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Review Article

Point of care ultrasound: focus on evidence for a critical appraisal

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ABSTRACT

Point-of-care ultrasound (POCUS) refers to a sonographic examination performed directly at the patient's bedside, integrated into clinical reasoning for diagnostic, monitoring, risk stratification, and therapeutic purposes. Its main applications in medical patients include causes of dyspnea, chest pain, abdominal pain, and shock. In dyspnea, a multiorgan POCUS approach allows for the identification of most underlying conditions. Moreover, in acute heart failure and pulmonary embolism, it aids in risk stratification. In chest pain, POCUS supports diagnosis, though in acute aortic syndromes and acute coronary syndrome, it remains part of a broader diagnostic process. For abdominal pain, it is particularly useful in detecting biliary tract diseases, ascites, acute appendicitis, and abdominal aortic aneurysm. Various POCUS protocols assist in identifying different types of shock (distributive, cardiogenic, hypovolemic, and obstructive). Most studies focus on diagnostic accuracy, highlighting valuable sensitivity and specificity in many conditions. While in many cases faster diagnosis has been shown, its efficacy in guiding treatment, reducing length of stay and the impact on mortality is much less defined. Misuse may derive from inadequate image acquisition, interpretation, and clinical integration, thus appropriate training is fundamental to ensure patient safety. Despite significant expansion in residency programs and medical schools over the past decade, barriers such as limited training access for practicing physicians, faculty availability, and longitudinal competency maintenance persist. The fragmented inclusion of POCUS in disease-specific guidelines underscores a delay in recognizing evidence in some cases, but mostly highlights the need for further research and standardization.

The term point of care ultrasound (POCUS) refers to a sonographic examination directly performed at the patient's bedside, ideally by the treating physician, to interpret and integrate images into the clinical reasoning for diagnostic, monitoring, risk stratification and therapeutic scope. Many denominations have been used to indicate differences in devices: for example, 'echoscopy' usually refers to examination with pocket-size device [1]; in operator expertise: for example, 'limited echocardiography' refers to a bedside echocardiogram with reduced items assessment but performed by a specialist; in the considered organ: for example, FoCUS refers to focused echocardiography, a POCUS where only the heart is evaluated [2]. Nevertheless, POCUS is nowadays the most prevalent term summarizing the characteristics of this easily available bedside tool [3]. Starting from its early use in emergency medicine and critical care, POCUS has been widely adopted in almost all specialties including internal medicine. Guidelines and consensus documents have been published regarding POCUS core curricula for many specialties [4–8].

Over the past 15 years, substantial evidence has accumulated supporting various POCUS applications, and in some cases, its use has become the standard of care—for example, in procedural guidance. Nevertheless, the rapid spread of POCUS use has surpassed in some cases the demonstration of POCUS efficacy, and the fast-increasing literature on the topic might overwhelm those searching for validation (beyond enthusiasm).

This review aims to provide a synthetic assessment of the main available evidence on the use of POCUS in patients presenting with dyspnea, chest pain, abdominal pain and shock or with suspected pathologies leading to these clinical presentations, focusing on non-trauma, non-ICU patients. To facilitate a critical appraisal, evidence from studies on diagnostic efficacy, monitoring, guides to therapy and

Abbreviations: ACS, acute coronary syndrome; ADHF, acute decompensated heart failure; ARDS, acute respiratory distress syndrome; CXR, chest x-ray; CTA, computed tomography angiography; ED, emergency department; RWMA, regional wall motion abnormalities; ecg, Electrocardiogram; HF, heart failure; IVC, inferior vena cava; LUS, lung ultrasound; LV, left ventricle; PE, pulmonary embolism; POCUS, point-of-care ultrasound; RV, right ventricle.

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the impact on patients' clinical outcomes have been considered separately. Moreover, the extent of incorporating the use of POCUS in clinical guidelines and recommendations for the above mentioned clinical conditions have been assessed. Lastly, limitations, areas of uncertainty and potential harms in POCUS application have been discussed.

DYSPNEA

Dyspnea is one of the most common causes of presentation to the Emergency Department (ED) and hospitalization in Internal Medicine Departments, leading to a substantial use of diagnostic and therapeutic resources. POCUS enables clinicians to identify several underlying pulmonary and cardiac conditions with various levels of diagnostic accuracy (Fig. 1). A systematic review using a symptom-based approach found that POCUS, when added to a standard diagnostic pathway, led to statistically significantly more correct diagnoses in patients with dyspnea [9] .

Diagnostic accuracy for most frequent causes of dyspnea

Acutely decompensated heart failure (ADHF): POCUS allows for the evaluation of both congestion and underlying cardiac disease. The former includes diffuse bilateral B-lines, pleural effusion, dilated inferior vena cava (IVC), while the latter comprehends left ventricular (LV) dysfunction, enlargement or hypertrophy, gross valvular disease, signs of increased LV filling pressure (i.e. LA enlargement [10] or Doppler parameters in more advanced evaluation). A meta-analysis by Martindale et al. showed that lung ultrasound (LUS) had the highest positive likelihood ratio for ADHF (7.4, 95 % CI: 4.2–12.8) compared to physical examination and chest X-ray (CXR) [11]. In a randomized controlled trial, Pivetta et al. demonstrated that incorporating LUS into clinical evaluation significantly improved diagnostic accuracy compared to using CXR plus NT-proBNP. Net reclassification improvement provided by LUS was noticeably higher than CXR/NT-proBNP (8.9 % vs 4 %) [12].

Pneumonia: Typical findings include focal B-lines, consolidation with air bronchograms, with or without pleural effusion. Of note, only consolidations reaching the pleura can be visualized. A meta-analysis including 5018 patients found a valuable POCUS pooled diagnostic accuracy when compared to CXR or CT scan (sensitivity 92 %; specificity 93 %) [13]. When CT scan was considered as a reference standard, sensitivity and specificity were 83 % and 96 % respectively, higher than CXR (64.3 %) [14]. Sensitivity raised to 92 % in patients with pleuritic chest pain [14].

Pulmonary embolism: The vast majority of hemodynamically stable pulmonary embolisms present with normal cardiac and LUS findings. However, right ventricular (RV) dilation or dysfunction may be observed in more severe cases. Conversely, in a patient presenting with shock, the absence of RV dilation and dysfunction virtually excludes pulmonary embolism as the cause of hemodynamic instability. Moreover, the identification of deep vein thrombosis through compressive ultrasound (CUS) can provide supporting evidence for the diagnosis; however, it is detected in fewer than half of cases. Although the sensitivity of single-organ POCUS in the diagnosis of pulmonary embolism (PE) is limited, its integration in a multi-organ approach can enhance diagnostic performance. In a study by Nazerian et al., the integration of cardiac, lung, and CUS achieved a sensitivity of 90 % and a specificity of 86 % for PE diagnosis [15]. Interestingly, sensitivity increased to 100 % when multi-organ POCUS was combined with the identification of an alternative diagnosis [15].

Interstitial lung disease (ILD): A thickened and irregular pleural line and diffuse B-lines are observed. Mild pleural effusion and, in advanced stages, small subpleural consolidations are frequently observed. Although LUS is not the primary diagnostic modality for assessing ILD, it can offer valuable preliminary bedside information. A meta-analysis of 11 studies found a pooled sensitivity and specificity of 86 % and 84 %, respectively, for ILD in connective tissue disease [16].

Acute respiratory distress syndrome (ARDS): An irregular pleural line with reduced gliding, consolidations and focal interstitial patterns alternating with preserved areas are the most usual presentation. POCUS demonstrates high pooled specificity and moderate sensitivity in diagnosing ARDS when compared to the Berlin criteria[17]. Similar ultrasound findings were found in severe **COVID-19 pneumonia** [18].

In **COPD/Asthma** no pathognomonic findings are observed. However, the use of POCUS to exclude other differential diagnoses can support the diagnosis of COPD/asthma when accompanied by a compatible physical examination. As expected, in this setting, POCUS has slightly lower sensitivity compared to standard diagnostic pathways (87 % vs. 92 %; $p < .001$) [19].

Pleural effusion: fluid detection was one of the earliest and most widespread applications of LUS, which has a higher diagnostic accuracy compared to CXR (sensitivity 95 % vs 68 %; specificity 98 % vs 85 %) [20]. Moreover, corpuscular structure, septations or swirling debris are easily detected, providing important elements for etiologic diagnosis and treatment strategy.

In an emergency setting, POCUS is an invaluable tool to rapidly detect **pneumothorax,** which is characterized by bilateral A-lines and the absence of lung sliding. The presence of B-lines excludes pneumothorax, while the identification of the lung point increases specificity, and its location may give a rough estimate of its extent. A meta-analysis by Ebrahimi et al. reported that POCUS sensitivity (87 %) and specificity (99 %) were higher than supine CXR for detection of pneumothorax [21].

Another cardiac cause of dyspnea is **pericardial effusion**, which can be easily identified by the presence of an anechoic or hypoechoic space surrounding the heart; signs of tamponade include IVC plethora, systolic right atrial collapse, diastolic RV collapse, and sonographic pulsus paradoxus (significant respiratory variation in mitral and tricuspid inflow velocities in pulse wave Doppler evaluation) [22]. Studies have shown a high degree of sensitivity and specificity in the detection of pericardial effusions in both medical and trauma patients using POCUS [23].

Finally, POCUS is recognized as fundamental in guiding **procedures** frequently needed in dyspneic patients, including thoracentesis, pericardiocentesis, and central venous catheter placement [24].

Prognosis assessment, therapeutic efficacy and impact on clinical outcomes

A recent meta-analysis found no significant differences in-hospital mortality when POCUS was used in addition to the standard diagnostic approach [9] in patients presenting with dyspnea, while minimal impact on length of stay or 30-day readmission rates were observed [9, 25]. However, POCUS significantly contributed to reducing time to diagnosis and treatment, and increased the likelihood of appropriate interventions [9,19,25]. The latter consideration is crucial for ensuring patient safety and facilitating efficient in-hospital workflows.

POCUS may greatly impact patient management in resource-limited settings with scarce radiological resources, especially in time-dependent clinical situations. A prospective case series study conducted in an emergency centre in Ethiopia showed using POCUS led to changes in diagnosis and management in a relevant proportion of patients [26].

In patients hospitalized for **ADHF**, the assessment of lung and IVC residual congestion at time of discharge can aid in determining the risk of decompensation recurrence and death in the short- and long-term [27,28]. In recent years, a comprehensive evaluation of visceral congestion (Venous Excess Ultrasound,VExUS score) has been proposed, adding pulsed wave doppler waveforms of hepatic, renal and portal veins to IVC evaluation. The VExUS score was originally developed to predict acute kidney injury in surgical patients and its role in heart failure patients is not fully understood. While a higher VExUS score has been associated with higher in-hospital mortality [29] and its improvement during hospitalization correlates with lower mortality [30], its prognostic value at discharge and during follow-up has shown conflicting results [31,32]. Interestingly, in a monocentric prospective

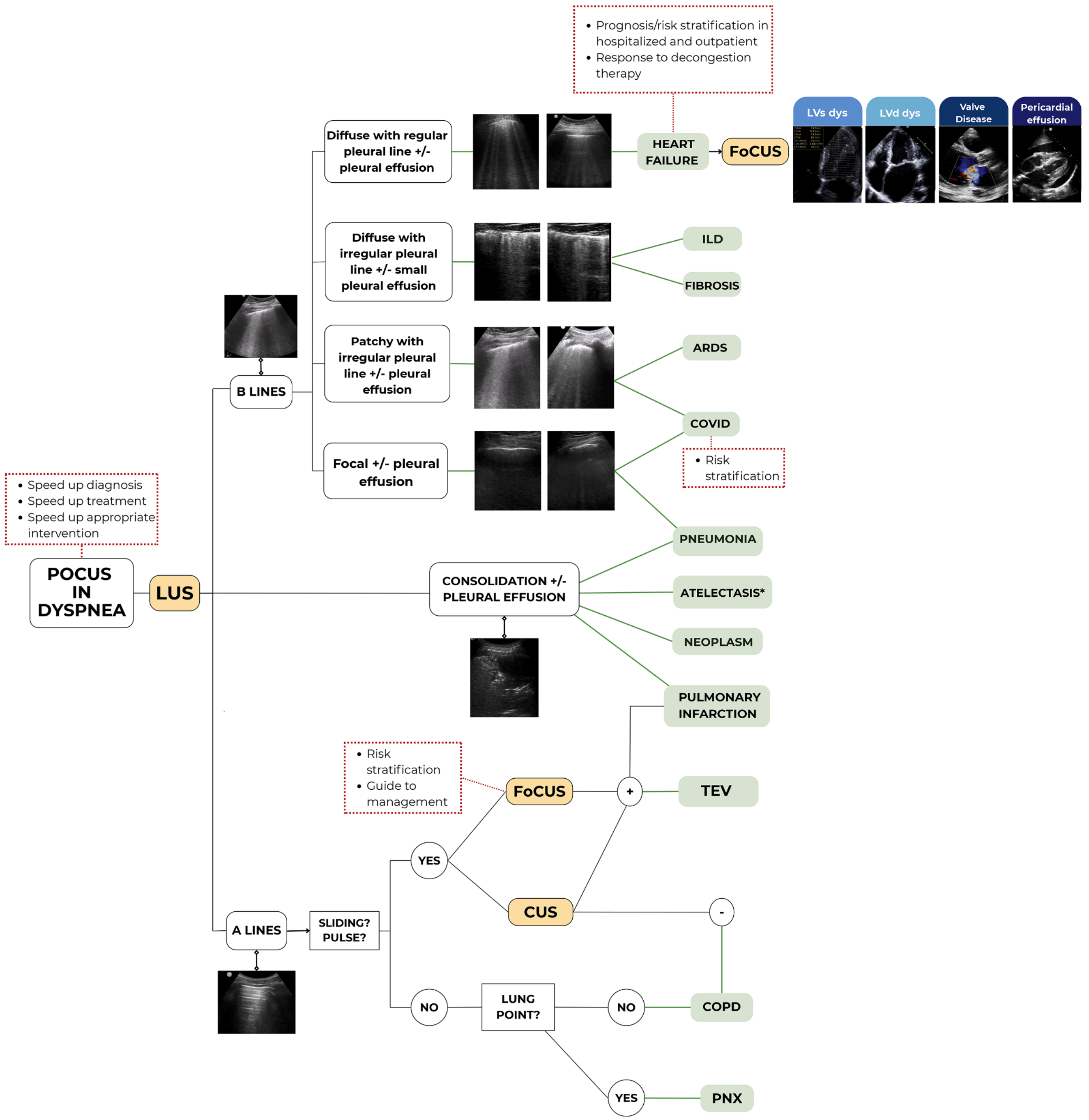

Fig. 1. POCUS-based algorithm for the evaluation of acute dyspnea.
The red dashed box highlights the outcomes for which there is evidence supporting a clinical impact of POCUS. Outcomes without supporting evidence or with conflicting data are not shown.
*The presence of a dynamic bronchogram excludes the diagnosis of compressive atelectasis.
ARDS: Acute Respiratory Distress Syndrome.
COPD: Chronic Obstructive Pulmonary Disease.
CT: Computed Tomography.
CUS: Compression Ultrasound.
CXR: Chest X-Ray.
FoCUS: Focused Cardiac Ultrasound.
HF: Heart Failure.
ILD: Interstitial Lung Disease.
IVC: Inferior Vena Cava.
LUS: Lung Ultrasound.
PNX: Pneumothorax.
POCUS: Point-of-Care Ultrasound.
TEV: Thromboembolic Venous Disease.

study in ambulatory HF patients, Pugliese et al. showed that simultaneous assessment of lung, IVC, and renal flow was able to identify a high prevalence of patients with sub-clinical congestion that was associated with poor outcomes [33].

POCUS may assist clinicians in assessing clinical response to decongestion therapy [34,35]. Some evidence showed that adding LUS to clinical evaluation during hospitalization may lead to earlier decongestion [36] and discharge [37]. Data regarding the impact on harder endpoints (reducing rehospitalizations/urgent visits and/or mortality) are conflicting, both for hospitalized [36] and ambulatory patients [38, 39]. A recent meta-analysis considering randomized controlled trials in all clinical settings found a reduction in major adverse cardiac events when LUS was added to standard clinical management [40]. Although the Authors reported low etherogenity in the studies considered, it is worth noting that some enrolled a very small population, with acute and chronic HF and,in some cases, a diverse clinical condition (for example, patients on dyalisis treatment).

In hemodynamically stable patients with **pulmonary embolism** and sPESI ≥ 1, the presence of RV dilation and/or impaired contraction in addition to troponin values identifies patients with “high-intermediate risk”, warranting additional monitoring and possibly a different therapeutic approach (i.e. thrombolytic therapy in selected patients) [41]. Conversely, the absence of RV dysfunction in patients with sPESI of 0 identifies a subset of patients at extremely low risk of death and complications, for whom a safe discharge from hospital can be planned [42,43].

A special note should be made on the application of POCUS in the recent **COVID-19 pandemic**, when the use of POCUS was an invaluable aid for clinicians regarding detection of lung involvement and patient risk stratification, especially in situations of extreme distress for emergency departments and medical wards [18,44].

Table 1 summarizes how current guidelines have integrated POCUS or ultrasonography into the assessment of dyspnea and its etiologies in clinical practice and to what extent this tool is recommended.

Chest pain

Diagnostic accuracy for most frequent causes of chest pain

While electrocardiogram (ECG) and cardiac enzymes remain the mainstay for the diagnosis of acute coronary syndrome (ACS), the assessment of regional wall motion abnormalities (RWMA) may appear earlier in ACS evolution [45]. A recent meta-analysis evaluated the accuracy of cardiac ultrasound for diagnosing acute myocardial ischemia in patients presenting to the ED with chest pain: in five studies that considered POCUS, the pooled sensitivity and specificity were 76.4 % (47.9–91.9 %) and 84.7 % (59.5–95.4 %), respectively [46]. This relatively low accuracy highlights the technical challenges associated with the assessment of RWMA and underscores significant interobserver variability, even among experienced operators [47]. In this regard, the American Society of Echocardiography and the American College of Emergency Physicians recommend that POCUS should not be used as the primary mode for this purpose [2]. However, POCUS offers early insights into LV systolic function, facilitating the timely initiation of appropriate therapies prior to a comprehensive echocardiographic evaluation. Furthermore, some studies showed that POCUS including lung congestion evaluation may help in risk stratification of acute myocardial infarction, increasing the prognostic value of Killip classification [48–50]. Finally, POCUS can identify post-ischemic complications, including ventricular wall rupture, ventricular aneurysm, impaired LV or RV function, and significant acute mitral regurgitation [51].

Acute Aortic Syndrome is a life-threatening condition with a mortality rate exceeding 50 %, necessitating prompt diagnosis and urgent intervention. While computed tomography angiography (CTA) is the diagnostic gold standard with >95 % sensitivity, POCUS is a valuable first-line tool for initial assessment in emergency settings. Indirect signs of aortic dissection -namely aortic root dilation (>40 mm), aortic regurgitation at Color Doppler and pericardial effusion- can raise suspicion of the condition even in the absence of direct visualization of an intimal flap or intramural hematoma. The latter findings are often more challenging to visualize and require more advanced echocardiographic expertise. In a study of 281 patients, Nazerian et al. reported that POCUS identification of direct signs had 54 % sensitivity and 94 % specificity for type A aortic dissection [52]. On the other hand, including both direct and indirect sonographic signs increased sensitivity to 88 % but reduced specificity to 56 %, due to the nonspecific nature of indirect signs, which can mimic other conditions like pericarditis or heart failure [52]. In general, a negative POCUS cannot rule out aortic dissection, making further imaging modalities like CTA or transesophageal echocardiography essential for a definitive diagnosis in the presence of concrete suspicion [2,52]. Conversely, the recently published PROFUNDUS study evaluated a diagnostic protocol integrating clinical data with POCUS and D-dimer, finding that patients with a negative POCUS, low pretest probability, and a negative D-dimer had a 30-day incidence of acute aortic syndrome of 0 % [53]. POCUS demonstrated a specificity of 100 % for type B aortic dissection but a sensitivity of only 81.9 %, likely attributable to the challenges in visualizing descending aorta [54]. Of note, a combined POCUS protocol incorporating transthoracic echocardiography and abdominal aorta assessment improved sensitivity to 93.2 % and specificity to 90.9 %in identifying type B aortic dissection [55].

The role of POCUS in identifying other causes of chest pain, such as pneumothorax, pulmonary embolism, pneumonia, and pleural effusion, is discussed in the section on dyspnea.

Prognosis assessment, therapeutic efficacy, and clinical outcomes

Although most studies have not shown a statistically significant impact of POCUS on mortality in patients presenting with chest pain, a study involving 465 patients found that its use was associated with reduced mortality in non-ST-elevation myocardial infarction, particularly when performed within the first 90 min of arrival [56]. Similarly, evidence collected in a pilot study focusing on aortic dissection where POCUS was routinely used in ED [57] showed a significant reduction in time to diagnosis, emphasizing its role in time-sensitive conditions [58]. Moreover, in patients admitted to internal medicine wards with chest pain, the early use of POCUS was associated with faster appropriate treatment (nearly 20 h earlier on average), compared to a control group [57]. Preliminary evidence seems to show that POCUS implementation is associated with a shorter length of stay both in the ED [59] and in hospital [56].

Table 1 outlines the degree to which current guidelines have integrated POCUS or ultrasonography in the management of chest pain causes.

Abdominal pain

Diagnostic accuracy for most frequent causes of non-traumatic abdominal pain

Studies regarding POCUS performance in patients presenting with the aspecific symptom ‘abdominal pain’ are still few. In contrast with early sudies [60,61], a recent bicentric randomized trial on unselected patients presenting to the ED with undifferentiated acute abdominal pain found no difference in diagnostic accuracy between a usual and a POCUS-implemented approach [62].

Conversely, reports focused on diagnostic accuracy in suspected abdominal pathologies are abundant.

Biliary tract pathology. Gallstones are present in approximately 6 % of the general population, and their complications are a common cause of hospitalization [63]. Gallstones appear as bright

Table 1
Recomendation regarding pocus or ultrasound examinations reported in scientific societies guidelines for dyspena, chest pain, abdominal pain, shock presentations and possibile causes.

	GUIDELINE SOURCE*	ULTRASOUND RECOMMENDATION	TYPE OF RECCOMANDATION AND/ OR LEVEL OF EVIDENCE AS STATED BY THE ORIGINAL GUIDELINE #
DYSPNEA	ACEP Ultrasound Guidelines: Emergency, Point-of-care, and Clinical Ultrasound Guidelines in Medicine [116]	TTE§ + LUS differentiate acute HF from other causes of dyspnea and guide management.	NS
HEART FAILURE	2021 ESC Guidelines for Diagnosis and Treatment of Acute and Chronic Heart Failure [117]	TTE§ is recommended for ventricular function, chamber size and valvular function assessment	Recommendation class I, evidence class C
		LUS not considered in diagnosis of Chronic HF	NS
		LUS may be considered in 'de novo' HF	Recommendation class IIb
		LUS may be considered at admission, during hospitalization, and pre-discharge for congestion evaluation	Recommendation class IIb
	ACEP Clinical Policy: Critical Issues in the Evaluation and Management of Adult Patients Presenting to the Emergency Department With Acute Heart Failure Syndromes (2022) [118]	Use of lung POCUS an imaging modality in conjunction with medical history and physical examination to diagnose acute HF syndrome when diagnostic uncertainty exists as the accuracy of this diagnostic test is sufficient to direct clinical management	Evidence class B
PNEUMONIA	ERS/ESICM/ESCMID/ALAT guidelines for the management of severe community-acquired pneumonia [119]	POCUS/LUS are not mentioned	
	ACEP Ultrasound Guidelines: Emergency, Point-of-care, and Clinical Ultrasound Guidelines in Medicine [116]	POCUS is 85–92 % sensitive and 93 % specific for pneumonia diagnosis	NS
		POCUS is advantageous in pediatric patients due to reduced radiation exposure.	NS
	Guideline of the American Thoracic Society and Infectious Diseases Society of America [120]	POCUS/LUS are not mentioned	
PULMONARY EMBOLISM	2019 ESC Guidelines for the diagnosis and management of acute pulmonary embolism developed in collaboration with the ERS [121]	It is recommended to accept the diagnosis of venous tromboebolism (and PE) if a CUS shows DVT in a patient with clinical suspicion of PE	Recommendation class I, evidence class A
		If CUS shows only a distal DVT, further testing should be considered to confirm PE	Recommendation class IIa, evidence class B
		In suspected high-risk PE, as indicated by the presence of haemodynamic instability, bedside echocardiography or emergency CTPA (depending on availability and clinical circumstances) is recommended for diagnosis	Recommendation class I, evidence class C
		Assessment of the RV function by imaging techniques or laboratory biomarkers should be considered, even in the presence of a low PESI or a negative sPESI scores	Recommendation class IIa, evidence class B
		In patients without haemodynamic instability, further stratification of patients with acute PE into intermediate- and low risk categories is recommended	Recommendation class I, evidence class B
	ASH guidelines for management of venous thromboembolism [122,123]	Use of ultrasound in PE diagnosis – management not mentioned. Only mentioned for DVT	NS
	Thrombosis Canada 2023 Pulmonary Embolism (PE): Diagnosis [124]	TTE§ used in patients unstable to undergo CTPA, if right heart overload (without other diagnosis) or embolus in the right ventricle (RV) or main pulmonary arteries anticoagulation should be started	NS
	ACR Appropriateness Criteria® Suspected Pulmonary Embolism (2022) [125]	Suspected pulmonary embolism. Low or intermediate pretest probability with a negative D-dimer. US duplex Doppler lower extremity and TTE§ usually not appropriate as initial imaging.	NS
		Suspected pulmonary embolism. Low or intermediate pretest probability with a positive D-dimer. US duplex Doppler lower extremity and TTE§ usually not appropriate as initial imaging.	NS
		Suspected pulmonary embolism. High pretest probability. US duplex Doppler lower extremity and TTE§ may be appropriate as initial imaging.	NS
		Suspected pulmonary embolism. Pregnant patient. US duplex Doppler lower extremity usually	NS

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Table 1 (*continued*)

	GUIDELINE SOURCE*	ULTRASOUND RECOMMENDATION	TYPE OF RECCOMANDATION AND/ OR LEVEL OF EVIDENCE AS STATED BY THE ORIGINAL GUIDELINE #
		appropriate as initial imaging. TTE§ usually not appropriate as initial imaging.	
	NICE Venous thromboembolic diseases: diagnosis, management and thrombophilia testing (2020 – updated 2023) [126]	Consider a proximal leg vein ultrasound scan if DVT is suspected in PE likely patients with PE not identified by CTPA, V/Q SPECT or V/Q planar scan	NS
INTERSTITIAL LUNG DISEASE	ATS/ERS/JRS/ALAT Clinical Practice Guidelines [127]	POCUS not mentioned.	
ARDS	ESICM Guidelines on ARDS [128]	POCUS not mentioned.	
	ARDS Clinical Practice Guideline 2021- Japanese Respiratory Society [129]	LUS and diaphragm ultrasound require expertise and have not been definitively shown to be superior to traditional methods for PEEP adjustment	NS
	ACEP Ultrasound Guidelines: Emergency, Point-of-care, and Clinical Ultrasound Guidelines in Medicine [116]	POCUS protocols are mentioned for detecting interstitial lung fluid in ARDS	NS
PNEUMOTHORAX	SPLF/SMFU/SRLF/SFAR/SFCTCV Guidelines [130]	The group proposes not to solely rely on LUS to assess the size of a PSP	Evidence class C
		The group suggests not to solely base the diagnosis of PSP on LUS in the absence of signs of severity.	Conditional recommendation, low level of evidence
		LUS is recommended in drained patients to assess residual pneumothorax	Conditional recommendation, moderate level of evidence
		The group suggests obtaining an ultrasound visualization before performing needle aspiration or chest tube drainage using the anterior or axillary approach, in order to reduce the risk of complication	Conditional recommendation, low level of evidence
	Joint ERS/EACTS/ESTS [131]	POCUS/LUS are not mentioned	
	ACEP Ultrasound Guidelines: Emergency, Point-of-care, and Clinical Ultrasound Guidelines in Medicine [116]	Extended focused assessment with sonography in trauma (EFAST)'s scope is detection of pneumothorax, intrathoracic hemorrhage, and/or pulmonary contusions	NS
		LUS is more sensitive than chest X-ray; however, disease management should not be delayed while attempting to identify a lung point.	NS
PLEURAL EFFUSION	ACR Appropriateness Criteria® Workup of Pleural Effusion or Pleural Disease (2023) [132]	Recent pneumonia with suspected parapneumonic effusion or empyema. US chest may be appropriate as initial imaging (Disagreement)	NS
		Recent minor blunt trauma with suspected pleural effusion. US chest may be appropriate as initial imaging (Disagreement)	NS
		Dyspnea, cough, or chest pain with suspected pleural effusion, noninfectious. US chest may be appropriate as initial imaging (Disagreement	NS
		Pleural effusion incidentally detected on incomplete thoracic imaging study. US chest may be appropriate as next imaging study (Disagreement)	NS
	ATS/STS/STR: Clinical practice guideline for the management of malignant pleural effusions (2018) [133]	In patients with known or suspected malignant pleural effusion (MPE), we suggest that ultrasound imaging be used to guide pleural interventions	conditional recommendation, very low confidence in estimate of effects
	The STS consensus guidelines for the management of empyema (2017) [134]	Pleural ultrasound (US) should be performed routinely in addition to conventional chest x-ray (CXR) in the evaluation of pleural space infection, both for diagnostic purposes and image-guidance for pleural interventions	Recommendation class I, evidence class B
	BTS Guideline for pleural disease (2023) [135]	Image-guided thoracentesis should always be used to reduce the risk of complications.	Strong—by consensus
		Ultrasound may be a useful tool at presentation to support a diagnosis of pleural malignancy, particularly in the context of a pleural effusion, where appropriate sonographic skills are present.	Conditional

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Table 1 (*continued*)

	GUIDELINE SOURCE*	ULTRASOUND RECOMMENDATION	TYPE OF RECCOMANDATION AND/ OR LEVEL OF EVIDENCE AS STATED BY THE ORIGINAL GUIDELINE #
		There is no difference in diagnostic accuracy between CT-guided closed pleural biopsy and ultrasound-guided closed pleural biopsy.	Very low
PERICARDIAL EFFUSION	2015 ESC Guidelines for the diagnosis and management of pericardial diseases [136] Pericardial Diseases International Position Statement on New Concepts and Advances in Multimodality Cardiac Imaging (2024) [137]	TTE§ is recommended in all patients with suspected pericardial effusion	Recommendation class I, evidence class C
		In a patient with clinical suspicion of cardiac tamponade, TTE§ is recommended as the first imaging technique to evaluate the size, location and degree of haemodynamic impact of the pericardial effusion	Recommendation class I, evidence class C
		A judicious clinical evaluation including TTE§ findings is recommended to guide the timing of pericardiocentesis	Recommendation class I, evidence class C
		Urgent imaging technique (TTE§ or CT) is indicated in patients with a history of chest trauma and systemic arterial hypotension	Recommendation class I, evidence class B
		State-of-the-art pericardiocentesis must be guided either by fluoroscopy or TTE § under local anaesthesia. Blind procedures must not be used	NS
	Pericardial Diseases International Position Statement on New Concepts and Advances in Multimodality Cardiac Imaging (2024) [137]	TTE§ remains the first-line imaging modality for pericardial evaluation	NS
		Cardiac POCUS is useful when performed by trained clinicians	NS
ACUTE CHEST PAIN	2021 AHA/ACC/ASE/CHEST/SAEM/SCCT/SCMR Guideline for the Evaluation and Diagnosis of Chest Pain [138]	Bedside TTE§ is recommended to evaluate ventricular/ valvular function, wall motion abnormalities, and pericardial effusion.	Recommendation class I, evidence class C
		Cardiac POCUS is useful when performed by trained clinicians.	NS
ACUTE CORONARY SYNDROME	2023 ESC Guidelines for the management of acute coronary syndromes [139]	Emergency TTE§ is recommended in patients with suspected ACS presenting with cardiogenic shock or suspected mechanical complications.	Recommendation class I, evidence class C
		Emergency TTE§ should be considered at triage in cases of diagnostic uncertainty but this should not result in delays in transfer to the cardiac catheterization laboratory if there is suspicion of an acute coronary artery occlusion	Recommendation class IIa, evidence class C
	NICE ACS guidelines (2020) [140]	Assess left ventricular function§ in all people who have had an NSTEMI.	NS
		Consider assessing left ventricular function§ in all people with unstable angina	NS
		POCUS/LUS not mentioned	
THORACIC AORTIC DISSECTION	ACCF/AHA/AATS/ACR/ASA/SCA/SCAI/SIR/STS/ SVM Guidelines 2010 [141]	POCUS not mentioned; TTE§ strongly recommended for diagnosis in non-acute patients	NS
	ACEP Clinical Policy: Critical Issues in the Evaluation and Management of Adult Patients With Suspected Acute Nontraumatic Thoracic Aortic Dissection (2015) [142]	In adult patients with suspected nontraumatic thoracic aortic dissection, do not rely on an abnormal bedside TTE§ result to definitively establish the diagnosis of thoracic aortic dissection.	Level B recommendations
		In adult patients with suspected nontraumatic thoracic aortic dissection, immediate surgical consultation or transfer to a higher level of care should be considered if a TTE§ is suggestive of aortic dissection	Level C Recommendations
SHOCK	International Guidelines for Management of Sepsis and Septic Shock 2021 [143]	POCUS not mentioned TTE§ recommended to guide volume resuscitation	Weak recommendation, low-quality evidence
	ACEP Clinical Policy: Early Care of Adults With Suspected Sepsis in the Emergency Department and Out-of-Hospital Environment: A Consensus-Based Task Force Report (2021) [144]	Ultrasound mentioned to guide volume resuscitation (stroke volume, inferior cava)	NS
	NICE Guidelines 2021- update 2024 [145]	POCUS or ultrasound not even mentioned	NS
CHOLELITHIASIS	Evidence-based clinical practice guidelines for cholelithiasis 2021 – The Japanese Society of Gastroenterology [146]	Abdominal ultrasound§ suggested as first-line imaging exam to diagnosis	NS

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Table 1 (*continued*)

	GUIDELINE SOURCE*	ULTRASOUND RECOMMENDATION	TYPE OF RECCOMANDATION AND/ OR LEVEL OF EVIDENCE AS STATED BY THE ORIGINAL GUIDELINE #
	Diagnosis and management of gallstone disease – NICE guidelines 2014 [147]	Abdominal ultrasound§ recommended as first-line imaging exam to diagnosis	Based on moderate to very low quality observational studies
CHOLECISTYTIS	WSES Guidelines 2020 [148]	Abdominal ultrasound§ is strongly recommended as the first-line diagnostic test	Strongly recommended despite moderate evidence.
ASCITIS	EASL Clinical Practical Guidelines 2023 [149]	Abdominal ultrasound§ mentioned to assess the severity of ascites	NS
ABDOMINAL AORTIC ANEURISM	ACC/AHA Guideline for the Diagnosis and Management of Aortic Disease 2022 [150]	Abdominal ultrasound§ is strongly recommended for aneurism screening and surveillance, especially for patients with risk factors	Classe of Reccomendation I, based on moderate-quality randomized controlled trials
NEPHROLITHIASIS	NICE Guideline (2019) [151]	Ultrasound§ mentioned as the first-line imaging modality for children, pregnant women and young people with suspected renal colic	NS
APPENDICITIS	WSES Jerusalem guidelines – 2020 update [152]	POCUS is recommended as the first-line diagnostic tool in both adults and children when imaging is indicated based on clinical assessment	Recomandation class I, evidence class B
	ACEP Clinical Policy: Critical Issues in the Evaluation and Management of Emergency Department Patients With Suspected Appendicitis (2023) [153]	In pediatric patients with suspected acute appendicitis, if readily available and reliable, use right lower quadrant ultrasound§ to diagnose appendicitis. An unequivocally positive examination with complete visualization of a dilated appendix has comparable accuracy to a positive CT or MRI in pediatric patients. A non-visualized or partially-visualized appendix should be considered equivocal.	Level B Recommendations
		In adult patients with suspected acute appendicitis, an unequivocally positive right lower quadrant ultrasound§ has comparable accuracy to a positive CT or MRI for ruling in appendicitis. A non-visualized or partially-visualized appendix should be considered equivocal.	Level C Recommendations
		Abdominal ultrasound§ might be useful for diagnosis of small bowel occlusion when exposure to radiation is undesirable	NS
BOWEL OBSTRUCTION	Bologna guidelines for diagnosis and management of adhesive small bowel obstruction – 2017 update [154]	Abdominal ultrasound§ might be useful for diagnosis of small bowel occlusion when exposure to radiation is undesirable	NS
	(UMHS Clinical Guideline 2021 [155]	Ultrasound§ has no role in diagnosis of an acute small bowel obstruction in adult patient	NS

* Ultrasounds Guidelines have not been considered.
# The classification of recommendations and/or levels of evidence is reported here as stated in the original guidelines and may differ between guidelines.
§ in these cases the organ-specific ultrasound examination was considered, not specifically POCUS

CPR Cardiopulmonary Resuscitation
CRP C Reactive Protein
CUS Compressive Ultrasound
DVT Deep Vein Thrombosis
HE Heart Failure
LUS Lung Ultrasound
NS Not Specified.

surface/echogenic structures with posterior acoustic shadows; ultrasound signs of cholecystitis include increased wall thickness, presence of pericholecystic fluid, lumen distention and pain elicitation by probe compression over the visualized gallbladder (sonographic Murphy sign).

POCUS detects gallstones and signs of cholecystitis with high diagnostic accuracy [64–66]. However, sensitivity is lower in cases of chronic cholecystitis [67], where typical sonographic signs of inflammation may be absent. To avoid errors in gallbladder evaluation, clinicians should remember that lumen distension and wall thickening can occur in generalized edema and that gallbladder walls are physiologically contracted if fasting is not observed [68].

Ascites. Initially performed to detect hemoperitoneum (FAST - Fast Assessment Sonography for Trauma- protocol) [69], abdominal POCUS can also identify free fluid in non-trauma patients with high diagnostic accuracy (sensitivity 85 %–96 % and specificity >98 %) [69,70].

Abdominal Aortic Aneurism: POCUS can be useful both in the suspicion of a ruptured aortic aneurysm and as a screening tool for aneurysms in primary care settings [71]. The echographic findings in this context are similar to those described for thoracic aortic aneurysms. Common pitfalls include mistaking the aorta for other abdominal vessels or limited visualization due to interposed intestinal gas [72]. A meta-analysis reported very high diagnostic accuracyof POCUS in detecting abdominal aortic aneurysm, with pooled sensitivity of 98.33 % and specificity of 99.8 % [73].

Nephrolithiasis and urinary tract disorders. In patients with suspected renal colic, POCUS has a modest diagnostic accuracy (pooled sensibility 70.2 % and pooled specificity 75.4 %): the detection of typical direct sonographic signs (hyperreflective image determining acoustic shadow) may be difficult especially for ureteral stones. However, the finding of moderate or greater unilateral hydronephrosis yielded a specificity of 94.4 % [74]. Bladder distention is easily and accurately detected using POCUS, expediting diagnosis and treatment decisions [75].

Appendicitis. A recent meta-analysis demonstrated a pooled sensitivity of 84 % (95 % CI: 72 %−92 %) and pooled specificity of 91 % (95 % CI: 85 %−95 %) in diagnosing appendicitis [76]. Sonographic signs of appendicitis are a non-compressible appendix, obstructing appendicolith, discontinuity of the echogenic submucosa, periappendiceal fluid collection and McBurney signs.

Bowel obstruction. Sonographic signs of small bowel obstruction (e.g. the presence of a dilated, fluid-filled bowel, "to-and-fro" peristalsis, wall thickening) are better validated than for colonic obstruction. A study by Shokoohi et al. found that a diagnostic algorithm incorporating patient age, physician pretest probability and POCUS signs (increased small bowel diameter and the presence of free intraperitoneal fluid between bowel loops) accurately predicted small bowel obstruction diagnosis in the emergency department (C-statistic of 0.89) [77].

Prognosis assessment, therapeutic efficacy, and clinical outcomes

Evidence on impact of POCUS use on clinical outcomes in patients presenting with abdominal pain is limited. While an association between the use of POCUS and a reduction in the number of additional laboratory or imaging tests performed was not found in two studies [78,79], a randomized, single center study reported a reduction in length of stay in the ED in both the discharged and hospitalised patients [80].

On the other hand, some evidence indicate it may be useful in reducing the time to surgical intervention in cases of cholecystitis [65].

In acute aortic syndrome, evidence suggests that incorporating POCUS detection of an enlarged aortic diameter into clinical scores and laboratory parameters shortens the time to diagnosis; moreover, it also allows for the reclassification of patients into higher risk categories and enables a safer rule-out process [53].

Ultrasound guidance has become routine for diagnostic/therapeutic procedures, such as paracentesis [81].

Table 1 provides an overview of how current guidelines on abdominal pain and its causes have integrated the use of POCUS or ultrasonography for diagnostic purposes.

Shock

Diagnostic accuracy for the most frequent causes of shock

Shock is a life-threatening condition of circulatory insufficiency. The initial effects of shock are reversible but can rapidly become irreversible, leading to multiorgan failure and death. It is estimated that the pre-hospital mortality rate from shock is 33–52 %, while the in-hospital mortality rate is 12 % [82].

Originally developed for trauma patient evaluation in emergency settings, POCUS has now become an integral part of clinical practice for shock management, including non-trauma patients, to guide diagnostic and therapeutic processes [83] (Fig.2). Various diagnostic algorithms have been proposed to distinguish among the four different types of shock (distributive, cardiogenic, hypovolemic, and obstructive). Among these, the most used is the RUSH (Rapid Ultrasound in SHock) protocol. By assessing ‘the pump’ (cardiac contraction), ‘the tank’ (IVC, pleural, peritoneal, and pelvic fluid), and ‘the pipes’ (aortic and deep venous pathologies), the RUSH protocol provides a comprehensive and rapid evaluation of a patient in shock [84]. Evidence suggests that POCUS has high diagnostic accuracy in defining shock etiology, particularly in cases

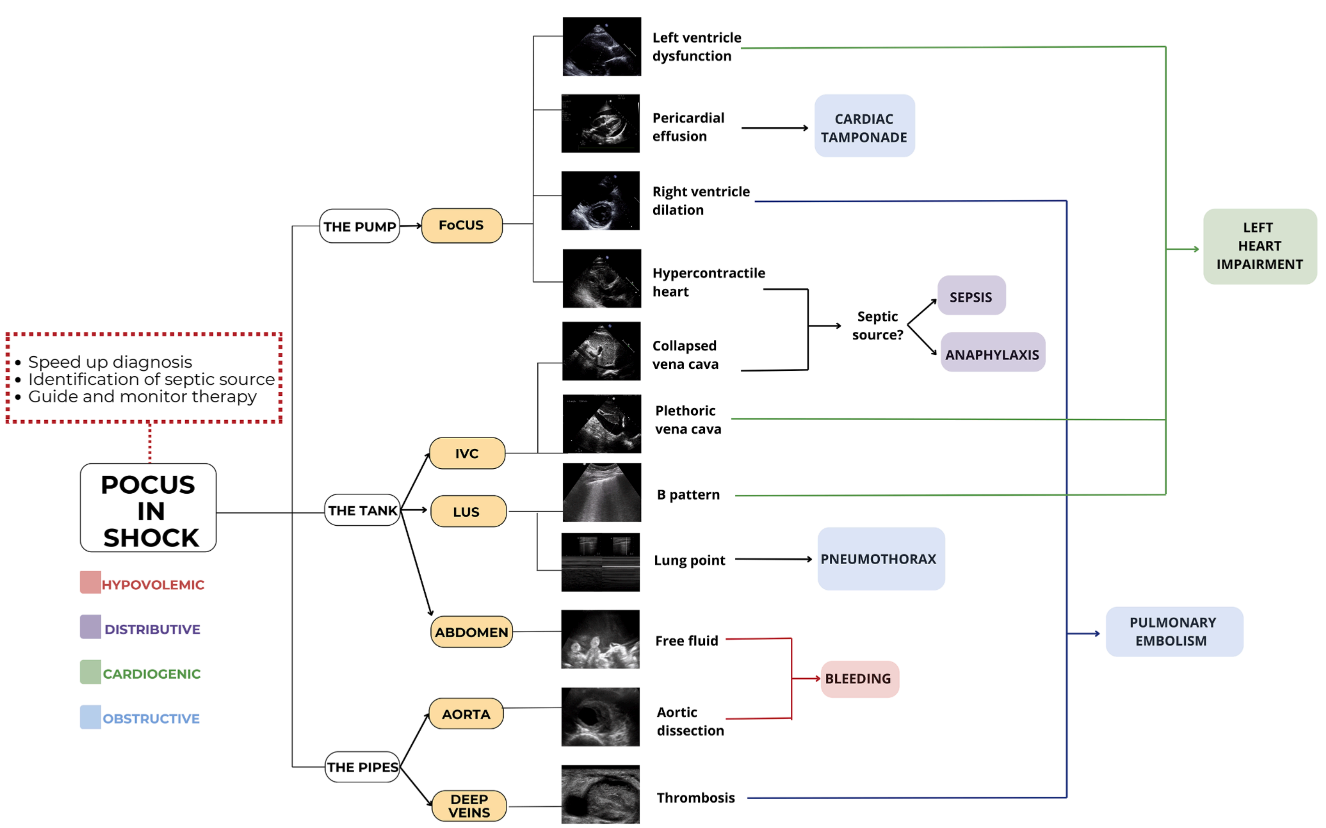

Fig. 2. POCUS-based algorithm for the evaluation of shock.
The red dashed box highlights the outcomes for which there is evidence supporting a clinical impact of POCUS.
FoCUS: Focused Cardiac Ultrasound.
IVC: Inferior Vena Cava.
LUS: Lung Ultrasound.
POCUS: Point-of-Care Ultrasound.

of obstructive conditions [85].

Prognosis assessment, therapeutic efficacy, and clinical outcomes

POCUS can be used to predict and/or monitor the response to fluid administration in shocked/hypotensive patients. Repeated measures of the left ventricular outflow tract velocity-time integral ($LVOT_{VTI}$) can be used to identify an increase in cardiac output during provocative manoeuvres (passive leg raising or intravenous fluid bolus) thus assessing fluid responsiveness: a cutoff at a 10 % increase in cardiac output has been identified as discriminative [86]. On the other hand, muli-organ POCUS can be used to guide the administration of intravenous fluids and inotropes, documenting improvement in hemodynamic status or, conversely, early signs of congestion. A recent systematic review and meta-analysis found that ultrasound-guided fluid resuscitation was associated with a reduction in mortality compared to usual care [87], in addition to faster lactate clearance, reduction in duration of vasoactive medications and the need for renal replacement therapy. However, no significant variations in fluid administration and ICU admissions/length of stay were identified, thus caution in interpreting the results is advised. Other potential benefits of POCUS include prompt identification and control of the source of infection [88].

A recent systematic review highlighted that the incorporation of POCUS into clinical approaches to identify the cause of shock is superior to conventional workup and could reduce length of stay in ED and the necessity for invasive maneuvers [89]. However, the randomized controlled study by Atkinson et al. found that POCUS did not confer any benefits over the standard of care in terms of 30 days survival or hospital discharge (primary outcome) nor in CT scan rates, inotrope use, or fluid administration (secondary outcomes) [90].

Table 1 summarizes how current guidelines on shock has integrated the use of POCUS or ultrasonography in assessment and management.

Artificial intelligence and pocus

In recent years the rapid evolution of Machine Learning (ML) algorithms, defined as the ability for a computer to learn and adapt without following explicit instructions but by the creation of algorithms that can analyse patterns in data and make predictions or decisions based on those patterns, is opening endless new possibilities in medical imaging [91].

The initial applications were mainly reserved for Computed Tomography (CT) and Magnetic Resonance Imaging (MRI), due to the fact that obtaining highly repeatable image series in these settings is relatively easy. In contrast, Artificial Intelligence (AI) integration in ultrasound (and particularly in POCUS) has lagged behind because creating machine learning algorithms on moving images that present operator dependency and greater acquisition variability is way more difficult and less efficient [91,92].

However, with the advancements in technique, AI applications in POCUS are more and more under investigation. A recent review on this subject by Kim et al. [92] reported that AI has the potential to increase POCUS accessibility and usability, aiding novice users in both training and image interpretation providing real-time feedback on image quality and guiding probe manipulations. By reducing operator dependency, AI integration is particularly promising in low resource settings where skilled operators are harder to find [93]. Moreover, AI may reduce examination time while maintaining high diagnostic accuracy in some applications such as measuring left ventricle ejection fraction, left ventricular outflow tract velocity time integral, inferior vena cava collapsibility index and B-lines [92,94,95]. In addition, a recent multicentre study found that AI guided POCUS was able to identify under-recognised cardiomyopathies [96].

Several limitations in wider adoption of AI in POCUS are to be mentioned [91,92,97]; first of all, AI interpretation is dependent on image quality, and the latter is generally poorer in exams carried out on critical patients, thus limiting its role in this setting. Secondly, widespread lack in clinical validation studies and legal regulations may prevent institution from adopting its use. Lastly, there are technical limitations, due to the fact that AI software must be able to perform real-time image interpretation and has to be integrated in machine hardware.

In conclusion, AI holds great promise for enhancing POCUS, but its widespread adoption still faces important technical and clinical challenges.

Limitations, potential harms and areas of uncertainty in pocus application

Spreading use of POCUS makes awarness of potential harm arising from inappropriate use necessary (Fig. 3). Potential points of concern include:

1. **Lack of education or training.** POCUS competency relies both on adequate skills achievement and continuous practice [98]. Competency requirements, in terms of scan number and type, varies widely among different applications and consequently recommendations from scientific societies and experts consensus documents. Learning curve differ for various anatomic district and longitudinal practice/learning is of paramount importance [98].
2. **Lack of an indication for POCUS use in addressing a specific clinical question.** Physicians should apply POCUS for indications supported by robust evidence. An example of erroneous POCUS use is ruling out pulmonary embolism based on normal bedside echocardiography in hemodynamically stable patients [99]. More nuanced errors might arise when POCUS is applied to an appropriate clinical question but in a context that differs from those supported by literature. For example, applying evidence drawn from critically ill patients [100] to patients with mild dyspnea may lead to incorrect conclusions [98].
3. **Errors in the acquisition and interpretation of ultrasound images.** Errors may arise from non-modifiable and modifiable factors. The former include inadequate acoustic windows due to patient characteristics, like obesity, psychomotor agitation, being bedridden and pulmonary hyperinflation. The latter rely on clinician expertise in probe choice, US machine regulation, anatomy including normal anatomic variance, US semeiotics and familiarity with artifacts, all combined with appropriate pattern recognition [99]. Furthermore, technical equipment characteristics and performance may affect quality of acquired images.
4. **Lack of integration in the clinical context.** The integration of US findings with data acquired through patient history, physical examination and other investigations is fundamental in correct patient management. For example, when approaching a patient with chest pain, a finding of pericardial effusion should not automatically lead to pericarditis diagnosis without considering other criteria as well as other causes of chest pain. Clinical reasoning is a complex mental process that should take into account the patient's pretest probability, the diagnostic accuracy of POCUS and the potential harm of misdiagnosis.
5. **Direct potential harms of US.** Although US is considered a safe diagnostic procedure, physicians should be aware of how to interpret biological exposure index displays (thermal index and mechanical index) applying ALARA principles (as low as reasonably achievable) [101], in particular when managing vulnerable sites, like the ocular area, or patients, like pregnant women. Moreover, adequate probe disinfection is crucial for patient safety in the era of multidrug resistant bacteria and hospital-acquired infections [102].
6. **Managing incidental findings.** Incidental findings may occur, particularly when POCUS is used without a specific clinical question. It is of paramount importance to describe, appropriately communicate and guarantee further evaluations when appropriate.

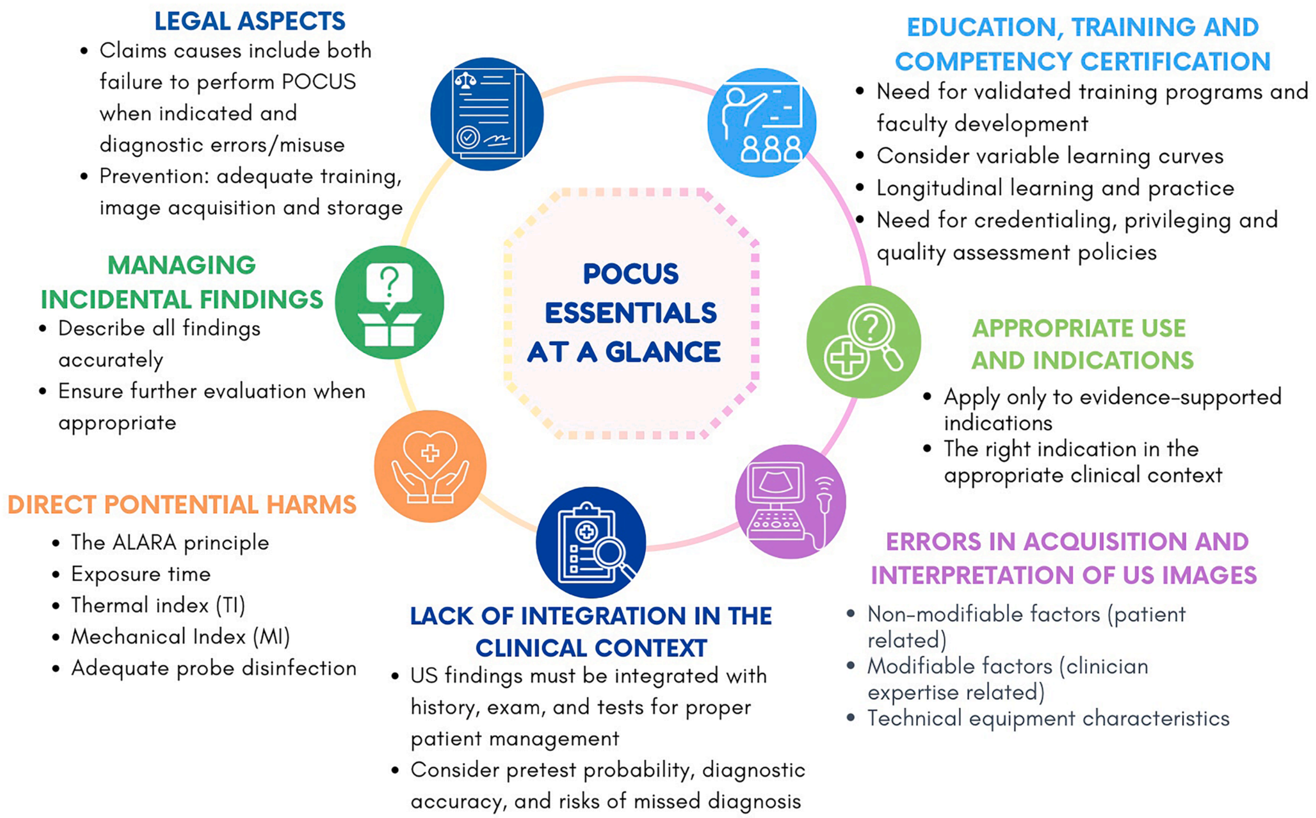

Fig. 3. Critical points for appropriate use of POCUS.
POCUS: Point of Care Ultrasound.
ALARA: As Low as Reasonably Achievable.
US: Ultrasound.

7. **Legal aspects.** Legal liability has been described to be associated to failure to perform POCUS when indicated. Other causes of lawsuits regard inadequate skills, misdiagnosis, incorrect approach, insufficient patient assessment, and incomplete documentation [103]. The last is preventable by the careful and intentional incorporation of POCUS within diagnostic protocols, adequate record collection and storage of the images.

Conclusions

The use of POCUS in clinical practice is a major recent revolution [104,105], due to its immediate availability for attending physicians in expanding diagnostic capabilities, speeding up diagnosis and therapeutic decision-making, and adding relevant information for risk stratification. In addition, a beneficial effect on patients satisfaction hase been reported [106,107]. As we have attempted to highlight in this review (Table 1), the adoption of evidence in clinical guidelines is still scarce, unless documents issued by ultrasound societies are considered. This is at least partly attributable to the delayed adoption of this tool across specialties, and it is no coincidence that emergency physicians—who were the first to use POCUS and in many cases provided evidence of its use—are also those who have most widely included this technique in clinical guidelines. However, in some cases guidelines still recommend a complete ultrasound examination (for example TTE echocardiography) even though evidence may be sufficient to recognize the appropriateness of POCUS use (for example: searching for pericardial effusion). In other cases the use of ultrasound is not even considered in the diagnostic approach despite high sensitivity and specificity in comparison to reference standard radiologic examination, as occurs for example for LUS in suspected pneumonia. The fact that POCUS has often not been considered into clinical guidelines may hinder its widespread adoption. Nevertheless, randomized controlled trials are generally still scarce, and meta-analyses often show the limitation of high heterogeneity among the studies included. Greater effort in clinical research is thus needed.

Furthermore, there is still limited data available regarding the impact of POCUS on therapeutic effectiveness and especially on patient outcomes, including morbidity and mortality endpoints [108]. Nevertheless, the evidence gathered to date on the diagnostic use of POCUS likely surpasses information regarding other tools used in clinical practice and adopted in earlier times. Reasonably, a test with very high diagnostic accuracy for a specific condition has a significative chance to ameliorate the patient clinical management [109]

Another relevant issue pertains education and training. Operators included in the studies were, in most of the cases, POCUS experienced physicians, and the generalization of the evidence is unfortunately affected by the still limited spread of ultrasound training. Despite significant growth in the last 10 years of residency and medical schools US-programs -especially in Europe and North America- access to training for working physicians, faculty availability and longitudinal competency maintenance remain well-known barriers to wide diffusion [110–113]. POCUS use without appropriate competence acquisition jeopardizes safety, making health institution/department policy procedures -including credentialing, privileging and quality assessment- fundamental [114]. Moreover, data regarding training validation and inter-observer variability in short-trained operators are necessary, considering that use of POCUS by inexpert physicians is quite frequent [115].

Notwhithstanding the aforementioned issues, collected evidence is progressively shaping appropriateness and usefulness of this tool that is fast becoming hard for physicians to give up. Sometimes technology may help in bringing us back to patients' bedside.

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