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Internal and Emergency Medicine (2020) 15:395–408
https://doi.org/10.1007/s11739-020-02284-5

IM - REVIEW

Point of care ultrasonography from the emergency department to the internal medicine ward: current trends and perspectives

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Received: 13 January 2020 / Accepted: 22 January 2020 / Published online: 7 February 2020

Abstract

The advent of portable devices in the early 80s has brought ultrasonography to the patient's bedside. Currently referred to as 'point of care ultrasonography' (POCUS), it has become an essential tool for clinicians. Initially developed in the emergency and critical care settings, POCUS has gained increasing importance in internal medicine wards in the last decade, with both its growing diagnostic accuracy and portability making POCUS an optimal instrument for everyday clinical assessment and procedures. There is large body of evidence to confirm POCUS' superiority when compared to clinical examination and standard X-ray imaging in a variety of clinical situations. On the contrary, only few indications, such as procedural guidance, have a proven additional benefit for patients. Since POCUS is highly user-dependent, pre- and post-graduate curricula are needed and the range of use should be clearly defined. This review focuses on trends and perspectives of POCUS in the management of diseases frequently encountered in emergency and internal medicine. In addition, questions are raised regarding the teaching and supervision of POCUS needing to be addressed in the near future.

Keywords Point of care · Ultrasonography · Ultrasound · Internal medicine · Emergency medicine

Introduction

In 1819, René Laennec published the book *L'auscultation médiate* [1] introducing the world to a revolutionary diagnostic tool: the stethoscope. It was subsequently universally adopted in clinical practice, becoming a symbol of medical science but also as a source of criticism due to deceptive diagnostic performances [2]. Two hundred years later, point of care ultrasonography (POCUS) is emerging as a change of paradigm in clinical practice. This bedside technology allows caregivers to answer basic diagnostic questions, guide procedures and make choices on therapies [3]. As soon as POCUS appeared Roy Filly, an American radiologist, declared it with skepticism the *stethoscope of the future*, a performant tool in improper hands [4]. Whether POCUS is a complement or a replacement for the stethoscope remains a source of debate [5]. Mastering POCUS has a steep learning curve and its success is explained by its increased diagnostic accuracy in comparison to clinical examination and standard X-rays [6], its absence of ionizing radiations, and its growing availability. This article reviews the expanding use of ultrasonography (US), from pioneer disciplines to pre-graduate medical schools, focusing on its practical applications for emergency and internal medicine physicians.

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s11739-020-02284-5) contains supplementary material, which is available to authorized users.

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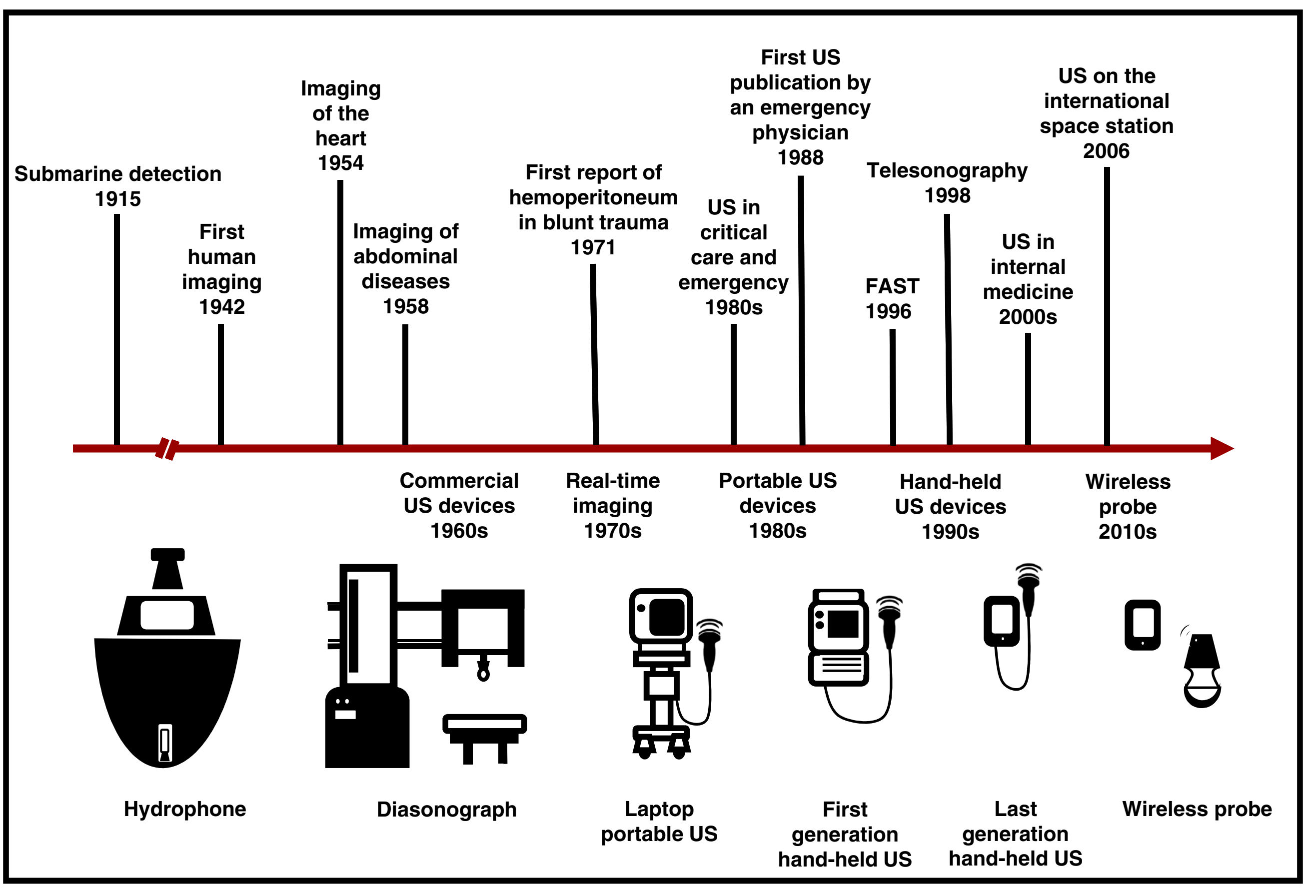
From World War I to medical school

The first ultrasound transducer, called a *hydrophone*, was created by Paul Langevin in 1915 to detect German submarines during World War I. Clinical US appeared in medicine 40 years later through a pioneering paper on abdominal pathologies by Ian Donald, a Scottish obstetrician [7]. US was progressively adopted by obstetricians, radiologists and cardiologists in the subsequent decades. POCUS, also known as focused, clinical or goal-directed US, started gaining ground in the 1980′s in the hands of emergency and critical care physicians. In 1990, the American College of Emergency Physicians (ACEP) issued their first statement supporting POCUS, which has been followed by regularly updated guidelines [3]. Simultaneously, surgeons developed the *Focused Assessment with Sonography in Trauma* (FAST) [8]. This first pivotal bedside protocol for blunt abdominal trauma is currently endorsed by the Advanced Trauma Life Support and adopted worldwide in emergency departments (ED). Joint efforts from the American College of Chest Physicians (ACCP) and the Société de Réanimation de Langue Française (SRLF) resulted in the first international stance on US competence in critical care settings being published in 2008 [9]. POCUS concurrently spread to other medical disciplines being adopted in the field of internal medicine during the last decade [10, 11]. Although the American College of Physicians (ACP) recently called for international guidelines for the use of POCUS in internal medicine, such guidelines are yet to be published. Over recent years, the wide-spread use of POCUS in clinical practice in Europe and the USA has prompted medical schools to develop curricula for students [12, 13]. This boom in the practice of US has largely been facilitated by the digitalization and technological progress, which have led to the development of compact, high-quality and highly portable devices. Wireless probes and telesonography with remote readers are a reality nowadays with the classic piezoelectric crystal system being replaced by versatile microchip technology in last generation transducers. The advances in miniaturization, as well as the historical milestones of this ongoing process, are summarized in Fig. 1.



US = ultrasonography; FAST = Focused Assessment with Sonography for Trauma

Fig. 1 History of ultrasonography

Indications for POCUS

In conventional practice, a frontline clinician asks a specialist (e.g. radiologist, cardiologist) for a comprehensive US imaging based on his initial clinical suspicion. With POCUS, the frontline doctor acquires and interprets relevant US images, while collecting a medical history and performing a physical examination. POCUS results are immediately integrated into the care plan reducing delays from clinical assessment to US results [3]. There are various indications for POCUS which whilst depending on the clinical setting can be classified under the general headings of diagnostic, resuscitation, procedural guidance and monitoring. Table 1 outlines the differences and overlap of POCUS use in internal and emergency medicine. Table 2 reports existing diagnostic indications of POCUS with sensitivities and specificities. Selected indications are discussed below.

From the resuscitation room to the ward: the unstable patient

As shown for the early introduction of antibiotic therapy in patients with septic shock, faster diagnosis and commencement of appropriate therapy are likely to reduce morbidity and mortality in acutely ill patients [14]. POCUS is useful in resolving relevant clinical questions with minimal time delay, probably explaining its increasing usage in ED and prehospital units [15]. Several POCUS protocols have been developed to ensure a structured and rapid approach to acute respiratory failure [16], shock state [17], severe trauma [18] and cardiac arrest [19]. Some of these protocols are reported in Fig. 2. As trauma does not come under the general umbrella of internal medicine, trauma procedures including extended FAST have been deliberately left out in this review.

Acute respiratory failure

Respiratory failure is associated with poor short-term outcomes [20]. POCUS outperforms clinical judgment and/or standard X-rays in assessing the main causes of respiratory failure, such as acute heart failure [21, 22], pneumonia [23, 24], pneumothorax [25], pulmonary embolism [26, 27], acute respiratory distress syndrome [28], pleural effusion [29] and exacerbation of COPD or asthma [30]. Details of diagnostic performance of POCUS for most of the aforementioned diseases are developed below. Integration of focused lung and vein US in the *Bedside Lung Ultrasound in Emergency* (BLUE) protocol (Fig. 2) has proven to be highly effective. In a retrospective study of 260 consecutive patients admitted to the intensive care, utilization of BLUE protocol allowed to identify the underlying cause of acute dyspnea with a diagnostic accuracy of 90.5%. Unclear, multiple and rare diagnosis were excluded from the study ($n=41$) [16]. Accuracy was lower (77.5%) in another single-center prospective observational study including 383 consecutive emergency patients [31]. In a large prospective trial, 320 emergency patients with acute respiratory failure were randomized to standard care or US of heart, lungs and deep veins. Results showed that in the intervention arm, POCUS increased the proportion of correct diagnosis in the first 4 h following admission from 64 to 88% (primary outcome). There was no evidence of clinical benefit in several secondary endpoints for which the study was not powered (length of stay, 30-day readmission and mortality rate) and a slight increase of further advanced test performed [32]. Recommendations for lung US are available in an international expert consensus [33].

Future perspectives

Faster baseline diagnosis leading to faster treatment is expected to influence clinically relevant outcomes. No currently existing data yet evaluate the impact of a POCUS-driven approach on patient- or community-targeted

Table 1 Goals of internal versus emergency medicine point of care ultrasonography

	Internal medicine	Emergency medicine
Diagnostic	Raise accuracy of daily clinical assessment[b]	Reduce time to first diagnosis and therapy[b]
Monitoring	Monitor treatment effect (e.g. decongestion) and complications (e.g. urinary retention after catheter removal)[b]	Monitor immediate treatment effect and complications (e.g. fluid overload after volume repletion)[a]
Resuscitation	Management of acute decompensated patients before transfer in advanced care units[a]	Management of acutely ill patients before orientation to wards, advanced care units or operating rooms[b]
Procedural guidance	Guide diagnostic and therapeutic procedures[b]	

[a]Occasional use

[b]Frequent use

Table 2 Sensitivity, specificity and comparator of diagnostic point of care ultrasonography

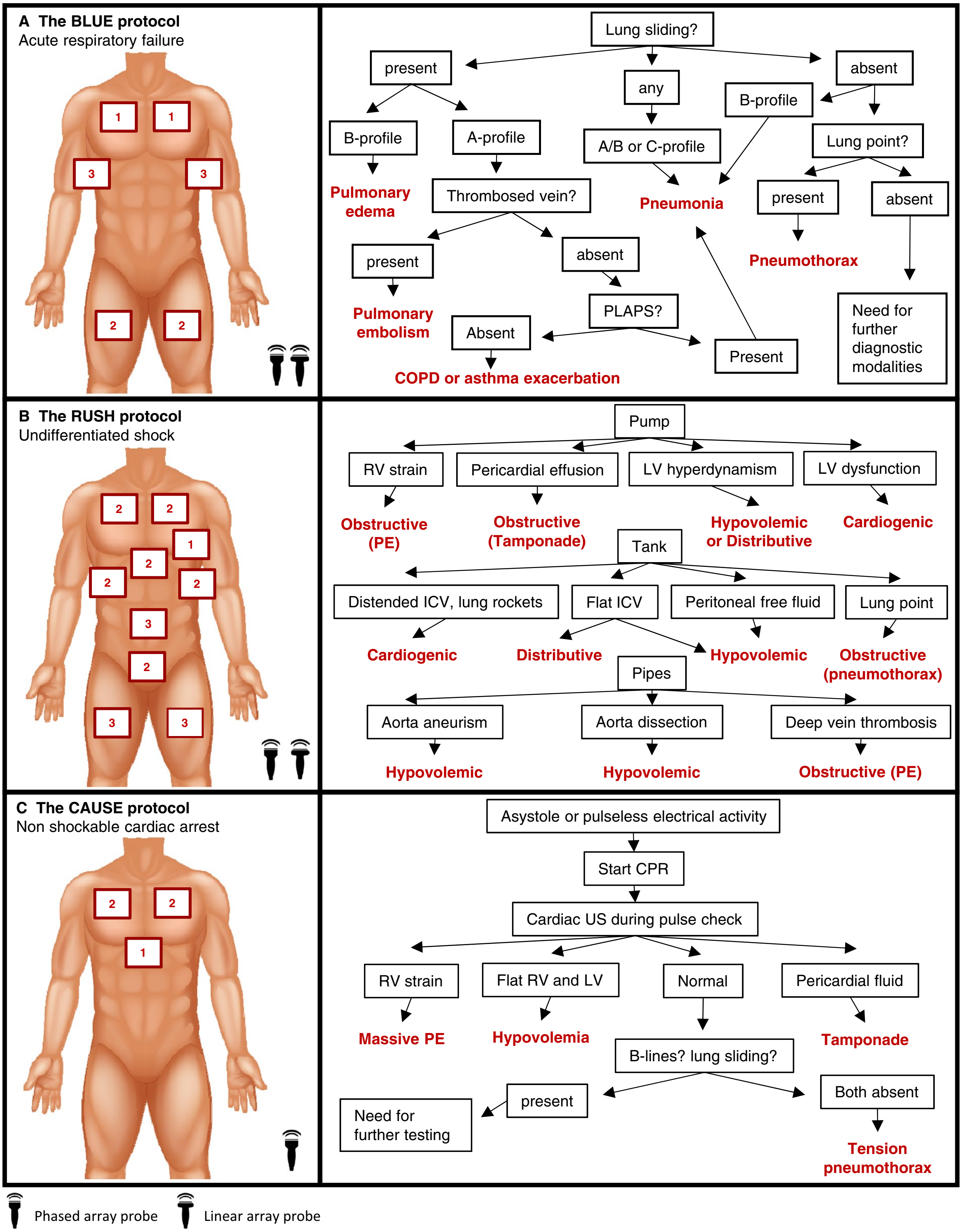
Diagnostic POCUS application	Diagnostic performance		Comparator
	Sensitivity (95% CI)	Specificity (95% CI)	
Sinus *Acute sinusitis*[a]	0.71 (0.61–0.79)	0.83 (0.71–0.91)	MRI, CT, antral puncture
Eye			
Optic nerve sheath *Intracranial hypertension*	0.90 (0.80–0.95)	0.85 (0.73–0.93)	Invasive measurement
Retinal detachment	0.94 (0.78–0.99)	0.96 (0.89–0.99)	Surgery, CT, ophthalmologist, follow-up
Trachea *Tube placement*	0.98 (0.97–0.99)	0.98 (0.95–0.99)	Capnography, direct visualization
Lung			
Effusion[b]	0.94 (0.88–0.97)	0.98 (0.92–1.00)	CT
Pneumonia	0.78 (0.70–0.84)	0.95 (0.68–0.99)	CT, MRR
Acute heart failure[a]	0.88 (0.75–0.95)	0.90 (0.88–0.92)	MRR
A-profile, with no PLAPS[a]	0.78 (0.67–0.86)	0.94 (0.89–0.97)	COPD or asthma exacerbation on MRR
Pneumothorax[b]	0.91 (0.86–0.94)	0.98 (0.97–0.99)	CT
Heart			
Left systolic dysfunction[a]	0.84 (0.74–0.91)	0.89 (0.85–0.91)	Cardiologist TTE
Pericardial effusion[c]	0.96 (0.90–0.99)	0.98 (0.96–0.99)	Image review by cardiologist
Right ventricle dilatation[c]	0.92 (0.65–0.98)	0.99 (0.95–1.00)	Cardiologist TTE
Abdomen			
Inferior cava vein *Fluid responsiveness*[b]	0.63 (0.56–0.69)	0.73 (0.67–0.78)	Transpulmonary thermodilution, TTE, NI BP, bioreactance
FAST *Blunt intra-abdominal injury*[b]	0.82 (0.75–0.89)	0.99 (0.98–0.99)	CT, surgery, autopsy, follow-up
Ascites[c]	0.96 (0.87–0.99)	0.82 (0.59–0.94)	CT, radiologist US, paracentesis
Cholecystitis[b]	0.82–0.91	0.66–0.95	Pathology
Gallbladder stones[a]	0.90 (0.86–0.93)	0.88 (0.84–0.91)	CT, MRI, radiologist US, surgery
Splenomegaly[c]	1.00 (0.57–1.00)	0.74 (0.57–0.85)	CT, radiologist US
Abdominal aortic aneurism	0.99 (0.96–1.00)	0.98 (0.97–0.99)	CT, MRI, aortography, US reviewed or performed by radiologist, surgery, autopsy
Hydronephrosis[c]	0.81 (0.80–83)	0.59 (0.56–0.63)	CT
Nephrolithiasis[b]	0.70 (0.67–0.73)	0.75 (0.72–0.78)	CT, follow-up
Small bowel obstruction[b]	0.92 (0.89–0.95)	0.97 (0.88–0.99)	Surgery, pathology, CT, colonoscopy, enteroclysis, contrast enema, clinical follow-up
Appendicitis[b]	0.84 (0.72–0.92)	0.91 (0.85–0.95)	Surgery, pathology
Pneumoperitoneum[c]	0.96 (0.86–0.99)	0.82 (0.73–0.86)	CT
Pelvis			
Bladder distention[c]	0.96 (0.79–0.99)	0.75 (0.53–0.90)	Urine catheterisation (≥ 600 ml)
Ectopic pregnancy[b]	0.99 (0.97–1.00)	0.42–0.90	Radiologist or gynaecologist US, images review by radiologist, medical record review, follow-up
Acute scrotal pain[c]	0.95 (0.78 to 0.99)	0.94 (0.72 to 0.99)	Radiologist US, surgery
Limbs			
Tendon injury[c]	0.94 (0.73–1.00)	1.00 (0.92–1.00)	Surgery
Long bone fracture[c]	0.93 (0.75–0.99)	0.83 (0.65–0.94)	Plain radiography, CT
Soft Tissue Abscess[a]	0.96 (0.89 to 0.98)	0.80 (0.56 to 0.93)	Purulent discharge from incision, CT, follow-up
Deep vein thrombosis[b]			
2-point	0.91 (0.68–0.98)	0.98 (0.96–0.99)	Radiologist US or contrast venography
3-point	0.90 (0.83–0.95)	0.95 (0.83–0.99)	Radiologist US or contrast venography

MRI magnetic resonance imaging, *CT* computer tomography, *MRR* medical record review, *PLAPS* posterolateral alveolar and/or pleural syndrome, *COPD* chronic obstructive pulmonary disease, *TTE* transthoracic echocardiography, *NI BP* non-invasive blood pressure, *FAST* focused assessment with sonography in trauma, *US* ultrasonography. A reference list is available in Online Resource 1

[a]Result from meta-analysis with no test for heterogeneity

[b]Result from meta-analysis with high heterogeneity ($I^2 \geq 75\%$)

[c]Result from single studies



Numbers correspond to the ultrasonography views sequence of protocol. BLUE = Bedside Lung Ultrasound in Emergency; COPD = chronic obstructive pulmonary disease; PLAPS = posterolateral alveolar and/or pleural syndrome; RUSH = Rapid Ultrasound in SHock; RV = right ventricle; LV = left ventricle; PE = pulmonary embolism; ICV = inferior cava vein; CAUSE = Cardiac Arrest UltraSound Exam; CPR = cardiopulmonary resuscitation; US = ultrasonography

Fig. 2 **a–c** The BLUE, RUSH and CAUSE protocols [16, 17, 19] outcomes, such as length of stay in the ED or hospital, delay in receiving adequate therapy, survival and cost-effectiveness. Randomized controlled trials are vital to evaluate the net benefit of POCUS in comparison to conventional management in patients suffering from acute respiratory failure.

Acute circulatory failure

Shock is generally classified as distributive (e.g. septic, anaphylactic), obstructive (e.g. massive pulmonary embolism, tamponade), cardiogenic (e.g. acute coronary syndrome, acute valve dysfunction), hypovolemic (e.g. bleeding) or multifactorial. Early recognition and treatment are mandatory to prevent its progression to irreversible organ dysfunction. Treatment largely depends on the etiology and can be detrimental when prescribed inappropriately. Left ventricular or significant valve dysfunction, right ventricular enlargement, pericardial fluid, hypovolemia and ruptured abdominal aortic aneurism can be readily diagnosed using POCUS; it is, therefore, expected to allow the early differentiation and treatment of unexplained shock after a primary clinical evaluation. Additionally, the monitoring of signs of congestive overload with lung US can be used to tailor fluid administration [34]. Figure 2 illustrates the *Rapid Ultrasound in SHock* (RUSH) protocol evaluating the cardiac status (*pump*), the fluid status (*tank*) and the vascular status (*pipes*) [19]. The utility of bedside US using protocols in unstable patients has been suggested by several authors [35]. In a randomized trial including 184 patients with undifferentiated shock, immediate versus delayed POCUS significantly narrowed the differential diagnosis and raised the rate of correct diagnosis at 15 min from 50% (95% CI 40–60%) to 80% (95% CI 70–87%) [36]. In a subsequent observational trial of 118 emergency patients, utilization of POCUS changed the treatment plan and the imaging strategy in a quarter and a third of patients, respectively [37]. To date, only one multicenter randomized controlled trial has evaluated the effect of a POCUS strategy in 270 patients with undifferentiated shock and failed to show benefit in survival, length of stay or therapeutic choices. It is important to note that this trial did not achieve inclusion goals and was underpowered [38].

Future perspectives

POCUS is an integral part of routine practice for shock management but more data are needed to evaluate its impact on patient-centred outcomes. Future trials should aim at assessing the added value of artificial intelligence for automated measurement of velocity time integral in left ventricular outflow tract, as well as inferior cava vein size and collapsibility.

Cardiac arrest

Despite progress in basic and advanced life support, patients experiencing a cardiac arrest have low survival rates. Prompt uninterrupted chest compression and early defibrillation in the case of shockable rhythms are the cornerstone of cardiopulmonary resuscitation. Eighty percent of patients, however, presenting in out of- or in-hospital cardiac arrest situations have a non-shockable rhythm [39]. In these circumstances, guidelines emphasize the identification of a potential reversible underling cause summarized by the 5 H's (hypoxemia, hypovolemia, hyper/hypokalemia, hypothermia, H + (acidosis)) and 5 T's (tamponade, tension pneumothorax, pulmonary or coronary thrombosis and toxins) [40]. Ultrasonography is a reliable diagnostic tool for four of the above-mentioned conditions [41] and identification of the correct etiology coupled with timely adequate treatment (aggressive volume repletion, pericardiocentesis, chest tube insertion or thrombolysis) may improve survival rates in this subgroup of patients. Additionally, the prognostic value of POCUS in a cardiac arrest setting has been evoked. In one large multicenter study evaluating POCUS in non-shockable out of hospital and in-ED cardiac arrest, the absence of echographic cardiac motion during pulse check was associated with an extremely poor rate of survival at hospital discharge (0.6%). Survival increased to 4% in patients maintaining a wall and valve motion [42]. Another study reported that cardiac standstill was associated with 100% of mortality in the ED [43], suggesting that POCUS may help decision-making regarding interruption of resuscitation efforts. The *Cardiac Arrest UltraSound Exam* (CAUSE) protocol investigates the four leading potentially reversible causes of asystole or PEA by using a four chamber cardiac view and imaging the anterior bilateral pleura (Fig. 2) [19]. Due to a great risk of delay in compression cycles [44], international guidelines highlight the importance of brief imaging interval during pulse check with the review of saved clips during the next compression cycle [35]. In intubated patients, transesophageal-focused echocardiography offers an added advantage of avoiding interference with chest compressions, allowing continuous imaging during resuscitation. In 1 small retrospective study of 25 patients, pulse checking was significantly shorter with the transesophageal approach compared to that of the transthoracic (9 versus 19 s) [45].

Future perspectives

Whether POCUS is beneficial for, or interferes with, the resuscitation process remains an open question. Given the small amount of potentially reversible causes in asystole/PEA, large multicentric randomized controlled trials are needed to answer this research question.

Coma

Causes of coma are classified as structural brain diseases, diffuse neuronal dysfunction (e.g. metabolic imbalance, toxins) and psychogenic unresponsiveness. If neglected, a reversible cause can become irreversible (e.g. untreated subdural hematoma). Trans-ocular US of the optic nerve sheath accurately estimates high intracranial pressure and potentially influences the choice of brain imaging and therapeutic intervention [46]. Optic nerve sheath diameter is measured at 3 mm distance of the globe (Fig. 3). In a meta-analysis, a threshold between 5 and 5.9 mm diagnosed intracranial hypertension with a pooled diagnostic odd ratio of 51 (95% CI 22–121) compared to invasive measurement. The area under the summary receiver operating characteristic (ROC) curve was 0.94 (95% CI 0.91–0.96) [47]. In case of head trauma, a cut-off value of 5 mm showed moderate sensitivity (84%, 95% CI 60–97%) and low specificity (73%, 95% CI 59–86%) for any intracranial injury found by CT [48]. When toxins and drugs review, blood analysis and brain imaging fail to identify the cause, meningitis or encephalitis should be ruled out by a cerebrospinal fluid analysis. In patients with difficult anatomy, US-assisted lumbar puncture may improve success rates [49].

Future perspectives

Optic nerve sheath US has never been implemented in large prospective trials involving patients with undifferentiated coma in ED or internal medicine ward. Future studies should assess its sensitivity for space-occupying brain lesions, its potential benefit on time to diagnosis and treatment or on reduction of referral for brain imaging. Transcranial Doppler is used in neurocritical care as a non-invasive measure of intracranial pressure and midline shift. This technique may also be tested in the ED and in the ward [50].

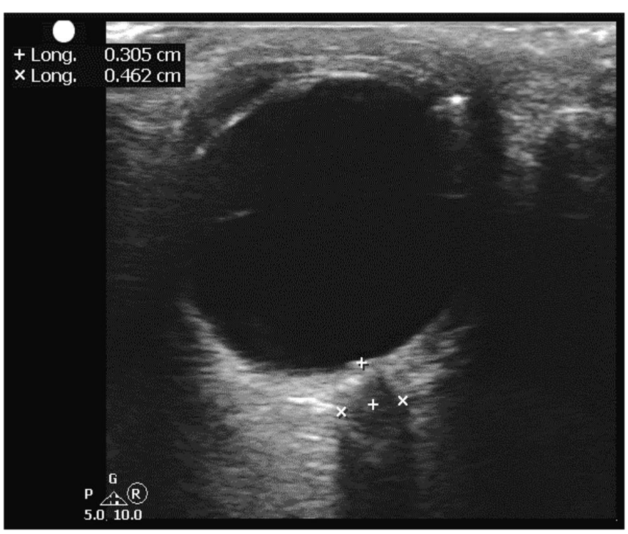


Fig. 3 Optic nerve sheath ultrasonography. To measure the optic nerve sheath diameter, a high-frequency linear array probe is applied to the closed eyelid. Both eyes are scanned in the sagittal and transverse plan. Optic nerve sheath diameter is measured at a 3 mm distance from the ocular globe. An average value of 5 mm or more indicate intracranial hypertension

From the emergency room to the ward: the stable patient

Development of POCUS skills in the ED has naturally spread to the ward. In fact, there is very much an overlap of most POCUS indications in internal and emergency medicine as the majority of patients attending ED are not critically ill and ward patients may develop acute conditions at any given moment. The above-mentioned BLUE, RUSH and CAUSE protocols may, therefore, be used for the management of deteriorating ward patients. The accuracy of clinical judgement can be enhanced with the use of POCUS in some of the most frequent diagnoses among medical patients, for example, heart failure, pneumonia, acute chest pain or acute kidney injury. Observational studies suggest that integration of POCUS in medical wards may change diagnosis and treatment in one-third of patients [51], may decrease by up to tenfold referrals for a focused echocardiography and surprisingly reduce the time needed for the ward round [52]. The use of POCUS in a few typical ward situations are discussed in the following paragraphs.

Acute heart failure

Acute decompensated heart failure is the leading cause of hospital admissions and one of the most frequent reasons for readmission [53]. US semiology has been well documented in this area and is summarized in Fig. 4. When applied to lungs, POCUS performs better than clinical examination and chest X-ray in the diagnosis of acute heart failure, raising the sensitivity from 0.73 (95% CI 0.70–0.76) to 0.88 (95% Cl 0.75–0.95) [21]. Additionally, in one multicenter randomized controlled trial including 518 dyspnoeic patients consulting the ED, POCUS significantly reduced time to definite diagnosis of heart failure from 104.5 to 5 min when compared to a chest X-ray plus NT-pro-BNP strategy [54]. The clearing of B-lines has a high correlation with clinical improvement and it can be used to guide diuretic treatment [55]. Persistence of B-lines after treatment is associated to an increased risk of readmission in hospitalized and outpatients [56, 57]. IVC diameter and collapsibility index have been used as a surrogate of central venous pressure and fluid status, but recent data from meta-analysis show insufficient performance [58]. Focused cardiac US performed by internal

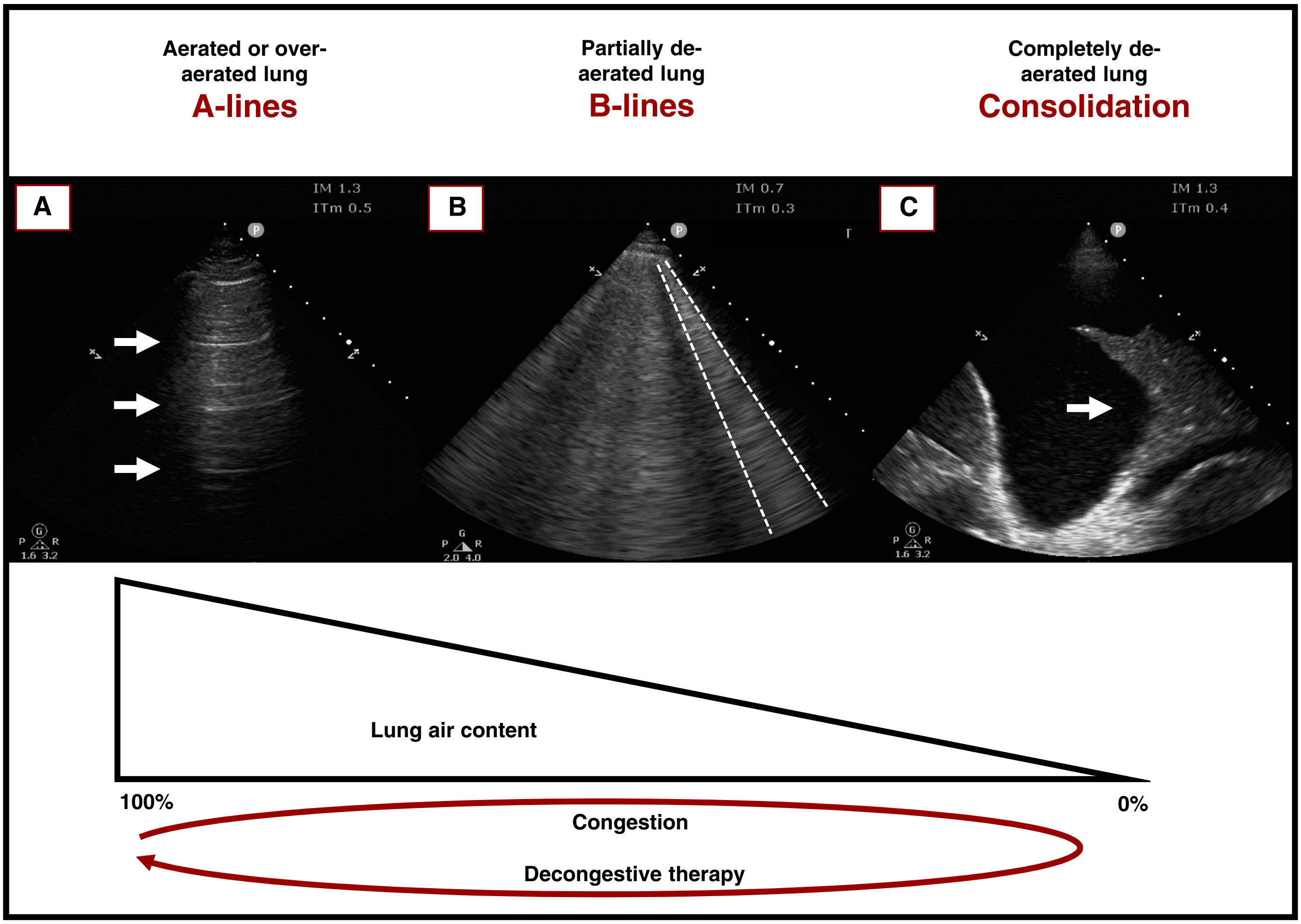


Fig. 4 **a–c** Lung ultrasonography. The concept of lung ultrasonography as densitometer presented by Gargani [80]: different lung patterns for different level of lung aeration. In setting of heart failure, these patterns correspond to incremental lung congestion

medicine residents accurately estimates left ventricular function and may in turn reduce cardiology referrals and healthcare costs [59, 60]. There is little evidence supporting the use of US-driven decongestive strategies. One randomized controlled study including 123 patients investigated the role of POCUS as a guide for therapy titration [61]. In outpatients, this study found a reduction of the number of urgent consultations for worsening heart failure but no effect on mortality and hospital readmission at the 6 months follow-up.

Future perspectives

Several protocols currently exist to evaluate lung congestion using different numbers of scanned regions. To date, no comparative prospective trials have been undertaken. Studies demonstrating POCUS cost-effectiveness and impact on hospital-related (e.g. length of stay) or post-discharge outcomes (e.g. readmission rate) in both ambulatory and hospitalized patients are still needed. Evaluation of left ventricular ejection fraction with new automated techniques as speckle tracking and strain have shown good performance leading to possible future generalization [62].

Pneumonia and COPD acute exacerbations

Given the poor accuracy of symptoms and physical signs [63], a radiological confirmation is generally recommended to differentiate pneumonia from exacerbated COPD or bronchitis. When integrated in clinical context, lung US outperforms chest X-ray in the identification of pneumonia with a summary ROC under the curve area of 0.901 versus 0.590, using chest CT as gold standard [24]. In a recent meta-analysis, pooled sensitivity and specificity for the detection of pneumonia were 0.78 (95% CI 0.70–0.84) and 0.95 (95% CI 0.68–0.99), respectively [30]. Additionally, in cases of non-response to adequate antibiotic therapy, POCUS can be used to identify complications. Ultrasonography identifies the presence of abscesses, and provides details about parapneumonic effusion size and characteristics (e.g. echogenicity, presence of septa or elements) whilst securely guiding thoracentesis [64].

Future perspectives

There is evidence supporting the use of lung ultrasound as a diagnostic tool among patients with suspected pneumonia or COPD exacerbation. Future prospective trials should evaluate the influence of POCUS on net diagnostic reclassification, on antibiotics down- or up-prescription decision, on hospital length of stay and costs. Randomized controlled trials should compare the different radiological modalities, including low-dose chest CT, in real life settings.

Acute chest pain

Chest discomfort is a troublesome symptom potentially related to life-threatening conditions. In the ED, POCUS can significantly narrow the differential diagnosis [65]. POCUS detects pericardial effusion, with sensitivity and specificity exceeding 95% [66]. Although excellent in detecting deep vein thrombosis [67], two-point (common femoral vein, popliteal vein) venous compression US has low sensitivity in the detection of pulmonary embolism. Sensitivity is higher when combined with lung (looking for lung infarction) and cardiac US (assessing right ventricle dilatation) and could potentially be an alternative in patients ineligible for CT chest angiography [36]. POCUS can accurately detect alternative diagnoses such as pleural effusion, pneumonia, pneumothorax or even acute coronary syndrome [68]. Even though POCUS findings may suggest acute aortic dissection in the presence of a dilatation of an enlarged aortic root (> 4 cm), an intimal flaps or an aortic insufficiency, it has suboptimal diagnostic accuracy in the detection of this condition [69].

Future perspectives

There remains a lack of well-designed and sufficiently powered studies to assess the discriminative value of POCUS in patients consulting in the ED with chest discomfort as the sole complaint. Integration of POCUS in prognosis and risk stratification scores for acute coronary syndrome or acute venous thromboembolism has been suggested but not yet tested in prospective trials.

Acute kidney injury and pyelonephritis

The identification and urgent treatment of urinary tract obstruction are vital in both acute kidney injury and pyelonephritis. Even though POCUS has insufficient diagnostic accuracy for nephrolithiasis [70], it accurately identifies acute urinary retention and rules out obstructive nephropathy requiring procedural drainage. In a large multicenter trial including 2759 suspected cases of nephrolithiasis, patients were randomized to an emergency physician renal POCUS or a radiologist US or an abdominal CT scan. Complication rates were similar in the three groups. Radiation exposure in the 6 months following randomisation was significantly lower in US groups. The trial was powered to detect differences among study groups of 5% for high incidence events (10%), 0.34% for low incidence events (0.5%) and a difference of 0.14 SD for radiation exposure [71]. Acute kidney injury is a common complication in patients suffering from acute heart failure following the introduction of diuretic therapy. Increases in serum creatinine may correlate with effective decongestion and improved outcomes (pseudo-worsening) or indicate an excessive and deleterious fluid loss (true worsening) [72]. In this context, fluid status assessment using POCUS could guide diuretic therapy and directly influence kidney outcomes.

Future perspectives

POCUS can be safely used in urinary tract obstruction and should be implemented in both emergency and internal medicine clinical practice. Studies should assess its effect on kidney recovery time and length of ED or hospital stay. Futures trials should also evaluate the benefit of POCUS in the management of cardio-renal syndrome type 1.

Procedural guidance

Diagnostic or therapeutic procedures are an integral and important part of both emergency and internal medicine. The greatest evidence of benefit to patient care using POCUS has arisen in the field of procedural guidance. A meta-analysis of 35 studies enrolling 5108 patients, showed that US supervision of central venous catheter insertion reduced the rate of complications by 71% (RR 0.29, 95% CI 0.17–0.52) and increased the success rate by 12% (RR 1.12, 95% CI 1.08–1.17) [73]. In a large cohort, US increased the success of abdominal paracentesis and thoracentesis and reduced, albeit rare, bleeding complications by 68% (OR 0.32; 95% CI 0.25–0.41) and the risk of pneumothorax by 19% (OR 0.81; 95% CI 0.74–0.90), respectively [74]. Moreover, US efficiently guides peripheral arterial and venous catheter insertion, arthrocentesis and lumbar puncture [49]. Due to the increase in successful procedures and the decrease in mechanical complications, US-guided procedures have become the standard of care.

The educational challenge

The availability of US devices in healthcare centres is rising exponentially and an increasing number of physicians worldwide is enthusiastically following basic US courses. The benefit of POCUS depends essentially on the experience and skill of the operator. Indiscriminate use and lack of supervision can lead to unfounded reassurance, false positive diagnosis or an increased number of additional tests. A study demonstrates that a well-trained resident experiences a net loss of proficiency after only 2 years of non-use [75]. Such rapid growth of US use in internal medicine has seemingly left tutors struggling to provide adequate supervision. In order that POCUS established benefits be maintained and in addition to strengthen them, efforts should be directed towards training trainers and tutoring programs. Some authors suggest that this transition period could be overcome by close collaboration between the internist and highly skilled emergency physicians [76]. Concerned by the indiscriminate use of this valuable tool, pre- and post-graduate POCUS curricula have been developed in our institution (Geneva University Hospitals). The country's pre-graduate medical program now incorporates specific objectives to familiarize students with US devices and imaging and to teach them sonographic patterns in healthy subjects and the identification of pathological free fluid (ascites, pleural effusion). Our post-graduate internal medicine program targets doctors at the beginning of their internal medicine residency with residents individually following an e-Learning course. Their newly obtained theoretical knowledge is then put into practice on both healthy volunteers and patients during a 1-day hands-on workshop. Finally, new practitioners follow a tutoring program for their first POCUS exams. Training content is in global agreement with the Canadian internal medicine ultrasound curriculum and a recent position paper of the European federation of internal medicine [10, 77] with an emphasis put on focused lung and cardiac US. Post-graduate training has been described elsewhere in Western countries with the same objectives of identifying POCUS core and advanced competencies for internal medicine physicians, structuring training and defining criteria for certification [78, 79]. It is essential that internal medicine departments accept the challenge of developing training courses to allow learners to gradually achieve competency on image acquisition, image interpretation and the integration of POCUS in clinical reasoning.

Conclusion

Point of care ultrasonography is an innovative approach and a milestone in the clinical management of patients. The miniaturization process and the ready availability have changed the paradigm, bringing clinical imaging from radiology to the patient's bedside. When compared to clinical examination, POCUS has demonstrated increased diagnostic accuracy for most of the diseases encountered in the ED and the ward. The net benefits of POCUS for patients are clearly demonstrated for procedural guidance with a strong level of evidence. However, for other POCUS indications, methodologically rigorous studies demonstrating benefits on patient-centered outcomes are still lacking, despite a wealth of publications produced to date. The near future has to answer two crucial questions: *is POCUS useful for patients? Can medical institutions ensure high-quality POCUS training?* Only a positive answer to these two questions can guarantee POCUS a brighter future than that of the stethoscope. Contrary to Filly's prophecy [4], this will help make POCUS a performant tool, in good hands.

Acknowledgements The authors are grateful to Tamara Mann for correcting grammatical errors of the manuscript. AL and OG thank Pr Thierry Fumeaux and Dr Damien Tagan for the E-learning elaboration.

Author contributions The idea for this article originally came from OG. AL carried out the literature search, and conceptualized and wrote the first draft of the manuscript. All authors have read, critically revised and approved the final version of this manuscript.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Statement of human and animal rights This article does not containany studies with human participants or animals performed by any ofthe authors.

Informed consent None.

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