort) and a $cIVC$ greater than 40–42% in spontaneously breathing patients

are commonly associated with a high probability of fluid response. It is imperative to interpret these cut-off points within the framework of the patient’s clinical condition and the technical factors that may influence the measurement. These factors encompass the measurement site, respiratory effort, intra-abdominal pressure, and right heart function. A recent systematic review by Zhang et al. concluded, after evaluating 15 articles focused on δIVC and six focused on $cIVC$, that the Sn and Sp of δIVC were 0.79 and 0.82, respectively, and the Sn and Sp of $cIVC$ were 0.92 and 0.93, respectively. In patients receiving mechanical ventilation, a tidal volume of at least 8 mL/kg or positive end-expiratory pressure (PEEP) of at least 5 cmH₂O could compromise the effectiveness of fluid resuscitation by decreasing cardiac return due to increased right atrial pressure. However, these effects were not confirmed in the subgroup analysis. In the context of sepsis, a δIVC greater than 16.5% demonstrated a Sn of 0.69.²³

Lung ultrasound is imperative for the early detection of preclinical or clinical fluid overload. The detection of extravascular lung water (EVLW) is achieved through the visualisation of B lines, which are perpendicular to the pleural line. The development of EVLW can be attributed to a variety of underlying conditions, including heart failure and acute respiratory distress syndrome (ARDS). These pathologies result in alterations in oncotic pressure, precipitated by an inflammatory storm and subsequent disruption of the alveolar-capillary barrier. It is imperative to exercise extreme caution with fluid therapy and to prioritise the use of vasoactive drugs. The prognostic value of EVLW has been demonstrated in predicting mortality and multi-organ failure. The volume of lung water (VLW) is measured by transpulmonary thermodilution; however, there is a strong correlation with the detection of B-lines, with the latter method proving superior to radiography.^{24,25} Indeed, a correlation has been demonstrated between the presence of B-lines and mortality.²⁶ There are ongoing studies on multi-organ pulsed-wave Doppler assessment and venous excess ultrasound (VExUS) score, but current evidence is limited. Prager et al. detected severe congestion (EV \times US 3) in 19% of patients admitted with sepsis on the first day of admission. The VExUS 3 study, which included only 75 patients, demonstrated a statistically significant association with renal replacement therapy (hazard ratio 3.35; 95% CI, 0.94–11.88; $p = 0.06$).

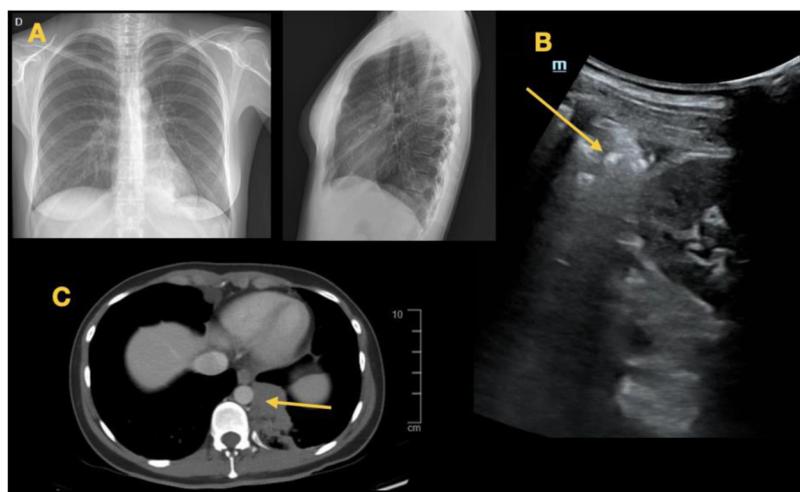


Fig. 4. Pneumonia examined by different imaging tests. Pneumonia in the left lung base in a young woman with haemodynamic instability. The chest X-ray (A) appears normal. The pneumonic infiltrate (yellow arrow) is visible on lung ultrasound (B) and thoracic CT scan (C).

Further research is required for both invasive ventilated and spontaneously breathing patients.²⁷

Suggested monitoring scheme

Despite the absence of high-quality studies that have established the optimal frequency of POCUS assessment in septic patients, clinical practice supports a dynamic and goal-oriented approach. A pragmatic approach to the management of these patients could involve an initial assessment at the time of presentation, followed by a re-assessment after a fluid bolus or haemodynamic intervention. Further examinations should be considered in cases of clinical deterioration or lack of expected improvement. It is recommended that a multi-organ ultrasound evaluation be performed at least once daily as an adjunct to the physical examination, with the aim of increasing its sensitivity and specificity. This approach facilitates the early detection of evolving haemodynamic changes and enables the early adaptation of the therapeutic strategy.

Usefulness of ultrasound in identifying the source of sepsis

In most series, the primary sources of sepsis are respiratory, urinary and intra-abdominal. Rarer causes of such infections include skin and soft tissue infections, meningitis, and catheter-associated infections.^{28,29}

The identification of the source of sepsis is of crucial importance in selecting the most appropriate antibiotic therapy and in assessing the necessity for invasive procedures (e.g. microbiological sampling, drainage of abscesses at any site, thoracocentesis in cases of empyema, paracentesis, etc.). The initial diagnostic tools used to determine the aetiology of sepsis (e.g. chest X-rays, laboratory tests, and microbiological studies such as blood and urine cultures) are not always sufficient for accurate diagnosis. In such cases, a thoracoabdominal computed tomography (CT) scan is often required, although this procedure poses technical difficulties in clinically unstable patients who require continuous monitoring. In such cases, the utilisation of bedside ultrasound has been demonstrated to be a beneficial intervention. Multi-organ ultrasound, as previously outlined in this review, should be performed, encompassing lung, abdominal and cardiac ultrasound.

Lung ultrasound

Pneumonia, whether community-acquired or nosocomial, is one of the most common causes of septic shock.^{28,29} The diagnostic yield of plain chest X-rays is suboptimal in critically ill patients with limited mobility and cooperation.³⁰ The reliability of LUS in diagnosing

pneumonia is well established.^{31,32} A proper exploration technique is essential, involving systematic sweeps of the posterior, lateral, and anterior aspects of both lungs. A prevalent error, especially in unstable and monitored patients, is an inadequate evaluation of the posteroinferior lobes. It is important to note that consolidations in these regions may not be discernible on chest radiographs. Furthermore, the presence of small pleural effusions may be inadvertently overlooked, as illustrated in Fig. 4. LUS has been shown to have diagnostic accuracy comparable to that of chest CT in the identification of pleural effusions. It is important to note that parapneumonic effusions are present in 30–40% of pneumonia cases.³³ Furthermore, ultrasonography can estimate the volume of the effusion and identify complications, such as fibrous septa or high-density contents. In such cases, therapeutic thoracocentesis may be indicated³⁴ (see Fig. 5). A key constraint of LUS is its incapacity to discern lesions that do not come into contact with the pleural line. Lung lesions located in the upper or middle lobes (e.g., lingula, middle lobe) are frequently not visualised with ultrasound. Fortunately, chest X-rays can be very beneficial in such cases, providing a valuable complement to the findings of LUS.

Abdominal ultrasound

Pneumonia is the most prevalent underlying condition, but urinary tract infections are the second most common cause of septic shock. The diagnosis of this condition is typically made on the basis of a detailed medical history and is subsequently confirmed through the identification of abnormalities in urinalysis, as well as positive results from urine and blood cultures. However, abdominal ultrasound is very useful in identifying hydronephrosis and complications such as renal abscesses, although CT is generally the preferred imaging modality in these cases.³⁵ In the event of pyonephrosis being identified, ureteral drainage is imperative. Although patients with septic shock are usually catheterised to monitor diuresis, ultrasound can detect acute urinary retention and the presence of debris or other intravesical abnormalities (e.g. stones, foreign bodies), which may influence treatment decisions (see Fig. 6).

Furthermore, ultrasonography has been demonstrated to be a highly effective diagnostic modality in detecting hepatobiliary pathology as a potential causative agent of septic shock (Smith et al., 2022). The reliability of the method is comparable to that of CT in the detection of cholelithiasis and bile duct dilation.³⁶ The capacity to discern abscesses or liver tumours is also possessed by the ultrasound, although the CT scan is the preferred imaging modality in such cases. In instances where

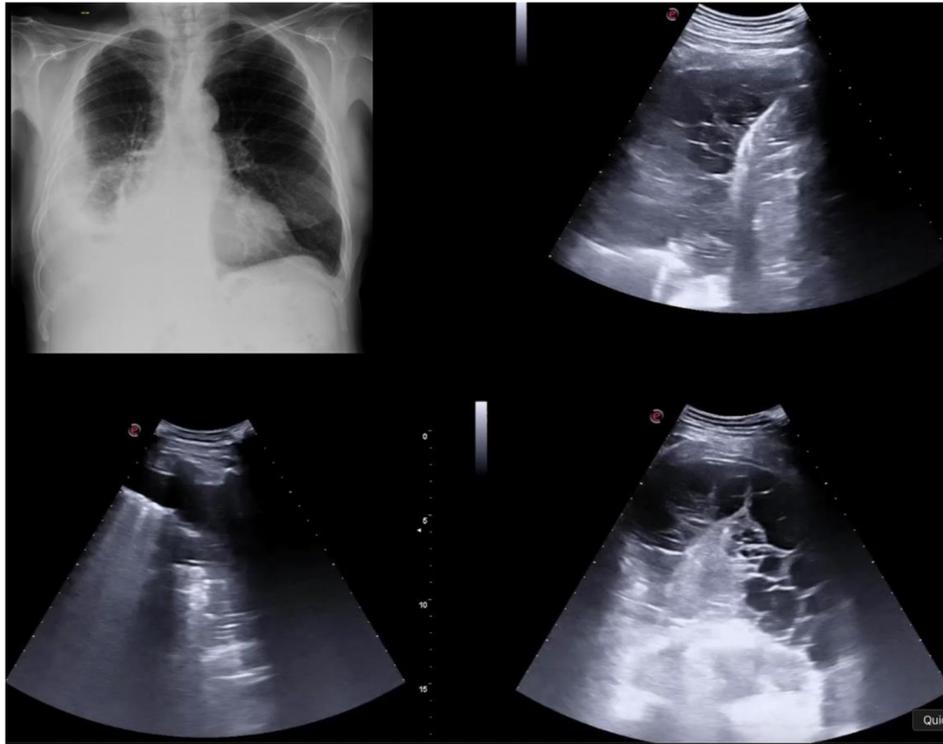


Fig. 5. Complicated pneumonia. Pneumonia in the right lung. Ultrasound reveals a significant complicated pleural effusion (characterised by numerous fibrous septations within the fluid).

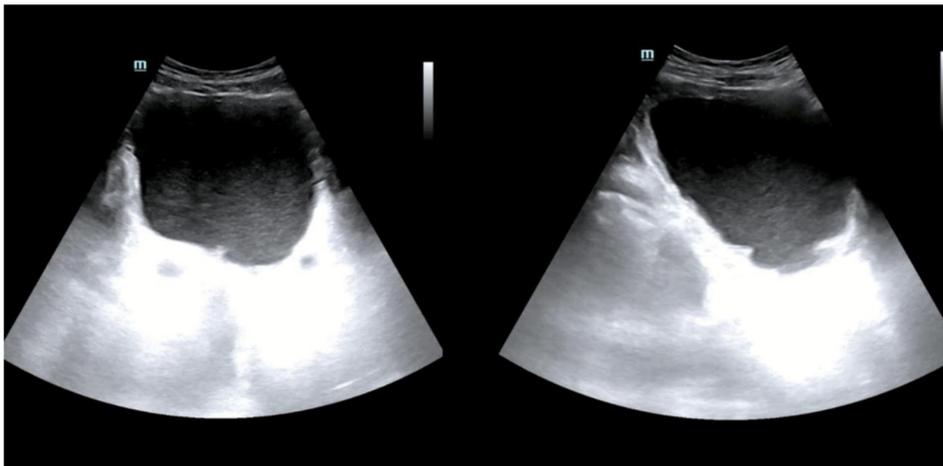


Fig. 6. Ultrasound findings in a patient with sepsis with a urinary focus. Severely distended urinary bladder (acute urinary retention) with abundant internal content (pyuria).

a biliary origin is suspected in a patient with septic shock, there are several considerations that are of paramount importance.

- a) The prevalence of cholelithiasis and bile duct dilation in adults is approximately 10–20% and 10%, respectively.³⁷ Consequently, these findings should be interpreted with caution.
- b) Although rare in the absence of gallstones, acalculous cholecystitis can occur, particularly in critically ill or septic patients. Consequently, alternative diagnoses should be considered in the absence of gallstones.³⁸
- c) The diagnosis of cholecystitis is primarily clinical in nature. The presence of ultrasound signs, including gallbladder wall oedema and pericholecystic fluid, is not specific for infection and may be observed in patients with a variety of conditions, including hepatitis, liver

congestion, or ascites of any origin. These signs do not necessarily indicate infection.^{39,40}

- d) In the early stages of cholecystitis, ultrasound signs may not be present. Consequently, cholecystitis should be considered in cases where clinical suspicion is high.⁴¹

Ultrasonography of the abdomen is a highly sensitive method for detecting ascites and free fluid. The aetiology of ascites is multifactorial and can present a diagnostic challenge. It is important to note that any intra-abdominal inflammatory or infectious process (e.g., cholecystitis, pancreatitis, pyelonephritis, colitis, appendicitis, diverticulitis, gynecologic infections) has the potential to result in the production of ascites. It is important to note that both primary and secondary bacterial peritoni-

tis present with ascites. Furthermore, ultrasound facilitates diagnostic paracentesis in any abdominal location.

Echography in other scenarios

As previously outlined, echocardiography is imperative for the haemodynamic monitoring of patients with septic shock. Endocarditis is an uncommon source of sepsis. Patients suffering from endocarditis have the potential to develop severe valvular lesions (particularly of a regurgitation nature), which can result in haemodynamic instability and the urgent requirement for surgical intervention. It is also important to note that, in expert hands using high-end devices, the sensitivity Sn of transthoracic echocardiography to diagnose native valve endocarditis ranges from 50% to 90%.⁴² However, the Sn is significantly lower in prosthetic valves. Consequently, bedside transthoracic echocardiography performed with mid-range equipment by less experienced operators may exhibit a considerably lower diagnostic Sn.

Skin and soft tissue infections are a relatively common cause of sepsis. Cellulitis and other superficial infections can often be identified by inspection. However, ultrasonography has been demonstrated to be a valuable diagnostic tool in the identification of collections of drainable fluid or abscesses.⁴³ The utility of the method extends to the diagnosis of necrotising fasciitis.⁴⁴

Operator dependency and training requirements

Operator dependency represents a significant limitation in the utilisation of POCUS for the management of sepsis. The precision and reproducibility of ultrasound findings are contingent on the operator's training and experience. Achieving proficiency necessitates mastery of both image acquisition and interpretation, a process which involves a steep learning curve, particularly in the context of advanced haemodynamic assessments. The implementation of structured educational programmes, standardised protocols, and the supervision of practical sessions are of paramount importance in the minimisation of variability amongst operators and the assurance of consistent diagnostic quality. The variability in clinicians' skills can have a substantial impact on the reproducibility of results and may constrain the generalisability of study findings to routine clinical practice, particularly in settings where there is heterogeneity in the levels of POCUS expertise. It is recommended that future research endeavours focus on the identification of the most efficacious training models and implementation strategies to optimise performance in a range of clinical settings.

Conclusions

POCUS is a crucial tool in the management of sepsis and septic shock. This approach facilitates a rapid, real-time, and non-invasive evaluation and treatment of patients, which is imperative in medical emergencies. POCUS is a valuable tool that assists in the differentiation between different types of shock, the assessment of cardiac function, and the guidance of fluid administration. It is evident that established protocols, including RUSH and VExUS, provide a systematic approach to evaluating perfusion, venous congestion, and fluid overload. LVOT-VTI and IVC collapsibility are useful parameters with which to predict fluid response, although it is important to consider their limitations. POCUS has been demonstrated to enhance the recognition of undifferentiated hypotension, including cases of septic shock. It assists clinicians in identifying the source of the infection, a process which is critical in selecting the appropriate antibiotic therapy and ascertaining the necessity for invasive procedures.

LUS has been shown to be a more effective diagnostic tool than conventional X-rays in the detection of pneumonia and pleural effusions. Furthermore, the ability to discern EVLW is of significance, as this has been demonstrated to be a reliable predictor of mortality and multi-organ failure.

Abdominal ultrasound is a valuable diagnostic tool that can be used to identify various infectious foci, including urological and biliary infections, as well as abscesses. The scope of the examination extends further, encompassing the detection of hydronephrosis, kidney abscesses, and acute urinary retention.

Cardiac ultrasound is imperative for the monitoring of cardiac function in patients with sepsis, aiding in the identification of conditions such as septic cardiomyopathy and valvular heart disease, which have the potential to influence the efficacy of treatment.

The effectiveness of POCUS is contingent on the operator's skill and experience. Further research is required to standardise the application of the subject under discussion. This should include high-quality randomised clinical trials, which are needed to demonstrate its direct impact on patient outcomes.

Ethical considerations

It was not necessary to obtain informed consent for the preparation of this manuscript.

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