

Usefulness of Bedside Point-of-care Ultrasounds in Intensive Care Unit for Septic Patients: A Consensus Statement of the Italian Society of Echocardiography and Cardiovascular Imaging

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Abstract

Sepsis and septic shock remain major causes of morbidity and mortality and are frequently complicated by multiple organ dysfunction, making management particularly challenging for intensivists. Early recognition of hemodynamic instability, prompt identification of the infectious source, and timely interventions are crucial to improve outcomes. Bedside point-of-care ultrasound (POCUS) is a safe, rapid, and noninvasive tool that supports real-time assessment of the septic patient, guiding both diagnosis and treatment. A structured POCUS approach can be used for initial hemodynamic evaluation, detection of infectious foci, and ultrasound (US)-guided therapeutic procedures directly at the bedside. In addition, the relatively low cost and portability of US make it especially valuable in low-resource settings, promoting more standardized and equitable care. This article provides a practical guide to the use of bedside US in patients with sepsis and septic shock admitted to the intensive care unit, focusing on key views, essential findings, and their implications for clinical management.

Keywords: Critical care, intensive care units, point-of-care ultrasound, sepsis, septic, shock

INTRODUCTION

Sepsis is a globally prevalent clinical syndrome associated with high morbidity, mortality, and a significant risk of long-term functional impairments. It is defined as life-threatening organ dysfunction resulting from a dysregulated host response to infection.^[1] Septic shock is defined as a subset of sepsis in which particularly profound circulatory, cellular, and metabolic abnormalities are associated with a greater risk of mortality than with sepsis alone.^[1] Rapid diagnosis is a key objective for clinicians in the intensive care unit (ICU), yet it is often complex due to the nonspecific presentation and rapid progression of sepsis. Ultrasound (US) imaging is a cost-effective, safe, rapid, and noninvasive diagnostic tool

that can be performed at the patient's bedside. These features are especially valuable in critically ill patients, who often present with hemodynamic instability, particularly during the early stages of sepsis. US imaging can be performed at admission, and repeated as needed, orienting management

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and therapeutic procedures. In fact, it is a valuable tool for rapid assessment of the patient's hemodynamic status, enabling the identification of potential infectious sources and the implementation of appropriate source control measures and therapeutic procedures directly at the bedside. Moreover, US imaging can also be employed in low-resource settings where access to more advanced imaging modalities, such as computed tomography (CT) or magnetic resonance imaging, may be limited or unavailable.

DEFINITION

According to the 2021 Surviving Sepsis Campaign (SSC) guidelines, sepsis is defined as life-threatening organ dysfunction caused by a dysregulated host response to infection.^[1] Organ dysfunction is central to diagnosis and reflects the absence of a single specific test, requiring clinicians to integrate clinical evaluation, laboratory markers, and the trajectory of organ involvement. Septic shock is the most severe form of sepsis and is associated with significantly increased mortality. It is clinically characterized by persistent hypotension requiring vasopressor therapy to maintain mean arterial pressure ≥ 65 mmHg and a serum lactate > 2 mmol/L despite adequate fluid resuscitation.^[1] Elevated lactate reflects impaired perfusion and is incorporated into the diagnostic criteria and therapeutic targets. The SSC guidelines emphasize early recognition, rapid evaluation of infection likelihood, and continuous reassessment of response to therapy.^[1] Because clinical signs alone may be insufficient to determine intravascular volume status or organ perfusion, the guidelines recommend the use of dynamic measures to guide fluid resuscitation methods that rely on repeated assessment of stroke volume or cardiac output changes.^[1] In this context, bedside US becomes a natural and widely used tool, as it allows real-time, repeatable evaluation of cardiac function, preload dependency, and signs of organ dysfunction directly at the bedside.

WHY PERFORM BED SIDE POINT-OF-CARE ULTRASOUND IN SEPTIC PATIENTS IN THE INTENSIVE CARE UNIT?

Point-of-care US (POCUS) offers rapid, repeatable, and noninvasive bedside assessment, making it an essential tool in the management of septic and septic shock patients admitted to the ICU. Sepsis evolves quickly, with dynamic changes in perfusion, cardiac function, fluid status, and organ involvement. POCUS integrates clinical evaluation by providing immediate visual information that supports early diagnosis, guides resuscitation, and helps therapeutic decisions. POCUS permits:

Rapid hemodynamic evaluation

Identifying the predominant mechanism of shock (hypovolemia, vasoplegia, or septic cardiomyopathy [SCM]) by assessing

preload, ventricular function, and fluid responsiveness. This allows more precise titration of fluids, vasopressors, and inotropes in the early and most time-critical phase of treatment.

Early detection of infectious sources

US imaging can quickly identify potential foci such as pneumonia, pleural effusions, biliary sepsis, abdominal collections, renal obstruction, or soft-tissue infections. This enables timely source control without the need for patient transport, which may be unsafe in unstable patients.

Monitoring of organ dysfunction

POCUS supports ongoing assessment of pulmonary aeration, ventricular function, renal perfusion, and the evolution of complications such as acute respiratory failure or acute kidney injury (AKI). Its repeatability makes it ideal for tracking clinical trajectories.

Procedural support at the bedside

US guidance enhances safety and success rates for vascular access, drainage procedures, and other bedside interventions, reducing complications and accelerating treatment.

Utility in resource-limited settings

The portability and affordability of the US make it a valuable tool in environments where access to advanced imaging is limited. Its use promotes more standardized and equitable sepsis care worldwide.

A summary of the main reasons supporting the use of POCUS in septic patients is shown in Figure 1.

The use of US imaging is not included in the latest SSC guidelines.^[1] A possible explanation could be the lack of well-established and validated protocols for patients with sepsis or septic shock, as opposed to widely used POCUS protocols for undifferentiated shock. A focused, organ-oriented POCUS approach allows early identification of the most common infectious sources and sepsis-related organ dysfunctions at the bedside. Figure 2 summarizes the main US targets and key

Rationale for POCUS in Sepsis

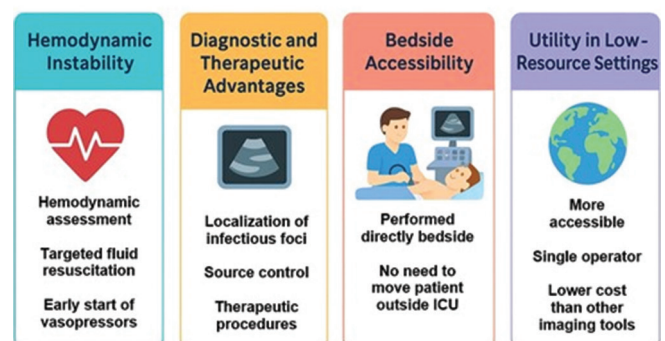


Figure 1: Rationale for point-of-care ultrasound (POCUS) in sepsis. POCUS supports hemodynamic assessment, facilitates early identification of infectious sources, enables bedside diagnostic and therapeutic interventions, and represents a valuable tool in low-resource settings. ICU = Intensive care unit

sonographic findings in septic patients, providing an overview of lung, cardiac, renal, and biliary assessment.

HEMODYNAMIC ASSESSMENT

Timely fluid resuscitation is a cornerstone of sepsis and septic shock management, yet inappropriate or excessive fluid administration may contribute to organ dysfunction and worse outcomes. For this reason, current practice guidelines consistently recommend the use of dynamic tests to guide fluid resuscitation, rather than relying on static parameters such as heart rate, systolic blood pressure, or central venous pressure, which have shown poor accuracy in predicting intravascular volume status or fluid responsiveness.^[1,2] Dynamic assessments—such as passive leg raising, fluid challenges combined with stroke-volume measurements, and respiratory-derived indices—have demonstrated superior diagnostic performance in predicting fluid responsiveness, defined as a significant increase in cardiac output (CO) following a preload-modifying maneuver or a fluid bolus.^[3] Importantly, fluid responsiveness is not synonymous with hypovolemia; rather, it reflects the position of the patient on the Frank–Starling curve and thus helps clinicians determine whether a fluid bolus is likely to be effective or potentially harmful. The US has emerged as a pivotal bedside tool to evaluate hemodynamic status in real time. Among US-based methods, ultrasonographic assessment of the inferior vena cava (IVC) has been widely adopted due to its simplicity, accessibility, and noninvasive nature. IVC diameter and respiratory variation correlate with right atrial pressure, and although IVC evaluation alone should not be used as a standalone predictor of fluid responsiveness,

it provides valuable information about preload and venous congestion.^[3] While IVC evaluation [Figure 3] provides important information on preload status, it does not directly measure CO. Therefore, more direct US-derived surrogates of stroke volume should be considered.

A more direct US-derived surrogate of stroke volume is the Left Ventricular Outflow Tract Velocity-Time Integral (LVOT-VTI). VTI represents the distance blood travels through the LVOT during systole, obtained by tracing the Doppler velocity envelope over one cardiac cycle [Figure 4]. Because stroke volume is proportional to $VTI \times LVOT$ area, changes in VTI directly reflect changes in forward flow. For this reason, VTI variation during a passive leg raise or after a fluid challenge is one of the most physiologically sound and clinically validated methods for assessing fluid responsiveness.^[4] Bedside echocardiography using VTI also serves additional purposes: it helps differentiate hypovolemia from SCM, evaluate the impact of vasopressors on CO, and identify right-ventricular dysfunction—all essential elements for tailoring hemodynamic therapy in sepsis. Given the dynamic nature of sepsis, hemodynamic reassessment must be repeated over time. Even patients who are initially fluid responsive may lose responsiveness later, and recurrent hemodynamic instability is common during septic shock.^[3]

Thus, the US provides a practical and repeatable method for monitoring the evolving interaction between preload, cardiac function, and the effects of resuscitative interventions.

Table 1 summarizes the recommended acquisition protocol, core measurements, and diagnostic thresholds for bedside hemodynamic US assessment.

CARDIAC POINT-OF-CARE ULTRASOUND IN SEPTIC PATIENT

Cardiac POCUS represents a cornerstone in the hemodynamic evaluation of patients with sepsis and septic shock. Sepsis profoundly alters cardiovascular physiology through a combination of vasoplegia, myocardial depression, preload fluctuations, and microcirculatory dysfunction, making bedside, repeatable cardiac imaging essential for guiding resuscitation and monitoring therapeutic response. Septic patients frequently

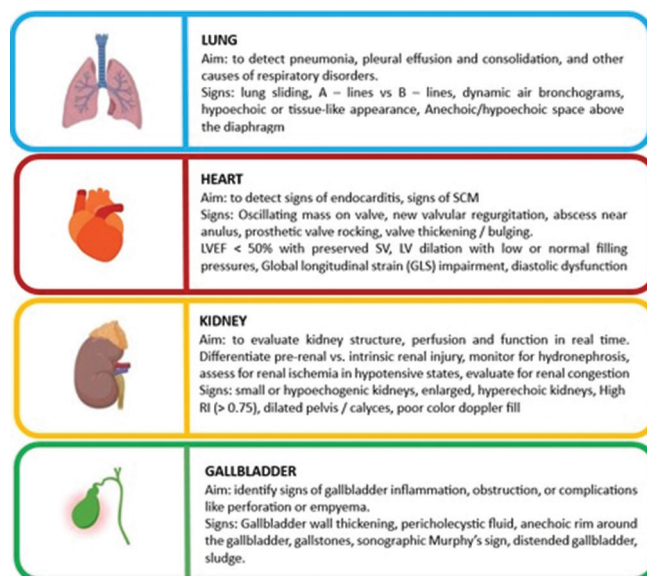


Figure 2: Point-of-care ultrasound assessment targets in septic patients. Schematic overview of the main ultrasound targets in sepsis. Each organ-specific examination contributes to hemodynamic assessment, identification of infectious sources, detection of organ dysfunction, and guidance of bedside therapeutic strategies. SCM = Septic cardiomyopathy

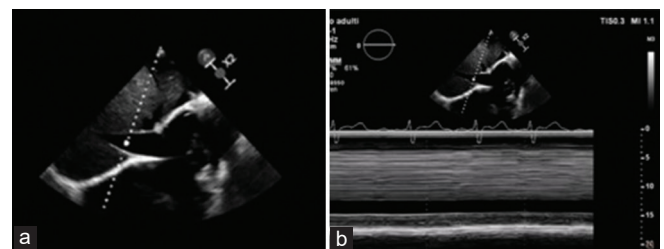


Figure 3: Inferior vena cava (IVC) evaluation. Subcostal long-axis view of the IVC entering the right atrium (a) with measurement of the maximum diameter approximately 1–2 cm from the cavoatrial junction. M-mode assessment (b) demonstrates respiratory variation in IVC diameter, used to estimate right atrial pressure and intravascular volume status

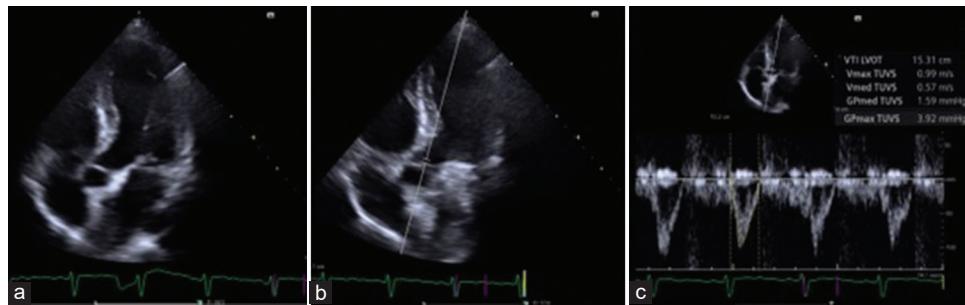


Figure 4: LVOT Velocity–Time Integral (VTI) assessment. (a) Apical five-chamber view demonstrating alignment of the ultrasound beam with the left ventricular outflow tract (LVOT). (b) Placement of the pulsed-wave Doppler (PWD) sample volume in the LVOT, just proximal to the aortic valve. (c) PWD spectral tracing with measurement of the LVOT VTI obtained by tracing the systolic velocity envelope over one cardiac cycle

Table 1: Practical bedside interpretation of inferior vena cava and velocity time integral in sepsis

Bedside hemodynamic ultrasound assessment	
IVC evaluation	
Parameters	Cut – off/clues
Patient position	Supine (flat on their back)
Probe	Curvilinear probe (2–5 MHz) for deeper imaging Alternatively, a phased array probe is also acceptable Set depth to ~10–15 cm, focus around 5–7 cm
Probe placement	Place probe in the epigastric region, just below the xiphoid process Probe marker points towards the patient's head (longitudinal view) Aim posteriorly and slightly to the right to visualize the IVC entering the right atrium
Identify key structures	IVC lies to the right of the aorta and is compressible Aorta has thicker, pulsatile walls and is noncompressible Follow IVC in long axis from the liver toward the heart
Measure IVC diameter	Use M-mode or freeze the image and use calipers to measure (Image 2.0) 2–3 cm caudal to the hepatic vein-IVC junction, or just below the diaphragm Measure maximal (inspiratory) and minimal (expiratory) diameters
Interpretation (IVC collapsibility index)	For spontaneously breathing patients $CI = \frac{IVC \text{ expiratory diameter} - IVC \text{ inspiratory diameter}}{IVC \text{ expiratory diameter}}$ >50% collapse → Suggests low RAP → likely hypovolemia <20% collapse with diameter >2.1 cm → Suggests elevated RAP For mechanically ventilated patients, distensibility is used instead $IVC DI = \frac{insp. \text{ diameter} - exp. \text{ diameter}}{exp. \text{ diameter}}$ 18% distensibility → Suggests volume repletion and fluid responsiveness
Evaluation of VTI	
Patient position	Supine/semi-recumbent position if tolerated
Probe	Cardiac probe
Step-by-step procedure	Obtain Apical 5-Chamber View - A5C (Image 3.0) Place the probe at the apex of the heart Aim to visualize LV, LA, RV, RA, and LVOT plus aortic valve Activate PW Doppler Place the PW Doppler at the LVOT, just below the aortic valve in the A5C view (Image 3.1) Adjust gain and sample size for a clear spectral Doppler trace Measure the VTI (Image 3.2) Trace the spectral envelope of the Doppler waveform of aortic outflow The result is the VTI (cm): The distance blood travels during one heartbeat
Interpreting VTI in septic shock	Low VTI (<18 cm) → Low stroke volume → consider hypovolemia or LV dysfunction High VTI (>22 cm) → Hyperdynamic state → often seen in early sepsis VTI variation >12%–15% with passive leg raise or respiration → Indicates fluid responsiveness
VTI=Velocity time integral, IVC=Inferior vena cava, RAP=Right atrial pressure, LV=Left ventricle, LA=Left atrium, RV=Right ventricle, RA=Right atrium, LVOT=Left ventricular outflow tract, PW=Pulsed-wave	

present with hypotension, tachycardia, altered mentation, or signs of organ hypoperfusion. Because these findings are nonspecific, cardiac POCUS helps differentiate between potential shock phenotypes – hypovolemic, distributive, obstructive, or cardiogenic components – thereby supporting early, targeted management. Current shock and sepsis guidelines emphasize the need for dynamic and physiologically informed resuscitation rather than fixed-volume strategies, and POCUS provides precisely this real-time physiological insight.^[1] Moreover, both left and right ventricular dysfunction are common in sepsis.

SCM, a reversible myocardial dysfunction associated with sepsis, may occur in 40%–60% of patients depending on the definition used.^[4] Right ventricle (RV) dysfunction is similarly prevalent and has been associated with worse early prognosis.^[5]

SCM is characterized by:

- Global or biventricular systolic and/or diastolic impairment
- Left Ventricular dilatation with normal or low filling pressures
- Reduced responsiveness to fluids and catecholamines
- Reversibility within 7–10 days.^[4]

An example of left ventricular systolic dysfunction in SCM is shown in Figure 5.

A multimodal approach integrating visual left ventricular ejection fraction (LVEF), left ventricular global longitudinal strain, and tissue Doppler imaging (TDI) parameters is recommended to better characterize myocardial performance. Right ventricular dysfunction is observed in 50%–55% of septic shock patients and may even appear in isolation.^[4] Assessment of RV size, tricuspid annular plane systolic excursion, systolic myocardial velocity (S' velocity), fractional area change, and estimation of pulmonary pressures is crucial, particularly because mechanical ventilation, acute respiratory distress syndrome (ARDS), and high positive end-expiratory pressure can worsen RV afterload. A structured echocardiographic approach is essential for the recognition and monitoring of SCM. A stepwise bedside protocol was proposed to

standardize echocardiographic assessment in patients with suspected SCM, emphasizing the integration of qualitative evaluation with quantitative parameters of both left and right ventricular function. That approach highlights the limitations of load-dependent indices such as LVEF and supports the use of longitudinal function markers, TDI, and serial examinations to capture the dynamic nature of myocardial dysfunction during sepsis. This standardized framework aligns with current clinical practice and reinforces the role of focused cardiac POCUS as a key tool for guiding hemodynamic management in septic patients.^[6]

Although transesophageal echocardiography (TEE) remains the gold standard for diagnosing infective endocarditis (IE), transthoracic echocardiography (TTE) and focused cardiac POCUS provide rapid clues to the presence of vegetations, valvular destruction, or perivalvular complications at the bedside.^[7] Findings such as mobile vegetations, new regurgitant lesions, abscesses, or leaflet perforation may be visible even on limited TTE windows.^[8] Given the rising prevalence of prosthetic valves and intravascular devices, early recognition is critical. Figure 6 shows main findings of TTE during endocarditis. When clinical suspicion persists despite negative POCUS/TTE, guidelines recommend prompt escalation to TEE or multimodality imaging (CT, positron emission tomography/CT).^[9]

Table 2 provides a focused overview of the echocardiographic hallmarks of SCM and IE, highlighting parameters that complement standard cardiac POCUS assessment in the septic patient.

LUNG POINT-OF-CARE ULTRASOUND IN SEPTIC PATIENT

Respiratory failure is common in sepsis, and lung US (LUS) represents a rapid, noninvasive, bedside tool to identify pneumonia, pleural effusion, interstitial syndrome, atelectasis, ARDS, and pneumothorax. When integrated with cardiac POCUS, it significantly improves diagnostic accuracy and accelerates therapeutic decisions in the ICU. Recent evidence shows that LUS enhances the evaluation of both circulatory and respiratory impairment in septic shock, acting as a fundamental

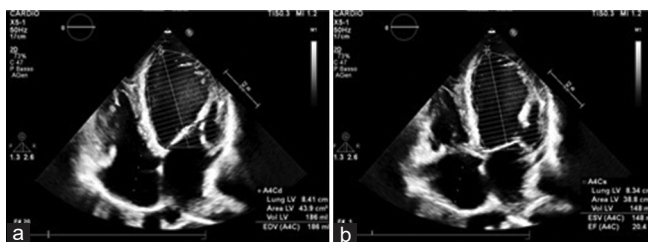


Figure 5: Septic cardiomyopathy with left ventricular systolic dysfunction. Apical four-chamber views demonstrating reduced left ventricular systolic function assessed using the Simpson's biplane method (a). End-diastolic and end-systolic tracings allow calculation of left ventricular volumes and ejection fraction, showing depressed systolic performance consistent with septic cardiomyopathy (b)

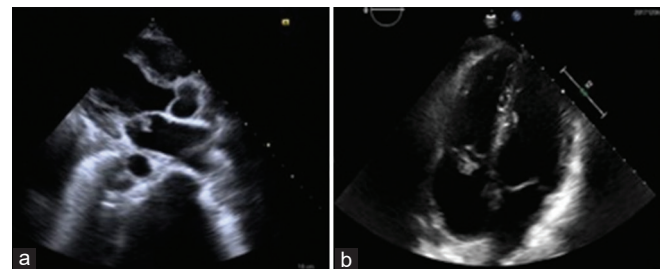


Figure 6: Infective endocarditis on transthoracic echocardiography (TTE). Parasternal long-axis view showing valvular involvement with a mobile echogenic mass suggestive of vegetation (a). Apical view confirming the presence of a valvular vegetation attached to the leaflet, consistent with infective endocarditis (b). TTE may provide rapid bedside identification of vegetations and associated valvular abnormalities

Table 2: Bedside cardiac point-of-care ultrasound protocol for septic patients

How to perform cardiac POCUS in septic patients	
Parameters	Cut - off
Patient position	Supine (flat) preferred Slight head-of-bed elevation ($\leq 30^\circ$) if needed to improve acoustic windows For subcostal views, deeper inspiration may improve image quality
Probe	Phased-array probe (1–5 MHz): Standard for cardiac imaging Curvilinear probe (2–5 MHz): Useful for subcostal views or poor transthoracic windows Optimize depth to center the heart; adjust gain to visualize endocardial borders
Key cardiac windows and what to assess	PLAX LV size and systolic function Aortic and mitral valve morphology Pericardial effusion Gross regional wall motion PSAX LV global/segmental contractility RV size and septal motion Assessment of LV shape (round vs. D-shaped) A4C RV/LV size ratio Global LV systolic function (visual EF) Mitral and tricuspid annular motion (MAPSE/TAPSE) Subcostal view Global cardiac function Screening for pericardial tamponade
Quantitative measures	Left ventricular systolic function Visual EF: EF $< 50\%$ suggests systolic dysfunction in sepsis GLS: Less negative than -18% indicates impaired contractility; more reliable than EF during changing loading conditions MAPSE: < 10 mm indicates reduced longitudinal LV function RV function TAPSE: < 16 mm suggests RV systolic dysfunction RV S' (TDI): < 10 cm/s supports RV impairment FAC: $< 35\%$ indicates RV systolic dysfunction Septal flattening ("D-shaped" LV): Indicates RV pressure overload, common in ARDS or high PEEP Diastolic function TDI e' velocity: Lateral or septal e' < 8 cm/s $\rightarrow$ impaired relaxation. E/e' ratio: > 13 suggests elevated LV filling pressure (interpret cautiously in sepsis) Left atrial size: Chronically enlarged in baseline diastolic dysfunction (not always reliable in acute sepsis)
Septic cardiomyopathy	
Key features	Global (not regional) reduction in LV systolic function LV dilation with normal/low filling pressures Depressed longitudinal function: $\downarrow$ MAPSE, $\downarrow$ TDI S' Impaired GLS even with normal EF RV dysfunction may coexist
Quantitative measures	MAPSE < 10 mm TDI S' < 6 – 7 cm/s GLS $> 18\%$ (less negative) TAPSE < 16 mm/FAC $< 35\%$ if RV involved
Endocarditis	
Key features	Mobile echodense mass attached to valve/device (vegetation) New moderate–severe valvular regurgitation Valve perforation or flail leaflet Paravalvular echo-free space (abscess) Prosthetic valve rocking or dehiscence
Quantitative measures	Vegetation often visible in PLAX/A4C Abscess: Perivalvular echo-lucent cavity Acute severe MR/TR with new jet origin

POCUS=Point-of-care ultrasound, LV=Left ventricle, RV=Right ventricle, PLAX=Parasternal long axis, PASX=Parasternal short axis, A4C=Apical four chamber, EF=Ejection fraction, MAPSE=Mitral annular plane systolic excursion, TAPSE=Tricuspid annular plane systolic excursion, GLS=Global longitudinal strain, FAC=Fractional area change, PEEP=Positive end-expiratory pressure, ARDS=Acute respiratory distress syndrome, MR/TR=Mitral regurgitation/tricuspid regurgitation

complement to physical examination).^[10-15] Representative LUS findings commonly observed in septic patients are illustrated in Figure 7. The goal of LUS is to assess lung aeration and identify patterns suggestive of the main pulmonary complications in sepsis. Normal lung parenchyma produces horizontal A-lines, whereas interstitial or alveolar interstitial disease generates vertical B-lines. B-lines are defined as discrete, laser-like, vertical hyperechoic reverberation artifacts that:

- Arise from the pleural line
- Extend to the bottom of the screen without fading
- Move synchronously with lung sliding.

Their presence and number correlate with extravascular lung water and with the severity of interstitial edema. Multiple, bilateral, and homogeneously distributed B-lines suggest cardiogenic pulmonary edema or fluid overload, whereas patchy or inhomogeneous distribution, pleural line irregularities, and subpleural consolidations support ARDS or infectious etiologies.^[16-19] LUS allows rapid differentiation between the main causes of acute respiratory failure that commonly coexist in septic patients. LUS allows rapid differentiation among the most common causes of acute respiratory failure in septic patients. Pneumonia or a primary infectious source typically appears as a focal pattern, characterized by localized B-lines, pleural line irregularities, and subpleural consolidations. In contrast, ARDS usually presents with a bilateral but inhomogeneous distribution of B-lines, with spared areas, small peripheral consolidations, and an irregular pleural line, reflecting the patchy nature of lung involvement. Cardiogenic pulmonary edema or fluid overload is suggested by the presence of diffuse, symmetric B-lines, often involving the anterior lung fields and associated with a smooth, regular pleural line. Pleural effusions are readily identified as anechoic or complex fluid collections in the dependent thoracic regions. Finally, pneumothorax should be suspected when lung sliding is absent, A-lines predominate, and, when visible, the lung point confirms the diagnosis. Thoracic US (TTE + LUS) is now regarded as the cornerstone of bedside evaluation in shock and acute respiratory failure, improving both diagnostic accuracy and real-time management.^[10] Lung POCUS provides a rapid and reproducible bedside assessment of pulmonary involvement in septic patients, allowing early identification of respiratory complications and potential infectious sources. A structured scanning approach is essential to ensure completeness and diagnostic accuracy. Table 3 summarizes a

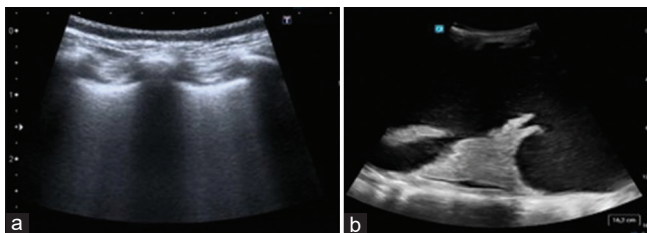


Figure 7: Pulmonary ultrasound abnormalities in the septic patient. Intercostal views demonstrating diffuse B-lines consistent with interstitial edema (a) and subpleural consolidation with air bronchograms compatible with infectious pneumonia (b)

practical step-by-step protocol for LUS evaluation in sepsis. This standardized approach facilitates rapid differentiation among pneumonia, interstitial syndrome, pleural effusion, and other causes of acute respiratory failure commonly encountered in the ICU.

ABDOMINAL POINT-OF-CARE ULTRASOUND IN SEPTIC PATIENT

Intra-abdominal infections represent a frequent and potentially life-threatening cause of sepsis and septic shock in critically ill patients. Early identification of the infectious source is a cornerstone of sepsis management, as timely source control is strongly associated with improved outcomes.^[1] However, clinical examination is often unreliable in the ICU due to

Table 3: Bedside lung ultrasound protocol in septic patients

How to perform lung ultrasound in septic patient	
Lung ultrasound evaluation	
Parameters	Cutoff
Patient position	Ideally, in sitting or semi-recumbent position If not possible, perform in supine or lateral decubitus positions
Probe	Curvilinear (preferred). A linear probe may be used for superficial pleura, not for deeper structures Set depth: ~8–12 cm for lung; adjust as needed Use “lung” preset or “abdomen” preset if lung is not available
Scan protocol: BLUE protocol	
Scan six regions per side	
Anterior chest: Upper and lower BLUE points (midclavicular line, 2 nd and 4 th –5 th intercostal space)	
Lateral chest: PLAPS point (posterolateral alveolar and/or pleural syndrome), posterior axillary line	
Posterior chest: (if accessible)	
Key features and diagnostic interpretation	
Lung sliding	
Use real-time B-mode or M-mode	
Normal: Shimmering pleura=“lung sliding”	
Absence: Could indicate pneumothorax, severe consolidation, or ARDS	
A-lines versus B-lines	
A-lines: Horizontal reverberation artifacts → normal aerated lung	
B-lines: Vertical, laser-like artifacts extending from pleura to bottom of screen → interstitial syndrome	
Pulmonary sepsis/pneumonia often shows	
Focal B-lines or confluent B-lines	
Lung consolidation (tissue-like pattern)	
Air bronchograms (dynamic=likely pneumonia)	
Consolidation	
Hypoechoic or tissue-like appearance	
Dynamic air bronchograms are specific for pneumonia (vs. atelectasis)	
Pleural effusion	
Anechoic/hypoechoic space above the diaphragm	
Often detectable when present pneumonia in sepsis	
ARDS=Acute respiratory distress syndrome	

altered mental status, mechanical ventilation, sedation, or concomitant organ dysfunction.

In this context, abdominal POCUS provides a rapid, repeatable bedside imaging modality that supports early diagnostic orientation, guides further imaging, and facilitates timely therapeutic decisions.^[20] Although CT remains the reference standard for comprehensive abdominal evaluation, POCUS is particularly valuable when patient transport is unsafe or delayed, allowing focused assessment of the most common and clinically relevant abdominal sources of infection.^[1] Among these, biliary tract disease and renal or urinary tract infections are especially relevant in septic patients and can be effectively screened using bedside US.^[20]

Performing POCUS for suspected acute cholecystitis in septic patients admitted to the ICU is highly valuable, particularly when patient instability makes transfer to the radiology department hazardous. Acute calculous and acalculous cholecystitis are well-recognized causes of sepsis in critically ill patients, with acalculous forms occurring more frequently in the ICU setting.^[21]

The primary goals of gallbladder US are to identify signs of gallbladder inflammation, obstruction, and complications such as empyema, gangrene, or perforation. Typical sonographic findings suggestive of acute cholecystitis include gallbladder wall thickening ($>3\text{--}4\text{ mm}$), gallbladder distension, pericholecystic fluid, intraluminal sludge or gallstones, and a positive sonographic Murphy's sign.^[21] In acalculous cholecystitis, the absence of gallstones does not exclude the diagnosis, and indirect signs of inflammation may be the only sonographic clues.^[21] Examples of these sonographic patterns are shown in Figure 8.

Beyond diagnosis, gallbladder POCUS plays a key role in guiding therapeutic decision-making. US-guided percutaneous cholecystostomy is a minimally invasive drainage procedure widely used for the treatment of acute cholecystitis in critically ill or nonoperative patients.^[21,22] In the ICU setting, bedside US facilitates both patient selection and procedural guidance, allowing prompt source control while minimizing procedural risk. Current international guidelines recommend early gallbladder drainage in high-risk septic patients when surgical cholecystectomy is contraindicated or must be deferred.^[21]

AKI is a frequent and severe complication in critically ill patients, occurring in up to half of ICU admissions, and sepsis represents its leading cause, accounting for approximately 40%–50% of cases. Sepsis-associated AKI is not merely an epiphenomenon of critical illness, but a condition strongly associated with adverse outcomes: progression of AKI in septic patients increases the risk of in-hospital mortality by six- to eightfold and is associated with prolonged ICU stay and long-term renal dysfunction.^[23–26]

Early identification of renal involvement and timely recognition of potentially reversible mechanisms are therefore essential. In this context, renal POCUS represents a noninvasive, repeatable bedside tool that complements clinical and laboratory evaluation by allowing real-time assessment of renal morphology, perfusion, and venous congestion. Unlike serum creatinine and urine output, which are delayed and indirect markers of kidney injury, US provides immediate physiological information that may support early diagnostic and therapeutic decisions. Illustrative renal US patterns ranging from normal anatomy to obstructive pathology are presented in Figure 9.

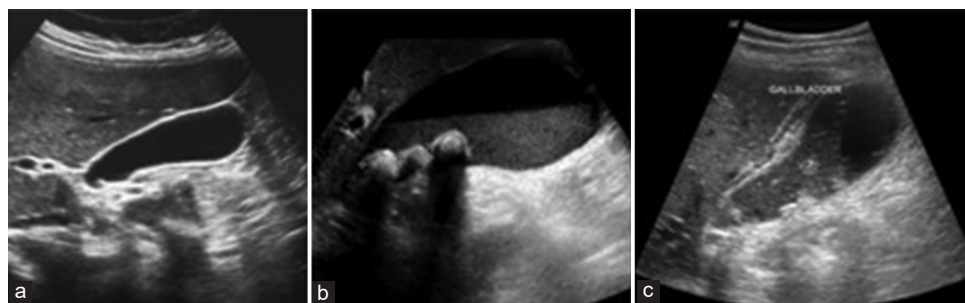


Figure 8: Gallbladder ultrasound findings in the septic patient. Left to right: Normal gallbladder with anechoic lumen and thin wall (a); gallbladder empyema characterized by echogenic intraluminal material and layering debris, possibly associated with gallstones (b); gallbladder wall thickening with inflammatory changes consistent with acute cholecystitis (c)



Figure 9: Renal ultrasound assessment of obstructive uropathy. Normal kidney (a), renal calculus with posterior acoustic shadowing (b), and hydronephrosis with dilation of the collecting system (c), illustrating progressive obstructive pathology detectable by point-of-care ultrasound

Sepsis-associated AKI is increasingly recognized as a multifactorial process, in which macrohemodynamic alterations alone do not fully explain renal dysfunction. Microcirculatory impairment, endothelial dysfunction, altered renal autoregulation, inflammatory injury, and venous congestion all play a relevant role in the development and progression of AKI during sepsis.^[27]

Vascular dysregulation and increased renal vascular resistance may lead to impaired renal perfusion even in the presence of apparently adequate systemic blood pressure. Renal hemodynamics can be evaluated noninvasively using Doppler US, most commonly through measurement of the renal resistive index (RRI). RRI is obtained from interlobar or arcuate arteries and reflects downstream resistance within the renal microcirculation. Several studies have demonstrated that an elevated RRI is acknowledged with the development of AKI in critically ill and septic patients, often preceding changes in serum creatinine.^[28-31]

RRI has been proposed as a useful bedside marker to:

- Identify patients at higher risk of developing AKI
- Assess alterations in renal perfusion
- Monitor the evolution and recovery of renal dysfunction
- Support hemodynamic optimization strategies in septic shock.

Although RRI is influenced by multiple factors, including heart rate, arterial stiffness, and intra-abdominal pressure, its integration with the clinical context and other POCUS findings enhances its interpretative value.^[32] An illustrative comparison between normal (resistive index [RI]: 0.60) and elevated (RI: 0.81) intrarenal Doppler waveforms is presented in Figure 10.

More recently, attention has shifted toward the role of venous congestion in sepsis-associated AKI. Elevated renal venous pressure may impair glomerular filtration despite preserved arterial inflow. In this setting, integration of renal Doppler with systemic venous US, such as IVC assessment and venous excess US, provides a comprehensive evaluation of renal perfusion pressure and congestion status.^[33]

This integrated approach may help guide fluid management and prevent fluid overload, which is itself associated with worsening renal outcomes. Overall, renal POCUS represents

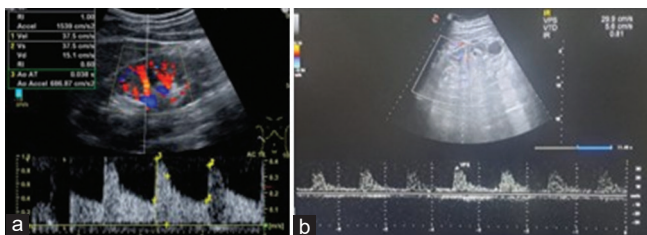


Figure 10: Comparison of normal and elevated renal resistive index (RI). Normal intrarenal Doppler waveform (RI: 0.60) with preserved diastolic flow (a) versus increased RI (0.81) characterized by reduced diastolic velocity (b), reflecting increased intrarenal vascular resistance

a valuable component of the multimodal US assessment in septic patients, enabling early detection of AKI, improving understanding of underlying pathophysiology, and supporting individualized hemodynamic and fluid management strategies at the bedside.

Table 4 summarizes a practical bedside approach to abdominal POCUS in septic patients, focusing on gallbladder and renal US assessment, including patient positioning, scanning technique, key sonographic findings, and clinically relevant cutoff values to support early source identification and evaluation of sepsis-associated AKI.

VASCULAR ACCESS AND DEEP VEIN THROMBOSIS SCREENING

In fact, vascular access placement and screening for deep vein thrombosis (DVT) are critical aspects of care in critically ill patients with sepsis and septic shock, due to the need for rapid resuscitation, medication delivery, and the high risk of thromboembolic complications. Accurate examination of the venous system is a fundamental goal in the care of the critically ill for several reasons:

- Venous thrombosis and subsequent pulmonary embolism are, unfortunately, frequent occurrences in the ICU^[34]
- Rapid and safe access to central veins is an obviously beneficial procedure
- Septic venous thrombosis must always be considered in critical care patients with prolonged ICU admissions and infectious signs.

Placing a central venous catheter (CVC) using US guidance is now the standard of care in critical care and emergency medicine, especially important in septic and shock states where access must be fast, safe, and reliable [Figure 11].^[35,36]

Prompt IV access is essential for:

- Early fluid resuscitation
- Rapid administration of vasopressors and antibiotics
- Hemodynamic monitoring
- Repeated blood sampling.

Performing DVT evaluation with US in ICU patients with sepsis or septic shock is a bedside, noninvasive, and crucial

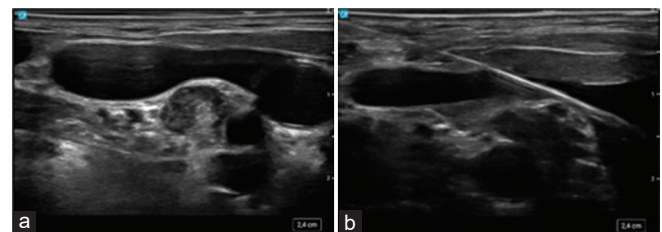


Figure 11: Ultrasound-guided central venous catheter placement. Short-axis view of the target vessel during real-time ultrasound-guided cannulation (a). The needle is visualized in-plane entering the vein under direct sonographic guidance (b). Ultrasound guidance improves first-pass success and reduces mechanical complications compared with landmark-based techniques

Table 4: Practical abdominal ultrasound evaluation in sepsis

How to perform abdomen ultrasound in septic patient	
Gallbladder evaluation	
Parameters	Cut - off
Patient position	Supine or left lateral decubitus to bring gallbladder into view
Probe	Elevate patient's head slightly, if possible, for a better window Convex probe (3.5–5 MHz)
Step – by – Step Procedure	Optional: Linear probe for superficial structures Place the probe starting in the right upper quadrant, midclavicular line Aim under the right costal margin, fan slowly Identify the Gallbladder: Anechoic, pear-shaped sac below liver Identify portal triad (portal vein, hepatic artery, common bile duct)
Diagnostic interpretation	POCUS criteria for acute cholecystitis Gallbladder wall thickening > 3 mm is suspicious Pericholecystic fluid (anechoic rim around the gallbladder) suggests inflammation Hyperechoic with posterior shadowing → Gallstones Sonographic Murphy's sign (maximal pain when probe presses over the gallbladder) Distended gallbladder (transverse diameter > 4 cm) Mobile echogenic material, often with stasis (sludge)
Kidney evaluation	
Patient position	Supine or slight lateral decubitus (left lateral for right kidney, right lateral for left kidney)
Probe	Curvilinear (3.5–5 MHz)
Step-by-step procedure	Kidney Identification (B-mode) Right kidney Place probe at right mid-axillary line below costal margin Use liver as acoustic window Left kidney More posterior, left posterior axillary line, may require deeper scanning Use spleen as window if possible
Key features	Size Normal length: 9–12 cm Small/shrunken → chronic disease Echogenicity Increased cortical echogenicity may indicate acute or chronic damage Corticomedullary differentiation Loss indicates parenchymal disease Hydronephrosis Dilated renal pelvis/calices → obstruction (e.g., catheter blockage, stone) Perinephric fluid May indicate inflammation or infection Doppler Assessment (Perfusion). Assess global renal perfusion Poor color fill → suggestive of low flow or obstruction Spectral Doppler: RI Place Doppler gate in interlobar or arcuate arteries Measure $RI = \frac{(\text{Peak systolic velocity} - \text{End diastolic velocity})}{\text{Peak systolic velocity}}$ Normal RI: 0.6–0.7 High RI (>0.75): May indicate Vasoconstriction Increased renal vascular resistance Acute tubular necrosis Early AKI RI is nonspecific and affected by heart rate, ventilator settings, IAP, etc., so must be interpreted in clinical context
Key findings in septic shock	Small or echogenic kidneys → chronic kidney disease Enlarged, hyperechoic kidneys → acute injury High RI (> 0.75) → impaired perfusion/AKI Dilated pelvis/calices → hydronephrosis/suspected obstruction Poor color Doppler fill → hypoperfusion/hypotension or vasoconstriction
RI=Resistive index, POCUS=Point-of-care ultrasound, AKI=Acute kidney injury, IAP=Intra abdominal pressure	

skill for early diagnosis of DVT, especially given the high risk in this population due to immobility, inflammation, and CVCs. Figure 12 summarizes a practical bedside US approach to suspected DVT in septic patients, integrating compression findings with clinical decision-making.

Critically ill patients, especially with sepsis, are at increased risk of DVT due to:

- Immobility
- Inflammation

- Endothelial injury
- Use of CVCs (especially femoral and subclavian).

POCUS plays a key role in critically ill septic patients, not only for diagnostic assessment but also for procedural guidance and complication screening. US-guided CVC placement improves safety and success rates, whereas bedside compression US allows rapid screening for DVT high-risk patients. Table 5 summarizes a practical, step-by-step approach for US-guided central venous access and focused lower-limb DVT assessment,

Table 5: Bedside vascular ultrasound applications in septic patients

Vascular access and DVT screening	
Central venous line placement	
Parameters	Cut – off/clues
Patient position	Supine, Trendelenburg, head turned slightly opposite (IJV) Supine, leg slightly abducted and externally rotated (Femoral Vein)
Probe	Ultrasound machine with sterile probe cover High-frequency linear probe (7–12 MHz)
Probe orientation	Use transverse (short axis) view for initial identification Switch to long axis for needle visualization if needed Use out-of-plane (transverse view) or in-plane (longitudinal view) technique Out-of-plane: Needle seen as dot; use tissue movement and compression to guide In-plane: Full needle visualization, better control (but harder in small space)
Usefulness	Insertion and confirmation Use ultrasound to visualize wire inside vein (especially IJV) Postinsertion checks Check for pneumothorax (especially after subclavian/IJ) Check correct positioning (bubble test)
DVT assessment	
Patient position	Supine, slight external rotation of the leg
Probe	High-frequency linear probe (7.5–12 MHz)
Step-by-step procedure	2-Point or 3-point compression ultrasound CFV Place probe in transverse view just below the inguinal ligament Identify the CFV and CFA side by side Apply gentle compression every 1–2 cm as you move down A normal vein should collapse completely with probe pressure If it does not collapse - suspicion of DVT Femoral vein/Proximal SFV Slide probe down the thigh along the femoral vein course Continue compression every 1–2 cm Popliteal vein (optional but recommended) Bend the patient's knee slightly Place probe in the Popliteal fossa Identify the popliteal vein (posterior and superficial) and artery (deeper) Apply compression The popliteal vein should also compress easily Optional: Color Doppler Assess for absence of flow or partial obstruction Not necessary for diagnosis, but helpful in unclear cases
Key features	Positive DVT signs Incompressible vein (main diagnostic criterion) Vein may be distended, lack respiratory variation Visualization of echogenic thrombus may be seen in some cases

CFA=Common femoral artery, SFV=Superficial femoral vein, CFV=Common femoral vein, DVT=Deep vein thrombosis, IJV=Internal jugular vein

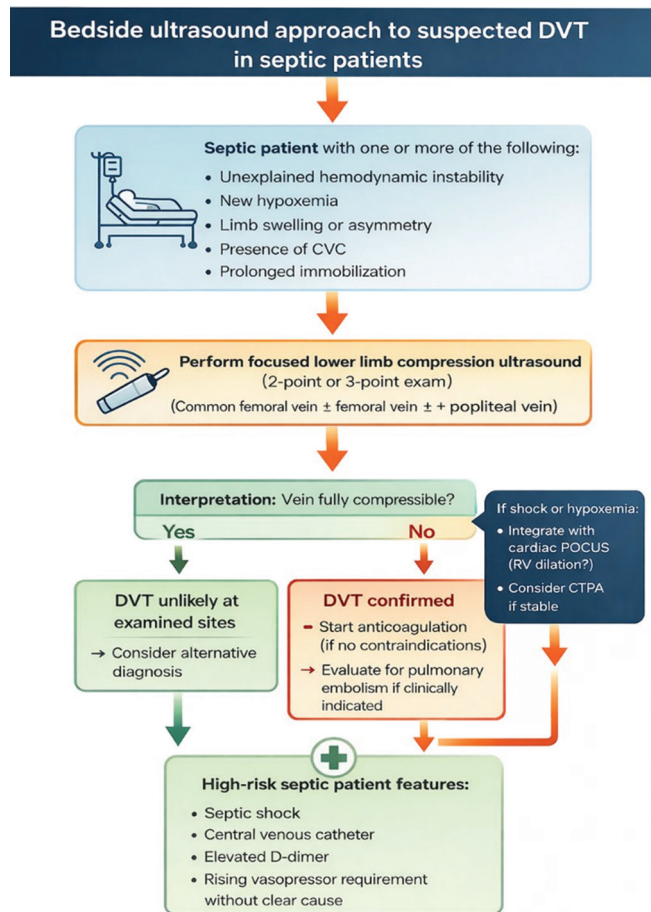


Figure 12: Diagnostic flowchart for ultrasound evaluation of suspected deep vein thrombosis in sepsis. Algorithm outlining bedside compression ultrasound assessment, interpretation of venous compressibility, and subsequent management pathways. DVT = Deep vein thrombosis, CVC = Central venous catheter, POCUS = Point-of-care ultrasound, CTPA = Computed tomography pulmonary angiography

including patient positioning, probe selection, scanning technique, and key diagnostic criteria.

CONCLUSIONS

POCUS has become an essential component of the bedside evaluation of patients with sepsis and septic shock, enabling rapid, noninvasive, and repeatable assessment of hemodynamics, organ dysfunction, and potential infectious sources. A structured, multimodal POCUS approach integrating cardiac, lung, abdominal, and vascular US allows clinicians to move beyond isolated parameters toward a comprehensive, physiology-driven evaluation, supporting timely diagnostic and therapeutic decisions in the ICU. Looking forward, the integration of standardized POCUS protocols into sepsis care pathways represents a key opportunity to improve diagnostic accuracy, guide individualized hemodynamic management, and enhance source control strategies. Advances in training, competency-based certification, and technological developments, including automated measurements and artificial intelligence-assisted image interpretation, are expected to

further expand the role of POCUS in critical care. Future research should focus on outcome-driven validation of integrated US protocols and their impact on clinical decision-making, resource utilization, and patient-centered outcomes in sepsis.

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Conflicts of interest

There are no conflicts of interest.

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