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Expansion of Point-of-Care Ultrasound (POCUS)

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Abstract | **Review Article**

Point-of-care ultrasound (POCUS) is an ultrasound examination performed and interpreted by the clinician at the bedside to obtain specific clinical information. POCUS exam had been designed to address a specific clinical inquiry with a focused, goal-directed evaluation. Its objective is to either "rule in" or "rule out" specific conditions or answer a "yes or no" question. By contrast, a comprehensive ultrasound performed by radiologists or cardiologists thoroughly evaluates the entire anatomical region. POCUS examinations provide clinical information in real-time within minutes. Recent studies have shown that POCUS can increase diagnostic accuracy and significantly reduce physicians' diagnostic uncertainty. Most patients admitted to an emergency department who agreed to undergo POCUS of the heart, lungs, and deep veins reported "very low" discomfort. Clinicians have also released statements advocating for POCUS. Additionally, undergraduate medical students who have encountered POCUS examinations earlier in their medical education have gained a better understanding of the clinical applications of POCUS. POCUS has become increasingly popular in emergency medicine, and so has POCUS education in residency programs. With the increased use of ultrasound in emergency and critical care settings, countries with emergency rooms and intensive care units (ICU) equipped with an ultrasound system have recently implemented health insurance coverage for POCUS in emergency and critical care areas. Although POCUS has been a rapidly growing technology in emergency, trauma, and critical care medicine, some concerns have been raised regarding its patient safety, which include overuse, inaccurate diagnoses, inappropriate usage, and excessive dependence on POCUS. To improve patient care and prevent unnecessary cuts in healthcare budgets, proper prescription, application of POCUS, as well as documentation of its findings, are required. This paper aims to comprehensively review the different types of POCUS used in clinical practice for emergency and critical care medicine.

Keywords: Point-of-care ultrasound (POCUS), Emergency medicine, Diagnostic accuracy, Medical education, Patient safety.

1. INTRODUCTION

Point-of-care ultrasound (POCUS) is becoming a more common tool that doctors use to check for serious health problems earlier [1]. Instead of going to the radiology department to conduct a longer ultrasound exam, physicians with the right training can use a small diagnostic ultrasound imaging device at the bedside [1]. With it, they can answer some binary clinical questions such as "is there free fluid in the abdomen?", "is there a pericardial effusion?," and "is there pleural effusion?" With more complex devices, they could even screen for more serious health problems like "is there a pulmonary embolism?" or "is there aortic dissection?" [2]. By answering these questions, physicians can better triage, treat, and transfer patients, thus improving patient safety [3]. Since the COVID-19 pandemic, there has been a significant and rapid expansion of POCUS by clinicians and healthcare workers around the world. Many have been trained through a blend of online and onsite teaching [4]. POCUS has been used more frequently and with more complex questions. However, there remain concerns about maintenance of training, quality assurance programs, and patient safety [1]. This article provides a summary of the current state of POCUS worldwide and offers some practical and educational recommendations for advancing POCUS safely [5]. Point-of-care ultrasound (POCUS) is defined as an ultrasound examination performed and interpreted by the clinician at the bedside to obtain specific clinical information. POCUS examines the heart, lungs, veins, and abdomen [6]. It is a focused ultrasound examination designed to address a specific clinical inquiry with a focused, goal-directed evaluation [7]. Its objective is to either "rule in" or "rule out" specific conditions or answer a "yes or no" question [1]. Clinicians with appropriate training and experience can be educated to

perform these exams [7]. In comparison, a comprehensive ultrasound performed by a radiologist or cardiologist is a more thorough evaluation of the entire anatomical region [8]. Thus, its sensitivity has often been confirmed to be higher [8]. However, while ordering, executing, interpreting, and reporting such comprehensive ultrasound examinations typically takes hours or days, POCUS examinations are meant to provide clinical information in real-time [9].

2. Historical Background

Point-of-care ultrasound (POCUS) describes the acquisition and interpretation of images by the treating clinician at the bedside, in which physician obtains real-time information to inform clinical decisions without reliance on a separated specialist from the treating team [10]. This ultrasound framework allows for procedures to be performed safely as well as rapid, assurance serial reassessments that may impact diagnosis and management, all at the bedside [11]. For example, in pediatric critical care, the having direct, immediate access to information is paramount [1]. Most of these patients are newly admitted and are undifferentiated at the point of care, whereby missing critical information on diagnosis or prognosis has huge implications [12]. Moreover, patients on the unit have rapidly evolving disease processes which introduce an ongoing need for reassessment; hence the low threshold for repeat imaging [13]. To achieve this, the imaging examinations need to be simple, rapid, robust and rationally targeted [1]. Pediatric POCUS is simple because it is limited to a few basic cardiac, lung, abdominal and vascular views that need only be memorized and practiced. [2] Pediatric POCUS is rapid because minimal preparation, no contrast agents, and no patient delay are needed. [3] Pediatric POCUS is robust because it provides high-quality, high-resolution images that virtually eliminates inter-operator imaging performance variability, at the same time being portable so that bedside imaging can be performed on portable devices. Lastly, pediatric POCUS is amply rationally targeted so it can be widely applied to numerous clinically relevant presentations, each with specific views targeted to rule out significant pathology and safety hazards [3]. Over the past ten years, pediatric critical care POCUS has undergone an unparalleled renaissance in its practice and knowledge base. Device advances have made it immensely portable and user friendly; applicable at a range of levels of care; and capable of use at the bedside for procedure assistance as well as continuous hemodynamic monitoring [14]. Multicenter studies have demonstrated a burgeoning broader-impact of its use that can be obtained unpredictably and sophisticatedly as required [14].

3. Technological Advances

The miniaturization of ultrasound machines and the increase in computing capacity have facilitated the development of portable ultrasound devices [15]. A vast selection of ultrasound devices is available in the POCUS market [15]. Developments in signal computational capacity allow even the smallest mobile devices to provide high-quality images [16]. Moreover, the price of POCUS has decreased dramatically, making the technique more accessible to physicians [16]. This article summarizes the types and characteristics of ultrasound machines used for POCUS.

Several types of ultrasound machines have been used for POCUS, categorized as “compact cart-based,” “hand-carried,” and “handheld or pocket-sized” [17]. Compact cart-based devices possess the most advanced features with powerful processors [17]. These machines are equipped with a semi-rigid cart allowing easy movement inside the unit [18]. Other types of ultrasound machines should be acquired with caution if this type of machine is being replaced due to the difficulty in obtaining specialized consumables and batteries [18]. If uncertainty regarding purchasing portable devices exists, it is safer to select a compact cart-based device [19]. Hand-carried ultrasound machines are relatively lightweight and capable of high-quality images [19]. Some machines in this category have docking stations, but the screening process is conducted with the body of the machine only. It is the most usable POCUS machine by a large margin and expected to follow the algorithm described in the introduction [20]. At present, “hand-held” ultrasound devices or pocket-sized devices are the most portable devices [20]. Due to the minimal space inside the engine, signal processing is limited, producing relatively low-quality images [21]. Such devices cannot propagate waves in aerosols such as gel, and this limitation results in poor skin contact screening [21]. While there are pros and cons of pocket-sized ultrasound machines, they can be used effectively with care when rapid screening of subjects is essential [20].

Recently, as the number of personal tablets and smartphones has increased dramatically, new machines provide a mobile application-based system that transforms a tablet or smartphone into a portable ultrasound by connecting a probe [22]. These machines can handle the software power by piggybacking on the simulator provided in a mobile-based machine [22]. From a workflow perspective, the mobile device presents more comfortable workflows for conventional styluses [23].

4. Clinical Applications

Point-of-care ultrasound (POCUS) is a powerful imaging tool that is increasingly utilized in various medical and surgical practices [17]. The impact of POCUS primarily stems from the immediacy of the examination and its ability to visualize anatomical structures, hemodynamic parameters, and pathologic changes in real time [24]. With its noninvasiveness, portability, and relatively low cost, POCUS can be easily used for bedside monitoring [24]. POCUS is now used not only in the fields of emergency medicine and intensive care units but also in hospital wards, outpatient clinics, and operating rooms [24]. It is applied to provide

a range of clinical information and to support various procedures. These applications increase by newly developing POCUS devices and software that make it feasible to visualize dynamic images in 3D formats [25]. Clinicians in fields such as obstetrics-gynecology, urology, and otorhinolaryngology are increasingly applying POCUS [25]. The recent introduction of wireless POCUS devices has led to the broader diffusion and use of POCUS beyond medical doctors to healthcare providers such as nursing and paramedical staff [26]. The increasing use of POCUS is driving research in novel applications such as perioperative neurosonology and lung ultrasound in patients with COVID-19 pneumonia [2]. When compared with traditional imaging tools, POCUS is more effective in accumulating specific clinical information [26]. Most practicing physicians claim that the clinical questions an ultrasound examination needs to answer are specific ones that require a focused evaluation [27]. POCUS examinations are designed to address a specific clinical inquiry such as 'Do I see pericardial effusion?' or 'Do I see a wide aorta? [27]. The technical and interpretive characteristic of a POCUS examination would be different from that of a comprehensive ultrasound examination performed in a radiology department [28]. Therefore, it is preferred to use the term 'POCUS' rather than 'ultrasound' when physicians are involved in both diagnostic and therapeutic use of ultrasound [28]. Nonetheless, it is necessary to acknowledge that this advantage could be limited in a major referral hospital where most physicians have access to experienced radiologists or cardiologists who thoroughly evaluate an ultrasound image [29]. Comprehensive ultrasound examinations typically provide clinical information which sometimes overlooked by POCUS examinations [29]. Nevertheless, a POCUS ultrasound examination is time-efficient, providing clinical information in real-time, usually within minutes following the examination [13]. In this regard, recent studies have shown that it is possible to increase diagnostic accuracy for a number of conditions and situations—such as the identification of traumatic hemoperitoneum, the detection of perforated peptic ulcer, the assessment of lower limb venous thrombosis and heart failure; it also significantly reduces physicians' diagnostic uncertainty [29].

5. POCUS in Emergency Medicine

Point-of-care ultrasound (POCUS) is an ultrasound examination performed and interpreted by the clinician at the bedside to obtain specific clinical information needed for the patient's management [13]. Emergency medicine (EM) as well as the abovementioned field of medicine encompasses a wide variety of diseases with a highly variable disease course, which means a wealth of information can be that could be useful [30]. This makes it suitable for POCUS [2].

POCUS has become increasingly popular in EM and so has POCUS education in EM residency programs [31]. Many recent studies have reported that POCUS can increase diagnostic accuracy and significantly reduce physicians' diagnostic uncertainty [31]. There are also studies that have shown that undergraduate medical students who have encountered POCUS examinations earlier in their medical education have not only performed these examinations more often later, but have also gained a better understanding of the clinical applications of POCUS [32]. These results suggest that it is important to increase the probability of exposure to POCUS examinations and their interpretation in the early years of medical education [32].

With the increased usage of ultrasound in emergency and critical care settings, countries have recently implemented health insurance coverage for POCUS performed in the emergency and critical care areas [33]. Studies conducted in many countries have shown that POCUS is widely used in EM and numerous studies have been performed using it. The rapid growth of POCUS usage in EDs and emergency departments (EDs), compared to other subspecialties, as well as the benefits of POCUS for emergency care, such as better profiling of the patient's condition, reduced prescription of unnecessary tests, and reduced prekey hold and logistical challenges posed by testing in a conventional imaging department, have also been reported [14]. Despite the rapid growth of POCUS as a new technology in emergency, trauma, and critical care medicine, some concerns have been raised regarding its patient safety [33]. Overuse and inappropriate usage, as well as excessive dependence on POCUS, can lead to inaccurate diagnoses [34]. Therefore, proper prescription and application of POCUS, as well as a method for clearly documenting POCUS findings, are required for commercially available healthcare budgets that are increasingly tightening and refusing to reimburse medical expenses for tests with poor diagnostic accuracy [34].

6. POCUS in Primary Care

Primary care is a critical component of a well-functioning health system. It is the primary point of entry into the health system for individuals seeking care [35]. Primary care involves a range of multifaceted tasks such as health systems management, the promotion of health across the lifespan, the prevention of illness, the treatment of acute and chronic disease, and end-of-life care [35]. Generally, the roles of primary care clinicians have been broadly defined to include [1] comprehensiveness, [2] continuity, [3] triaging of requests for specialty services, and [4] a health systems management function [2]. More recently, a fifth function was articulated, specifically, the activity of addressing barriers to health care [36]. However, the increased complexity of health conditions for adults and children has outpaced the development of primary care systems [36]. Nevertheless, primary care requirements differ by level of income [37]. Services that are more dependent on system characteristics do not differ [37]. As national

income is associated with increased rates of the availability of lower-level, first-contact care, it appears that the current state of global primary care is likely to have improved in many respects since the past survey [38].

Point-of-care ultrasound (POCUS) is an ultrasound examination performed and interpreted by the clinician at the bedside, which targets a specific clinical inquiry and aims to either rule in or rule out specific conditions [39]. POCUS examinations provide clinical information in real-time [39]. When emergencies arise and the clinician requires immediate information to assist in diagnosis and management, POCUS examination may be indicated [40]. POCUS in family practice is also a tool for asset-based community development, which usually begins with the identification of community assets and mobilizes them to generate community-led initiatives that improve conditions [40]. Community assets include skills held by people, such as POCUS training in family practice, which enables diagnosis at the point of care and saves time in treatment [41].

POCUS requires devices that are smaller, handheld, and portable. Studies show that mobile handheld ultrasound is acceptable, affordable, and applicable in family practice [27]. When experienced doctors use it, they can interpret images at a level similar to what can be achieved with larger machines [10]. Studies have shown that POCUS improves patient outcomes, enhances safety, and lowers costs [42]. Handheld ultrasound in family practice increases diagnoses [42]. In cases of heart failure, bacterial infection, and the need to drain an abscess, specialist referral decreased and patient satisfaction with the appointment process improved [43].

7. POCUS in Pediatrics

Ultrasound with high-frequency sound waves is being used more often to help with diagnosis and treatment in pediatric patients in different medical care areas [44]. Pediatric emergency pediatricians and specialists are the main users of this technique [44]. Although ultrasound imaging is usually done in imaging departments, it has been found that placing ultrasound machines and other devices near patients at the emergency room, intensive care unit, or inpatient floor is more efficient [45]. Point-of-care ultrasound is the term for ultrasound that is done at the patient's side [45]. POCUS can help pediatric doctors safely and effectively assess patients' conditions quickly and begin treatment without delay [46]. Several medical organizations have issued new educational guidelines and instruction references [46]. The American Academy of Pediatrics recommends that pediatric training programs teach the basic and advanced uses of ultrasound as part of their curriculum [46]. The written curriculum includes the indications, prerequisites, steps, risks, limitations, and illustrations of its use in 10 medical specialties (47). Pediatric emergency departments are now using POCUS to improve patient care [47]. Many papers have now demonstrated the benefit and safety of its use in pediatrics in many countries, even in the most ambiguous and high-stress situations [48].

There is also solid training, as many pediatric training programs have recently established ultrasound training programs [49]. In addition to independent imaging, it is possible to teach how to understand echocardiography, including some normal images and disease states [49]. Many primary and specialized care providers and imaging specialists are also starting to use this technology [50]. Teaching the importance of POCUS is paramount, as it can help avoid a big delay which can result in sudden clinical deterioration in patients [50]. Other points include that today's pediatricians will be tomorrow's pediatric specialists, and maintenance of skills will be much easier without the need for access to and availability of complicated machinery in the usual cases [51]. Important to those in need, like in some low-income areas, as its use in the right hands will benefit patients without exposing them to additional expenses [51]. Also, it is a helpful tool for research and data collection on a large scale [52]. A start has already been made in incorporating this technology into investigator research installations [52]. No matter what, it is essential that intensive training will proceed slowly and cautiously to ease a huge and painful transition [53].

8. POCUS in Obstetrics and Gynecology

Point-of-Care Ultrasound (POCUS) is a promising diagnostic tool for gynecologic pathology and large ovarian masses [54]. POCUS is an ultrasound performed at the bedside by the clinician and interpreted directly by the clinician for immediate diagnosis and treatment planning [54]. POCUS is an important clinical tool that may improve patient care by expediting diagnosis, treatment, and triage of patients [55]. Also, POCUS is relatively cost-effective, safe, and has the benefit of real-time imaging for immediate diagnosis [55]. However, it is highly operator and equipment dependent [2]. POCUS uses low-frequency probes that allow imaging of a large region of interest and evaluation of an abnormality found on the larger POCUS examination [56]. POCUS evaluates the abnormality in detail in hopes of assisting in diagnosis and treatment plan [56]. POCUS devices are portable and easy to clean, allowing safe use from the emergency department to the operating room; were termed handheld POCUS [57]. Because handheld POCUS devices are lightweight and portable, numerous leading ultrasound-manufacturing companies have developed lightweight handheld POCUS devices, including smartphone-based devices [57]. Additionally, many of the same companies have developed low-cost handheld POCUS devices for use in low resource countries [56].

POCUS devices have an array of available software and probes [29]. POCUS is performed with far

fewer views than a full obstetric or gynecologic ultrasound, however most obstetric and gynecologic pathology can be assessed with these targeted examinations [29]. POCUS adds value in the diagnosis, treatment, and triage of patients in a variety of clinical scenarios [57]. As a result of its ease of use and portability, POCUS has the potential to be very influential in low-resource settings, particularly in international medical work in low- and middle-income countries [57]. Handheld POCUS devices allow physicians greater ease of use confidently in a variety of settings, including international medical work in low resource countries [58]. The use of handheld devices has been shown to significantly improve diagnostic accuracy in a variety of clinical settings and decrease time to diagnosis, consultation, and treatment in obstetric and gynecologic pathology [58]. POCUS testing improves triage and quality of care for gynecologic and early pregnancy pathology [58]. POCUS testing can more easily triage patients who are high risk or require a higher level of care work for telediagnosis [59]. With the increased use of handheld devices for POCUS testing, availability needs to be assessed in a variety of clinical settings [59].

9. POCUS in Cardiology

Cardiovascular disease is one of the main causes of morbidity and mortality in developed and developing countries [60]. Given the high prevalence and impact of this disease, it is important to have early identification and diagnosis of the patient's condition [60]. Early management of the patient with cardiovascular disease improves prognosis and could decrease health expenditure [61]. Largely, POCUS in cardiology can assist either the detection or exclusion of common cardiovascular diseases [61].

Acute hemorrhagic shock is one of the most common reasons for resuscitation on arrival in the emergency room [2]. Until very recently, detecting the echogenic fluid surrounding the heart and the cavity and great vessels was a difficult challenge, requiring experienced clinicians, patients, and transducers [10]. The POCUS did not allow the identification of the echogenic fluid or acknowledge the structure; it was just a summary of the literature with little data and images [62]. However, with the recent innovations of POCUS such as panoramic views, multi-focus, higher frequency matrix array probes, and enhanced image post-processing, more and more suboptimal images can be utilized and broaden the scope of practice [62]. Notably, patients with a normal-sized heart received a very small amount of a pericardial effusion, leading to a large ascetic fluid collection in the peritoneal cavity [62].

Atrial septal defect (ASD) can also be detected via echocardiography [54]. If not taken care of, a right-ventricular overload can develop with right atrial dilatation and potentially atrial arrhythmia later on [56]. However, since POCUS is primarily performed for resuscitation, the clinicians mostly hurry to stabilize the patient, missing the one-minute window to apply a proper color Doppler to detect atrial shunting and right-ventricular overload [63]. Only after a sufficient volume of saline contrast enters the right atrium, ventricular enlargement can be noticed [63].

10. Education and Training

Further, the incorporation of effective education systems to teach medical students POCUS should be a multi-step process to ensure that the hurdles faced by students during the learning process are managed adequately [64]. Once a sufficient number of POCUS trainers have been recruited, a seminar should first provide educators with a detailed understanding of the goal of teaching ultrasound in the curriculum and how it can be met [64]. Faculty should be educated concerning the POCUS curriculum itself, with a focus on expected outcomes [65]. All participant educators should thereafter become POCUS practitioners, viewing a wide range of ultrasound procedures within the obstetric, musculoskeletal, and abdominal domains [65]. Diagnostic cases and normal imaging should be showcased so that the new educators are aware of commonly seen artifacts and anatomical variations [66]. It is important that each participant is confident with basic POCUS practice prior to its introduction to technical staff and students, as this familiarity will facilitate effective teaching, while also ensuring a level of pedagogical consistency across educators [67]. Training within departments at academic centers will require a robust quantity of obstetric, musculoskeletal, and abdominal use cases as well as a well-defined teaching plan that describes methods of practice, such as level of guidance with imaging and supportive resources [67].

Once the pre-existing knowledge gap is bridged, outreach and training for technical staff should be carried out [68]. In this first contact, technical personnel trained in either the obstetric or abdomen domains should first be introduced to the teaching equipment and protocols, which should be iteratively discussed with increasing levels of detail [68]. The second contact should explore case use and overall management of the learning programs [69]. The repeat training day should occur after the first training session is sufficient, with a minimum 1-week interim, but within 2–4 weeks [69]. Follow-up meetings should occur as often as needed, as new challenges in the implementation of POCUS education arise [69]. Further, it is essential for technical staff to carefully document the most common issues faced during the learning programs and invitational seminars to avoid referral to steps in training or information-disseminating sessions that address issues already confronted earlier by other technical staff [70].

11. Barriers to Implementation

There are many challenges to implementing point-of-care ultrasound (POCUS) for medical imaging

in low-resource settings (LRS). Implementing POCUS is influenced by a complex interplay of stakeholder perceptions and health systems context [71]. There are many barriers to optimal POCUS implementation [71]. POCUS still suffers from insufficient and for some groups, inaccessible initial training in ultrasound acquisition and interpretation [72]. Low-cost high-fidelity training and assessment tools would increase access to quality training [72]. Rapidly evolving POCUS technology sometimes discourages the use of POCUS and contributes to anxiety over training and education, particularly among specialists concerned about quantity and competency. Stakeholders frequently experience frustration in obtaining feedback, even when working with specific services. Education sessions and platforms have been developed to facilitate knowledge sharing and provide resources [73]. Wider use of patient photo ID stickers would also enhance plans for audit and feedback [73]. Setting up and maintaining a quality improvement framework for POCUS were also significant challenges for many groups [74]. Additional time and FTE would be required to ensure that quality assurance and education are properly funded and staffed [74]. This is particularly salient in the context of a shrinking pool of echocardiography and cardiac physiotherapy staff and the implementation of a high-volume TTE service [75]. Furthermore, POCUS is incompatible with some models of care in which it is more difficult to assess patients in a timely fashion without transport to another location [75]. POCUS champions, including experienced sonographers, fellows, medical students and others, are not always fluent in POCUS resulting in a co-education process that is not true multi-directional flow of information [76]. There are also insufficient number and location of hybrid rooms with TTE and POCUS capability [76].

12. Patient Outcomes

As the expansion of point-of-care ultrasound (POCUS) continues, interest in patient outcomes related to its use is growing as well [77]. Various imaging modalities exist for the evaluation of each of these and each modality has advantages and disadvantages, but defining patient outcomes related to such a multifactorial intervention as POCUS is challenging [77]. Ultimately, what matters most, both clinically and from a reimbursement standpoint, is patient outcomes that are meaningful to the patient and are improved by the use of POCUS. Efforts to define these types of patient outcomes in general for POCUS or for specific applications are relatively few [77]. Nonetheless, examination of the reported patient outcomes related to POCUS use is worthwhile and likely constructive as future studies are designed to evaluate this area [27].

Based on the search parameters and the accepted definitions of POCUS (low acuity setting, non-interventional, education-based), a good-sized group of papers were reviewed, both in terms of number and scope of applications [57]. Evaluation of patient outcomes related to POCUS use remains relatively immature [57]. Most studies of POCUS use that related to patient outcomes were positive, either reporting favorable outcomes or showing equivalence or non-inferiority of patient outcomes with POCUS use [78]. Interestingly, a good portion of studies focused on teaching and training efforts or primarily on technician performance testing showing advantages of technicians over physicians in focusing on use in lower acuity settings [78]. Negatively biased studies raised multiple concerns about introducing POCUS into routine practice or comparing with previous imaging modalities, often focusing on hand-carried echo devices in initial studies [79]. The remainder of studies evaluated various manual assessments and tools for measuring satisfaction, ability to make decisions, or severity of CAD used in POCUS imaging with mixed results [79].

Based on the study design and methods used, results could generally be divided into estimation studies, cohort studies with control groups, cohort studies without control groups, and case control studies (both pre-post interventions with care before a dermal flap and implementation of second-generation hand-held devices) [80]. Outcomes evaluated generally focused on clinical and process outcomes and, to a lesser extent, financial and cost-related outcomes [80]. Some studies reported evaluation of technical, operational, and educational outcomes (81). Overall, definitions of outcomes were broad [81].

13. Future Directions

Over the past two decades, POCUS has brought about a paradigm shift in the practice of emergency and critical care medicine [2]. It has revolutionized the way critical care and emergency physicians provide patient care by helping them make rapid decisions based on anatomical and pathological information [82]. In addition, it changed the practice of emergency and critical care medicine by allowing physicians to diagnose and treat patients in real time [82]. With rapid technological advances and growing availability of the device, the trend of POCUS evolution is still continuing, and these developments are anticipated to greatly change medical practice in the future [83]. Recently, POCUS has been increasingly implemented in various other fields as well as in critical care and emergency medicine [83]. It is anticipated to revolutionize diagnosis and treatment methods in various medical fields in the future, similar to the recent changes observed in critical care and emergency medicine [84]. Subsequently, it is reviewed how POCUS will be applied in various potential future medical settings besides emergency and critical care units [84].

As ultrasound technologies have evolved tremendously over the past two decades, many healthcare professionals around the world began to use POCUS [85]. It has been widely used in various clinical settings, including intensive care units, emergency

departments, and hospital wards [85]. Growth of handheld ultrasound devices has played a substantial role in the wider use of POCUS [86]. These compact and light devices are increasingly powerful, and they are connected to cloud storage to facilitate reading, sharing, and storing results [86]. Improved image quality and cheaper prices have also made POCUS more available [86]. Currently, POCUS devices are broadly utilized in various medical fields [87]. Intensive care and critical care physicians use them to assess cardiac, pleural, renal, and abdominal status of patients, as well as to assure proper position of catheters, tubes, and masks [87]. In emergency medicine, POCUS is routinely applied to guiding and ensuring safe performance of difficult procedures, identifying and diagnosing conditions including cardiac arrest, hemoperitoneum, and pericardial effusion, and obtaining vast amounts of useful information beyond what can be obtained using limited physical examination [87].

14. CONCLUSION

Nearly half of the world lacks access to diagnostic imaging, especially in low-resource and rural settings, where the majority of people do not have access to diagnostic tools [87]. With the rapid advancement of technology, point-of-care ultrasound (POCUS) is a versatile and relatively affordable imaging modality that offers promise as a means of bridging the radiology gap, improving care, obtaining a rapid diagnosis, and performing bedside procedures [88]. In addition to being non-invasive, POCUS does not use ionizing radiation, is portable, relatively affordable, does not require specialized staff, and the relatively low number of skills have made it attractive for a range of emergency, triage, and mass casualty applications [87]. However, crucially for low and middle-income countries, it can give results in real-time or near-real time [89]. By showing images of important anatomy and pathologies immediately to the clinician, it is an intuitive and pragmatic modality for non-imaging professionals [89]. Ultimately, POCUS devices could complement mobile telemedicine and be used in settings with very limited technology [2]. In spite of the increasing affordability and portability of POCUS devices, which can now be USB plug-ins for cell phones, there are still important barriers to the implementation of POCUS in resource-limited settings regardless of the modality's utility. Interviewees from both sites considered POCUS a valuable diagnostic tool that improved clinical decisions [90]. They perceived barriers to adequate training as one of the most important remaining barriers to POCUS implementation [90].

Access obstructions include lack of modalities, supply chain issues, too few technicians, unreliable power, and medical commodity opposition to POCUS implementation [91]. Perceived barriers include poor or absent local clinical champions and limited buy-in from medical leadership, physician skepticism about the antibody POCUS academic literature, and minimal response from professional organizations to local obstacles [91]. Interviewees from both sites expressed ambivalence about alternative implementations [92]. Case examples showed the nuances of these perceived barriers to alternative implementation at local institutions and the hardware and software vendors they worked with [92]. Interviewees viewed all-important training and capacity-building opportunities as needing to be parsed carefully to prioritize formative years over more advanced years in the POCUS implementation timeline [92].

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