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The evolving role of ultrasound in critical care unit

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Background
Basic ultrasound skills should be part of the staff of critical care. Therefore, the critical care community needs focused sonography for evaluation in real-time clinical decision making.

Objective
The aim was to highlight the emerging role of ultrasound and the recent updates as a routine diagnostic and procedural tool in the critical care unit.

Data sources
Medline databases (PubMed and Medscape) were searched, and all materials available on the Internet. The search was performed on April 2022.

Study selection
The initial search presented 120 articles. The number of studies that met the inclusion criteria was 21. The articles included the principles of ultrasound work, the devices used, and the various uses thereof, whether for evaluation or interventions in diseases of the lungs, heart, blood vessels, abdomen, and nervous system.

Data extraction
If the studies did not fulfill the inclusion criteria, they were excluded. Data from each eligible study were independently abstracted in duplicate using a data collection form to capture information on study characteristics, interventions, and quantitative results reported for each outcome of interest.

Data synthesis
Significant data were collected. Then, a structured review was performed.

Findings
In total, 21 potentially relevant publications were included. It was found that ultrasound allows the emergency physician to expedite care by decreasing time needed to obtain imaging and speak with consultants or to order additional tests or treatments based on the findings.

Conclusion
Ultrasound education is established as an essential part of all emergency medicine residencies, as well as some general surgery residencies, and is offered as an accredited fellowship. As physicians graduate from these training programs, the expectations of their ultrasound skills will grow. Bedside ultrasound is increasingly available, and emergency medicine physicians will continue to refine and optimize its use.

Keywords:
care, critical, evolving, role, ultrasound

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Introduction

Ultrasound gained a unique place over the past decade as a diagnostic and monitoring tool. The greater understanding of lung, abdominal, and vascular ultrasound plus the availability of portable machines have revolutionized the assessment of patients. Because ultrasound is not only a diagnostic test but can also be seen as a component of the physical examination [1].

Due to its bedside availability, accuracy, good reproducibility, cost-efficiency, and avoidance of radiation hazards, ultrasound has subsequently gained widespread popularity in many specialties. These advantages are of even greater value in the setting of critical care medicine, as immediate decision making can be lifesaving. Thus, the use of ultrasound is now rapidly spreading in critical care units worldwide [2].

Bedside ultrasound connects the physician to the digital system, allowing the physician to interrogate anatomy and physiology with instantaneous visual advances. Further, this information is now available for storage and documentation, transmission, consultation, manipulation, or fusion to other medical informatics [3].

Sonography will also expand the physical examination to new areas that previously limited the human senses. Advances in technique and technology allow us to go far, such as penetrating the skull, assessing, and predicting neurologic function and recovery. Adjuncts such as Doppler analysis or the use of ultrasound contrast agents may allow the earliest diagnosis of life-threatening pathology, before it manifests as obvious organ failure [4].

It is now believed that at least basic ultrasound skills should be part of the staff of critical care. Therefore, the critical care community needs to tackle the significant issues of providing the appropriate training for focused sonography and the delicate balance with expert referral services such as those providing diagnostic quality ultrasound, echocardiography, and interventional procedures. Finally, every clinician must realistically appraise how much to trust the urgently performed, focused evaluation in real-time clinical decision making [5].

The aim was to highlight the emerging role of ultrasound and the recent updates as a routine diagnostic and procedural tool in the critical care unit.

Materials and Methods

This review was conducted according to guidance developed by the center for review and dissemination. It was used to assess the methodology and outcome of the studies. The study was approved by the ethical committee.

Search strategy

Search was performed in several databases. It included Medline database (articles in Medscape and PubMed) and also materials available on the Internet. The search was performed on April 2022 and included all articles published. We used Care, Critical, Evolving, Role, Ultrasound, and Unit as searching terms. We also examined reference lists in relevant publications. The search was performed in the electronic databases from 2013 to 2020.

Study selection

All studies were independently assessed for inclusion. They were included if they fulfilled the following criteria:
(1) Case–control studies, cross-sectional studies, cohort studies, or systematic reviews and meta-analyses.
(2) The principles of ultrasound work, the devices used, and the various uses thereof, whether for evaluation or interventions in diseases of the lungs, heart, blood vessels, abdomen, and nervous system.
(3) Studies touched on the various uses of intravenous catheters and their role in cases of multiple injuries, and the study concludes with the potential dangers of using ultrasound and how to avoid them.
(4) Articles in English.

Exclusion criteria:
(1) Articles not in English.

The article title and abstract were initially screened. Then, the selected articles were read in full and further assessed for eligibility. All references from the eligible articles were reviewed to identify additional studies.

Data extraction

Data were extracted independently and in duplicate from eligible studies using a data collection form to capture information on study characteristics, interventions, and quantitative results reported for each outcome of interest. Conclusions and comments on each study were made.

The analyzed publications were evaluated according to evidence-based medicine criteria using the classification of the US Preventive Services Task Force and in addition to the Evidence Pyramid (Fig. 1).

US Preventive Services Task Force:
(1) Level I: Evidence obtained from at least one properly designed randomized controlled trial.
(2) Level II-1: Evidence obtained from well-designed controlled trials without randomization
(3) Level II-2: Evidence obtained from well-designed cohort or case–control analytic studies, preferably from more than one center or research group.
(4) Level II-3: Evidence obtained from multiple time series with or without the intervention. Dramatic results in uncontrolled trials might also be regarded as this type of evidence.
(5) Level III: Opinions of respected authorities, based on clinical experience, descriptive studies, or reports of expert committees.

Quality assessment

The quality of all the studies was assessed. Important factors included study design, attainment of ethical approval, evidence of a power calculation, specified eligibility criteria, appropriate controls, adequate information, and specified assessment measures. It was expected that confounding factors would be reported and controlled for and appropriate data analysis made in addition to an explanation of missing data.

Data synthesis

A structured systematic review was performed with the results tabulated.

Result

In total, 120 potentially relevant publications were identified: 99 articles were excluded as they did not meet our inclusion criteria (Fig. 2). A total of 21 studies were included in the review as they were deemed eligible by fulfilling the inclusion criteria. The significant data were collected. A structured systematic review was performed and the results tabulated in Table 1.

Discussion

According to Daniel *et al.* [6], Thoracic and Airway Ultrasound has revolutionized the care of patients in a modern ICU. It has also shown an impact in non-ICU settings such as in pulmonology and thoracic-surgery ambulatory clinics historically, lung ultrasonography has been a neglected area, given perceived notions about the utility of this modality in air-filled structures. Ultrasonography was considered as a valuable tool in evaluating lung pathologies. The utility of ultrasonography as a powerful adjunct to physical examination in the evaluation of the cause of breathlessness.

Williamson *et al.* [7], utility of ultrasound in alveolar exudates, pulmonary edema, and exudates. The lung parenchyma is mainly composed of air, these may be produced by interstitial fluid, edema in pulmonary edema or acute respiratory distress syndrome (ARDS), or even solids with different acoustic impedance from air-like collagen scarring/fibrosis.

Figure 1

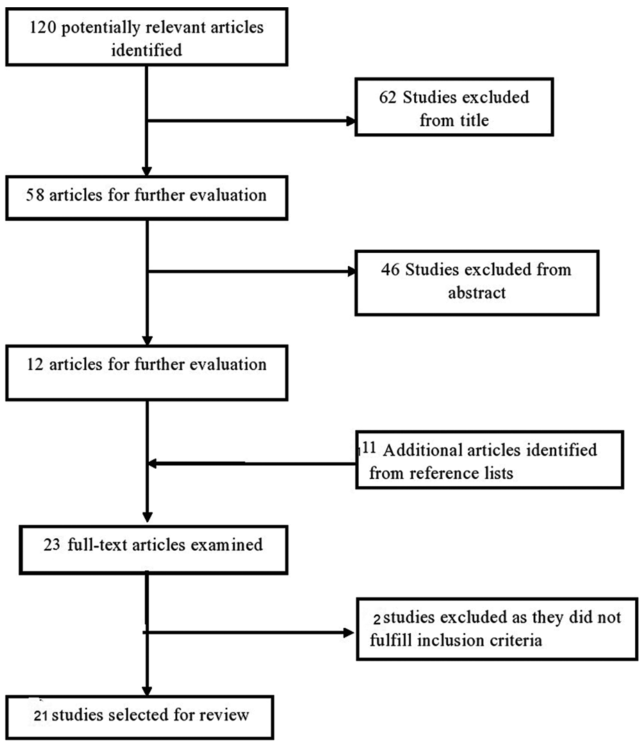
The pyramid of evidence-based medicine.

McNaughton *et al.* [8], pneumonia may be diagnosed if the consolidation is in continuity with the pleural membrane. The presence of dynamic air bronchograms assists in the diagnosis of pneumonia. It is critical for the person performing the scan to identify and demarcate the liver with the help of the diaphragmatic line of separation to avoid confusion with pneumonia. Chest computed tomography is the gold standard for diagnosis of pneumonia, however, it has a high radiation exposure and high cost. Chest radiographs are used most frequently in clinical practice, but have a poor sensitivity of 43.5% for the diagnosis of pneumonia (95% confidence interval: 36.4–50.8%).

Nazerian *et al.* [9] demonstrate lung ultrasound as superior to chest radiography for diagnosing pneumonia in the ICU setting. Lung ultrasound is reliable, rapid, and conclusive to arrive at a diagnosis of pneumonia even in the emergency room. The immediate changes in ultrasound are the absence of lung sliding and a still cupola with lung pulse, which are signs of poor lung expansion. The cupola (or cervical pleura) is the continuation of the costal and mediastinal parts of the pleura over the apex of the lung. Lung pulse is a phenomenon where the static pleural line moves due to the reverberations of the beating heart.

Daniel *et al.* [10], atelectasis can be seen in 10–50% of postoperative patients, depending on the type of surgery. In addition to absent lung sliding, still cupola

Figure 2



Flowchart of study selection.

Table 1 Characteristics and results of studies included in the review article

References	Type	Level of EBM	Result
Daniel *et al*.[6]	Case–control	Level II-2	Ultrasonography considered as a valuable tool in evaluating lung pathologies. Utility of ultrasonography as a powerful adjunct to physical examination in the evaluation of the cause of breathlessness
Williamson *et al*.[7]	Cross-sectional	Level II-2	Utility of ultrasound in alveolar exudates, pulmonary edema, and exudates. The lung parenchyma is mainly composed of air, these may be produced by interstitial fluid, edema in pulmonary edema or ARDS, or even solids with different acoustic impedance from air-like collagen scarring/fibrosis
McNaughton *et al*.[8]	Case–control	Level II-2	Pneumonia may be diagnosed if the consolidation is in continuity with the pleural membrane. Chest CT is the gold standard for diagnosis of pneumonia, however, it has a high radiation exposure and high cost. Chest radiographs are used most frequently in clinical practice for the diagnosis of pneumonia (95% CI: 36.4–50.8%)
Nazerian *et al*.[9]	Case–control	Level II-2	Demonstrate lung ultrasound as superior to chest radiography for diagnosing pneumonia in the ICU setting. Lung ultrasound is reliable, rapid, and conclusive to arrive at a diagnosis of pneumonia even in the emergency room
Daniel *et al*.[10]	Case–control	Level II-2	Atelectasis can be seen in 10–50% of postoperative patients, depending on the type of surgery. The ultrasound findings for atelectasis may be present even before radiological findings are seen
Ahmed *et al*.[11]	Case–control	Level II-2	Lung abscess is a thick-walled collection of pus within the lung. A lung abscess appears as a hypoechoic mass. A mildly hyperechoic peripheral wall may also be seen. Lung ultrasound can detect 94% of lung abscesses
Gryminski *et al*.[12]	Case–control	Level II-2	Ultrasound of pleura has a sensitivity of 93% in detecting pleural effusion when compared with radiographs that have a sensitivity of 83%, the absence of fluid was determined in 89% of cases in ultrasound as compared with chest radiography that could detect absence of fluid in 61% of cases
Glaser *et al*.[13]	Cross-sectional	Level II-2	Echocardiography has progressed to the point where it has become an invaluable tool for any treating physician in any department. Transthoracic echocardiography (TTE) has become a primary mode of assessment in both the emergency department and the ICU. TTE provides higher accuracy in patient assessment and management, with a potential prognostic impact by assessing the severity of cardiac dysfunction and response to treatment
Volpicelli *et al*.[14]	Cross-sectional	Level II-2	The rapid ultrasound for shock and hypotension exam was created. It later became increasingly popular in the emergency medicine community. Its objective is to assess for sources of hypotension in the undifferentiated shock patient
Boniface *et al*.[15]	A structured review	Level II-2	Due to the portability and accessibility of ultrasound (US), it is increasing to facilitate accurate diagnoses, to monitor the fluid status, and to guide procedures in emergency and critical care
Bogdahn *et al*.[16]	Case–control	Level II-2	Cerebral ultrasound is increasingly used in the critical care setting. Brain ultrasound can be performed to estimate the risk of raised intracranial pressure (ICP), using ocular sonography of the optic nerve sheath, as well as monitor intracranial hematoma or hydrocephalus, and measure mid-line shift
Liu *et al*.[17]	Cross-sectional	Level II-2	Optic nerve sheath diameter measurement using ocular sonography. The optic nerve sheath diameter (ONSD) can increase as pressure raises and is accessible to ultrasonographic measurement
Saugel *et al*.[18]	A structured review	Level II-2	Ultrasound guidance for vascular access, to ensure procedural safety and high cannulation-success rates, we recommend using a systematic protocolized approach for US-guided vascular access in elective clinical situations
Griffin *et al*.[19]	A review of the literature	Level II-2	Demonstrate the role of ultrasound in traumatic patient. CT remains the gold standard for diagnosing intra-abdominal injuries detecting as little as 100 ml of intraperitoneal fluid
Ollerton *et al*.[20]	Prospective study	Level II-2	Ultrasound has considerable advantages, including its bedside availability, ease of use, and reproducibility. Furthermore, it is noninvasive, employs no radiation or contrast agents, and is inexpensive. The use of ultrasound to detect intraperitoneal fluid was first described in Europe during the 1970s
Blanco *et al*.[21]	A review of the literature	Level II-2	Point-of-care ultrasonography (POCUS) is living a gold era in emergency and critical care medicine, because it is now widely recognized for its usefulness in complementing the physical examination and serving as a safe interventional guidance at the bedside

CI, confidence interval; CT, computed tomography; EBM, evidence-based medicine.

atelectasis may appear like alveolar consolidation but with absent dynamic air bronchograms. Even if air bronchograms are present secondary to trapped air in the bronchi, they are usually static in the case of atelectasis. Loss of lung volume that is indicated by the heart sign. The heart sign indicates that the heart is displaced secondary to loss of lung volume and it can be visualized anywhere in the right or left chest. The ultrasound findings for atelectasis may be present even before radiological findings are seen.

Ahmed *et al.* [11], lung abscess is a thick-walled collection of pus within the lung. A lung abscess appears as a hypoechoic mass. A mildly hyperechoic peripheral wall may also be seen. Lung ultrasound can detect 94% of lung abscesses. A 94% success rate is seen on the ultrasound (US)-guided aspiration of the detected abscesses with a 6% risk of developing pneumothorax. Ultrasound-targeted therapy of administration of antibiotics inside the abscess was shown to decrease the duration of systemic antibiotics needed to cause a resolution of the abscess.Pleural effusion can be diagnosed on ultrasonography reliably by the quad sign seen.

Gryminski *et al.* [12], ultrasound of pleura has a sensitivity of 93% in detecting pleural effusion when compared with radiographs that have a sensitivity of 83%, the absence of fluid was determined in 89% of cases in ultrasound as compared with chest radiography that could detect the absence of fluid in 61% of cases. The posterolateral alveolar and/or pleural syndrome point is one of the first points where we can pick up effusions as fluid collection is gravity driven.

Glaser *et al.* [13], echocardiography has progressed to the point where it has become an invaluable tool for any treating physician in any department. Transthoracic echocardiography (TTE) has become a primary mode of assessment in both the emergency department and the ICU. TTE provides higher accuracy in patient assessment and management, with a potential prognostic impact by assessing the severity of cardiac dysfunction and response to treatment. The focused cardiac ultrasound should be used to describe point-of-care evaluations performed by noncardiologists, thus allowing differentiation from a comprehensive TTE and a limited echo, which are exclusively performed by cardiologists.

Volpicelli *et al.* [14], the rapid ultrasound for shock and hypotension exam was created. It later became increasingly popular in the emergency medicine community. Its objective is to assess for sources of hypotension in the undifferentiated shock patient. There are four views utilized: the Parasternal long axial (PLA), Sinoatrial (SA), Subxiphoid (SX), and Antroposterior (AP) views. They evaluate left and right heart size and function, effusion, and Inferior vena cava (IVC) size and collapse. With the SA view, if the measured size difference between systole and diastole is less than 30%, this will indicate abnormal function.

Boniface *et al.* [15], due to the portability and accessibility of US, point-of-care US, which is performed by clinicians at the bedside, is increasing to facilitate accurate diagnoses, to monitor the fluid status, and to guide procedures in emergency and critical care. The main applications in abdominal regions include trauma, biliary, urinary tract, intrauterine pregnancy, and abdominal aortic aneurysm, which can be evaluated by a transabdominal approach.

Bogdahn *et al.* [16], cerebral ultrasound is increasingly used in the critical care setting. This technology is noninvasive, associated with low radiation exposure, and available at the bedside. Sonography of the brain can be used to visualize most of the intracranial structures in complement to transcranial Doppler, brain ultrasound can be performed to estimate the risk of raised intracranial pressure, using ocular sonography of the optic nerve sheath, as well as monitor intracranial hematoma or hydrocephalus, and measure mid-line shift.

Liu *et al.* [17], optic nerve sheath diameter measurement using ocular sonography. Tendon described the optic nerve sheath and the optic sclera as continuous with the dura mater. *In vivo*, the cerebrospinal fluid circulates in this space, from the posterior to the anterior part. This cerebrospinal fluid is subject to similar pressure changes to those in the intracranial and lumbar compartments, the retrobulbar part of the perioptic subarachnoid space is surrounded by fat and is therefore distensible. The optic nerve sheath diameter can increase as pressure raises and is accessible to ultrasonographic measurement.

Saugel *et al.* [18], ultrasound guidance for vascular access to ensure procedural safety and high cannulation-success rates, we recommend using a systematic protocolized approach for US-guided vascular access in elective clinical situations. A standardized approach minimizes variability in clinical practice, provides a framework for education and training, facilitates implementation, and enables quality analysis.

Griffin *et al.* [19] demonstrate the role of ultrasound in trauma patient. Traumatic injury is the leading cause of death among individuals younger than 45 years old, eighty percent of traumatic injury is blunt with the majority of deaths secondary to hypovolemic shock. In fact, intraperitoneal bleeds occur in 12% of blunt trauma, therefore, it is essential to identify trauma quickly. The optimal test should be rapid, accurate, and noninvasive. Historically, providers performed diagnostic peritoneal lavage to detect hemoperitoneum. While extremely sensitive (96–99%) and specific (98%), diagnostic peritoneal lavage is an invasive procedure with a complication rate of 1%. Computed tomography remains the gold standard for diagnosing intra-abdominal injuries detecting as little as 100 ml of intraperitoneal fluid. However, time delays and transportation out of the emergency department confound the evaluation of hemodynamically unstable patients.

Ollerton *et al.* [20] ultrasound has considerable advantages, including its bedside availability, ease of use, and reproducibility. Furthermore, it is noninvasive, employs no radiation or contrast agents, and is inexpensive. The use of ultrasound to detect intraperitoneal fluid was first described in Europe during the 1970s. The Focused Assessment with Sonography in Trauma is an ultrasound protocol developed to assess for hemoperitoneum and hemopericardium, sensitivities between 85% and 96%, and specificities exceeding 98%.

Blanco *et al.* [21], point-of-care ultrasonography is living a gold era in emergency and critical care medicine, because it is now widely recognized for its usefulness in complementing the physical examination and serving as a safe interventional guidance at the bedside. Moreover, an ultrasonography-supported paradigm is gradually becoming a routine approach when caring for critically ill patients.

Conclusion

Ultrasound education is established as an essential part of all emergency medicine residencies, as well as some general surgery residencies, and is offered as an accredited fellowship. As physicians graduate from these training programs, the expectations of their ultrasound skills will grow. Bedside ultrasound is increasingly available, and emergency medicine physicians will continue to refine and optimize its use. Ultrasound allows the emergency physician to expedite care by decreasing time needed to obtain imaging and speak with consultants or to order additional tests or treatments based on the findings. It decreases procedural complications by allowing real-time guidance of needles along specific tracts, avoiding inadvertent organ or vessel injury.

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Conflicts of interest

There are no conflicts of interest.

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