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Utilization of Point-of-Care Ultrasound (POCUS) in Emergency and Critical Care: Role of Nursing for Enhancing Diagnostic Accuracy and Efficiency-Systematic Review.

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In Loving Memory of Late Professor Doctor ""Mohamed Refaat Hussein Mahran""

Abstract

Background: Point-of-care ultrasound (POCUS) has emerged as a valuable diagnostic tool across various healthcare settings, role of nursing and specifically in emergency department, prompting efforts to enhance education, implementation, and technological innovations. This comprehensive review synthesizes recent data on POCUS techniques, uses, benefits, nursing roles, barriers, nursing role, and technological advancements. **Methods:** Data from diverse sources, including academic literature, surveys, and studies, were synthesized to provide a comprehensive overview of POCUS-related topics. Discussions encompassed POCUS techniques, clinical applications, benefits, nursing roles, barriers to implementation, and recent technological innovations. **Results:** Recent studies have highlighted the expanding utility of POCUS techniques in diverse clinical scenarios, ranging from obstetric and gynecologic care to trauma assessment and heart failure management. Furthermore, nurse-led POCUS initiatives have demonstrated promising outcomes in improving patient care and outcomes, particularly in rural and underserved communities. However, challenges persist, including barriers related to equipment availability, training, funding, infrastructure, and quality assurance. Technological innovations such as ultrasound-on-chip technology, artificial intelligence (AI), and augmented reality (AR) hold promise for addressing some of these challenges and advancing POCUS education and implementation. **Discussion:** The findings underscore the importance of ongoing efforts to address barriers and enhance POCUS education, implementation, and technology. Collaboration among healthcare professionals, policymakers, educators, and technology developers is crucial for realizing the full potential of POCUS in improving patient care and outcomes. **Conclusion:** While significant progress has been made in POCUS education, implementation, and technology, challenges remain. Continued investment in education, training, infrastructure, and technological innovations is essential for maximizing the benefits of POCUS across diverse healthcare settings.

Keywords: Point-of-care ultrasound, POCUS education, nursing roles, barriers, technological innovations.

1. Introduction

Point-of-Care Ultrasound (POCUS) has emerged as a valuable tool in enhancing diagnostic processes in emergency and critical care settings. Traditionally, ultrasound imaging was primarily performed by radiologists in dedicated imaging departments. [1-4] However, the portability and accessibility of modern ultrasound devices have made it possible for clinicians at the patient's bedside to utilize POCUS to quickly gather essential diagnostic information. Here are some key highlights of the significance of POCUS in emergency and critical care:

1. Rapid and Real-Time Diagnosis: POCUS enables immediate access to diagnostic information, allowing clinicians to assess and diagnose conditions promptly. Time-sensitive conditions such as cardiac arrest, trauma, and respiratory distress can benefit greatly from real-time imaging, as it aids in making rapid treatment decisions.

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2. Increased Patient Safety: POCUS reduces the need for patient transportation to imaging departments, decreasing the risk of complications during transit. By bringing the ultrasound to the patient, POCUS minimizes delays in diagnosis and treatment initiation, leading to improved patient outcomes. [3]

3. Bedside Monitoring and Assessment: POCUS allows continuous monitoring and assessment of critically ill patients. Clinicians can perform focused examinations to evaluate cardiac function, pulmonary status, abdominal abnormalities, and the presence of vascular access complications, among other things. This facilitates ongoing evaluation and guides therapeutic interventions. [4]

4. Guided Procedures: POCUS serves as a valuable tool for guiding invasive procedures in emergency and critical care settings. It provides real-time visualization during procedures such as central line placements, thoracentesis, paracentesis, and nerve blocks, enhancing accuracy and reducing complications. [5]

5. Non-Radiation Imaging: Unlike other imaging modalities such as X-rays and computed tomography (CT), POCUS does not involve ionizing radiation. This makes it particularly useful in scenarios where radiation exposure should be minimized, such as in pregnant patients or young children. [6]

6. Cost-Effectiveness: POCUS can potentially reduce healthcare costs by minimizing the need for more expensive imaging modalities or unnecessary diagnostic tests. It enables targeted and focused assessments, helping clinicians determine when further imaging or interventions are required. [7]

7. Enhanced Decision-Making: POCUS aids in real-time clinical decision-making by providing valuable information at the point of care. It helps clinicians assess the response to interventions, guide resuscitation efforts, and monitor treatment effectiveness, leading to more informed and tailored patient management. [7]

8. Education and Training: POCUS has become an integral part of medical education and training in emergency and critical care. Its portability and ease of use enable hands-on learning, allowing clinicians to develop proficiency in ultrasound-guided examinations and procedures. [8]

Overall, Point-of-Care Ultrasound plays a vital role in enhancing diagnostic processes in emergency and critical care settings. Its ability to provide immediate, accurate, and dynamic imaging at the bedside empowers clinicians to make timely decisions, improve patient safety, and optimize outcomes for critically ill individuals. [9-10]

Over the past few decades, technological miniaturization—from laptops to tablets to phones—has attracted a lot of attention. This trend also applies to ultrasound technology, as medical professionals are increasingly using handheld devices of different sizes for point-of-care ultrasound (POCUS) at the bedside. These devices are noticeably more portable than full platform systems. The use of POCUS has become commonplace among emergency medicine (EM) professionals and has also permeated many other specialties, such as rheumatology, trauma, critical care (CC), vascular medicine, and obstetrics. This progress has made it possible for very inexpensive technology to be distributed to resource-constrained environments across the globe [11-14]. POCUS was most recently used widely during the COVID-19 epidemic [15-16].

Point-of-care ultrasound (POCUS) is a fast-developing diagnostic instrument used in urgent care, inpatient, and outpatient settings. The speed and accuracy of diagnoses are improved when POCUS is incorporated into clinical exams and procedures. Because of its lower costs, lower radiation exposure, shorter imaging delays, and higher patient satisfaction, its use in primary care is growing. POCUS is also useful in settings with limited resources. POCUS training is becoming more common in family medicine residency programs, and practicing physicians can access resources. Nevertheless, the extensive training needed to achieve and retain proficiency limits the general adoption of POCUS. The strongest data on POCUS's efficacy in particular clinical situations and specifically in emergency department is reviewed in this article [17].

The importance of POCUS in the emergency department (ED) could be explored from the prompt diagnosis and rule out illnesses that pose a serious threat to life are essential. Point-of-care ultrasound (POCUS) is widely acknowledged as a superior non-invasive instrument that offers significant diagnostic data and procedural instructions to healthcare providers at the patient's bedside. Additionally, real-time ultrasonography is used to more safely guide invasive operations including thoracentesis, paracentesis, and joint aspiration, as well as provide central or peripheral intravascular (IV) access. It has been shown that using POCUS can shorten ED stays, increase patient happiness, and boost diagnostic precision [18-19].

From the point of nursing role, in order to provide patients with high-quality treatment, registered nurses (RNs) and nurse practitioners (NPs) are essential. As suggested by Gardner, Della, Middleton, and Gardner (2009), RNs and NPs need to take part in role development in order to stay up to date and broaden their scope of practice (SOP) [20]. This can be achieved by implementing new technologies that are representative of best practices and may improve patient outcomes. Point-of-care ultrasound (POCUS) is used by both RNs and NPs in Australia and around the world, however their educational backgrounds, practical training

experiences, and degrees of skill vary. These contemporary procedures highlight the need for an analysis of the global body of research on nurses' use of POCUS [20].

The primary objective of this role is to examine the revolution of POCUS in the emergency department, addressing its challenges, barriers, and various applications. Over the past 20 years, POCUS has evolved into a critical non-invasive tool, significantly enhancing diagnostic accuracy and reducing emergency department length of stay, thereby increasing patient satisfaction. Its utility in guiding invasive procedures such as central or peripheral IV access, thoracentesis, paracentesis, and joint aspiration has been well-documented, offering greater safety and immediate interpretation of results. Despite these benefits, the widespread adoption of POCUS faces challenges, particularly the training burden required to develop and maintain proficiency. Additionally, this role will provide recommendations and highlight the pivotal role of nursing in the effective utilization of POCUS, recognizing that RNs and NPs are increasingly integrating this technology into their practice to improve patient outcomes.

POCUS in Emergency Department:

POCUS technology is portable and enhances patient evaluations in a variety of healthcare settings when used as a diagnostic tool by licensed healthcare practitioners. Using a portable ultrasound machine or other handheld instrument at the patient's bedside, POCUS assists in differentiating between clinical hypotheses. Portable ultrasound systems, when used by a certified provider, provide an accuracy level that is comparable to diagnostic ultrasonography exams carried out by radiologists in imaging departments. As a result, POCUS may enable less traditional imaging tests to be performed. Over the past ten years, POCUS—which was first used in critical care approximately thirty years ago—has become more and more prevalent in ambulatory and prehospital practice settings. POCUS is now widely used by doctors, specialists, and, more recently, paramedics and advanced practice clinicians (including NPs), proving to be a valuable addition to physical exams conducted during both inpatient and outpatient stays [21-22].

The prevalence of POCUS utilization in the emergency department (ED) was determined by calculating the ratio of cases where POCUS was conducted during patient admissions to the total number of ED admissions over the study duration. The indications for POCUS were categorized into two primary domains: “diagnostic” and “procedural-ultrasound-guided procedures”. Diagnostic POCUS encompassed various modalities, including the following “*extended focused assessment with sonography in trauma (eFAST) and/or abdominal aortic aneurysm (AAA), deep vein thrombosis (DVT), renal, right upper quadrant (RUQ) and gallbladder, bedside echocardiography (Echo) following the Basic Echocardiography in Life Support (BELS) protocol, musculoskeletal (MSK), and soft tissue examinations*”. Monash Health's bedside echocardiography protocol, extrapolated from the BELS protocol, focuses on assessing chamber size, qualitative left and right ventricular function, pericardial effusion presence, and inferior vena cava (IVC) status. Pulmonary ultrasound is integrated within broader diagnostic contexts such as eFAST in trauma cases or bedside Echo evaluations for patients presenting with cardiopulmonary symptoms. Obstetrics and gynecological (O&G) POCUS is not standard practice at Monash Health except in suspected ectopic pregnancy cases, where patients with moderate-to-high pre-test probability are promptly referred for formal ultrasonography and O&G review [23].

Musculoskeletal (MSK) and soft tissue ultrasound primarily serve to assess conditions like abscesses, hematomas, effusions, fractures, and dislocations, and they guide fracture manipulation realignment. Ocular ultrasound is not routinely included in POCUS protocols. Procedural POCUS is frequently employed to assist various interventions, including vascular access establishment (central venous catheter insertion, arterial line placement, and peripheral intravenous cannula insertion), nerve blocks, paracentesis, thoracentesis, lumbar puncture, and arthrocentesis. While peripheral intravenous cannula insertion often utilizes direct visualization or landmark techniques without POCUS, ultrasound guidance becomes advantageous in cases of difficult access. Operators conducting POCUS were categorized as Senior Medical Staff, including Fellows of Australasian College of Emergency Medicine (FACEMs, Emergency Medicine consultants), Senior and Junior ED Registrars, and others, comprising Career and Hospital Medical Officers (CMOs and HMOs) [23].

Origins of POCUS Technology:

A significant turning point was the introduction of portable ultrasound machines for military usage in 1998, and early in the new millennium, research began to surface detailing the clinical use of POCUS. These portable ultrasounds were first referred to by a number of names, including pocket echocardiography, hand-carried ultrasound, and small portable ultrasonography devices (SPUD), before POCUS became the accepted word. However, the portability, image quality, and functionality of the early portable computers were still limited, frequently requiring their transportation in the shape of cumbersome laptop formats or carts. These devices featured few measuring possibilities, no standardized reporting systems, and no features like spectral Doppler and color flow. POCUS was widely embraced by early users, especially in emergency medicine (EM) and critical care (CC) settings, despite discussions over its alleged inferiority to full platform systems. This was because of POCUS's portability

and capacity to support timely patient care decisions [24-26].

On the other hand, modern POCUS devices have significantly improved in terms of image quality, technological features, and usability. These days, it's easy to find harmonic imaging, color flow Doppler, and spectral Doppler, and many systems have measurement packages and apps installed. In addition, the majority of contemporary POCUS devices use the DICOM format for storing data and make use of Bluetooth and wireless technology for picture sharing, transducer recognition, and battery charging. Usability has been further improved by touch screen interfaces and small sizes that can be operated via cell phone applications or fit in pockets. Special probe technologies have increased imaging capabilities (silicon chip arrays, for example), and artificial intelligence has been used to make image acquisition easier (especially for novice users) [27-28].

Even with these developments, there are still trade-offs between user training and image quality. In particular for complex quantification and three-dimensional imaging, full platform echocardiography devices continue to be the gold standard for high-quality diagnostic imaging. Moreover, not every user has received thorough instruction in image interpretation, and the extent of image acquisition during a POCUS examination is purposefully restricted. Therefore, even though POCUS has shown to be quite helpful in a variety of clinical contexts, formal, comprehensive tests performed by qualified echocardiographers are still required in many situations. However, POCUS's adaptability and usefulness continue to fuel its broad acceptance and application in a variety of medical fields.

POCUS Indications, Benefits, Education, and Training:

Beyond its ability to accurately diagnose conditions, POCUS has several other advantages, one of which is its ability to save costs for individuals, hospitals, and organizations. The complete prices of POCUS evaluations are significantly higher than those of more conventional diagnostic imaging methods like CT or MRI scans. Rising transportation expenses, high incidence of comorbidities, and limited access to healthcare services exacerbate the economic burden in places like Canada, where healthcare spending in northern isolated towns is disproportionately high compared to urban centers. Since NPs are the primary healthcare providers for these populations, it is necessary that they possess certification in the use of modern, affordable diagnostic techniques such as POCUS. By doing this, NPs can lessen the financial strain on healthcare systems and lessen the burden that these vulnerable communities' patients bear. Additionally, incorporating POCUS into NP practices can expedite diagnostic procedures, cutting down on the time needed to schedule tests and minimizing the need for follow-up visits [29].

Education and training related to POCUS are crucial elements that depend on the regulatory certification criteria in the clinical practitioner's jurisdiction. The American Registry for Diagnostic Medical Sonography in the United States and the Canadian Point of Care Ultrasound Society (CPOCUS) in Canada, for example, set the requirements for POCUS education. CPOCUS offers introductory and independent practitioner courses, which are one route to POCUS certification. Anatomy review, online lectures, and practical experience with supervised scans are usually included in these courses. Completing the independent practitioner course typically entails six steps, including passing written and practical tests and logging clinical scans while supervised by a proctor. Depending on the jurisdiction and employment norms, the certification fee may change and may be reimbursed. POCUS education is a fundamental component that guarantees clinical interpretation and accuracy, improving patient safety [30].

POCUS clinical accuracy is dependent on the credentials, education, and experience of the provider. To guarantee accurate application, interpretation, and competency, providers must be aware of their limitations and pursue ongoing professional development. The application of POCUS necessitates a special set of abilities that includes clinical assessment and interpreting expertise. There are serious dangers to patient safety when misdiagnosis and misinterpretation occur. The anatomical region being examined, and the extent of the examination have an impact on POCUS accuracy. The thoroughness of the test and the individual's degree of education are closely related to the accuracy of POCUS, as evidenced by the comfort and confidence of qualified practitioners [30].

POCUS serves as a valuable diagnostic tool in primary care across various medical domains. In cardiovascular assessments, it aids in detecting pericardial effusion, identifying decreased systolic function indicative of heart failure, and diagnosing deep vein thrombosis. Respiratory indications encompass identifying areas of consolidation, detecting pleural effusion, and diagnosing pulmonary edema. Gastrointestinal concerns such as abdominal aortic aneurysm, bowel obstruction, acute appendicitis, acute cholecystitis, and renal colic are effectively evaluated using ultrasound. In obstetrics and gynecology, ultrasound assists in distinguishing between intrauterine and ectopic pregnancies, identifying anatomic complications, assessing fetal heart activity, estimating gestational age, and determining the number of fetuses. Furthermore, ultrasound aids in diagnosing musculoskeletal conditions including soft-tissue injuries, joint injuries,

joint effusion, and differentiating between cellulitis and abscess [30].

Different Roles of POCUS:

POCUS is an essential clinical tool in prehospital and primary care settings, particularly for abdominal examinations and obstetrics. According to research, POCUS significantly improves primary care visits from the patient's point of view. Up to 95% of patients report feeling better about their appointment, and 45% say the relationship between the patient and the physician has improved. Surprisingly, not a single patient in the research mentioned having a bad experience using POCUS for their physical evaluation. Bedside ultrasonography is useful not only for abdominal and obstetric examinations but also for cardiac, soft tissue, and musculoskeletal evaluations. It is especially useful in primary care settings and communities with limited resources [31-32].

POCUS Role in Cardiovascular:

Cardiovascular point-of-care ultrasonography (POCUS) has been widely adopted by a variety of user groups, serving as an adjunct to physical examination and clinical assessment in a range of healthcare contexts. It can be used in serial fashion throughout inpatient admissions or during outpatient visits thanks to its integration. Research has indicated that POCUS can be useful in helping internal medicine (IM) residents, cardiologists, and medical students diagnose illnesses that are difficult to diagnose by physical examination alone. For example, POCUS users can now correctly identify chamber size anomalies such as ventricular hypertrophy and atrial enlargement after a brief training session [33-34]. POCUS has shown to be successful in detecting left ventricular dysfunction even with little training [45]. Notably, IM residents with brief POCUS training could predict left ventricular ejection fraction <40% earlier than routine echocardiogram in patients admitted with acute decompensated heart failure, allowing for prompt intervention [36].

Obesity and lack of familiarity in neck vein measurement are two examples of characteristics that can make volume assessment at the bedside difficult. Nonetheless, POCUS assessment of the inferior vena cava's (IVC) size and collapsibility has demonstrated potential in determining the right atrial pressure, outperforming physical examination accuracy, especially in internists [37]. Rotating resident physicians in the advanced heart failure clinic showed competence in obtaining high-quality IVC pictures and correctly determining volume status [38]. It has also been shown that POCUS visualization of IVC plethora at the time of hospital admission for heart failure is a useful predictor of death and readmission rates [39, 40]. Quick qualitative screening of potential etiologies and identification of prognostically relevant results can be achieved using POCUS examination in the outpatient primary care setting, where symptoms of clinically severe heart pathology may initially appear. Recent research has demonstrated the potential of POCUS-assessed left atrial size to improve referrals for high-end echocardiograms and consequently lower associated costs by linking it to considerable long-term mortality [41]. This emphasizes how appealing POCUS is as an affordable substitute, especially in underprivileged environments where access to upscale equipment may be restricted, hence reducing healthcare inequities [42].

POCUS has become an essential tool for emergency medicine (EM) procedures, fulfilling a number of vital roles in the emergency department (ED). The American College of Emergency Physicians has published an update that outlines five core categories that comprise the extent to which POCUS can be used in the ED, including both cardiac and non-cardiac domains. These comprise indications for therapy or monitoring, signs and symptom evaluation, diagnosis, procedural advice, and resuscitation. Among the most significant functions that fall under this purview are the identification of cardiac activity during cardiac arrest, the classification of heart failure subtypes, the assessment of dyspnea causes, the diagnosis and treatment of cardiac tamponade, and the measurement of central venous volume. Furthermore, cardiac POCUS has been included into trauma assessment procedures, most notably through the Focused Assessment with Sonography in Trauma (FAST) algorithm, which has shown effectiveness in accelerating surgical management and raising survival rates for patients with penetrating trauma [42-50].

In cases of cardiac arrest, one of the most important applications of cardiac POCUS in the ED is. Prospective studies and meta-analyses highlight the link between better outcomes in adult cardiac arrest cases with cardiac motion identified by POCUS. Furthermore, POCUS makes it easier to identify particular etiologies such cardiac tamponade or large pulmonary embolism (PE), allowing for more focused therapies and higher survival rates. To ensure that life-saving interventions happen as soon as possible, it is imperative to give resuscitation efforts first priority over picture acquisition and interpretation. POCUS is a useful diagnostic and risk-stratification technique for right ventricular (RV) dysfunction and dilatation in patients presenting with dyspnea and suspected or confirmed PE [51-55].

Despite the excellent sensitivity and specificity of POCUS in detecting RV dilatation, care should be used when interpreting the results, especially when separating acute from chronic diseases. Additionally, cardiac POCUS enhances standard critical care medicine indications, especially when evaluating undifferentiated shock. POCUS assessment of LV function, IVC fluid status, and vascular anomalies are all included in expanded protocols like the Rapid Ultrasound in Shock (RUSH) protocol. Lung ultrasonography adds additional

diagnostic capabilities and frequently outperforms conventional imaging modalities like chest radiography. To sum up, cardiac POCUS is essential for the quick and precise evaluation of heart disease and hemodynamic instability in the emergency department (ED), directing prompt therapies and improving patient outcomes [56-60].

POCUS Role in Respiratory:

POCUS is becoming a quick and affordable method for diagnosing patients with respiratory problems, treating both acute and long-term illnesses. Breathlessness is a common primary care issue that can be difficult to diagnose based alone on physical examination and medical history. With POCUS, lung anomalies can be quickly identified, allowing for the effective rule out of pneumonia (seen by areas of consolidation) or pleural fluid (effusion). Even though auscultation and chest X-rays are still the standard diagnostic methods for these kinds of diseases, POCUS is more accurate and quicker at diagnosing respiratory disorders. Essentially, POCUS has far higher sensitivity and specificity than chest X-rays, which makes it useful for both the diagnosis of certain heart disorders and respiratory diseases. POCUS is a useful tool that nurse practitioners (NPs) can use to quickly and accurately diagnose a variety of respiratory disorders. Because consolidation usually occurs close to the lung surface, POCUS is especially helpful in the evaluation of pneumonia. Furthermore, research indicates that when it comes to the detection of suspected pleural effusions, ultrasonography is three times more sensitive than radiography. With the right ultrasound expertise, professionals can identify aberrant B lines and make a targeted assessment to rule out or identify pulmonary edema. By employing POCUS, NPs may more easily distinguish between normal and abnormal respiratory processes since patients with pulmonary edema have a higher frequency of B lines compared to normal A lines in healthy persons [61-63].

POCUS Role in Gastrointestinal:

Beyond gastrointestinal, nurse practitioners (NPs) use ultrasound for a variety of abdominal symptoms and gastrointestinal problems. Nonetheless, patients sometimes face extended waiting periods for outpatient imaging procedures, such as CT scans and ultrasounds, which are considered the most reliable diagnostic methods for abdominal pain. Alternative imaging modalities, such POCUS, can reduce the impact of extended wait times for formal diagnoses by quickly ruling out illnesses like abdominal aortic aneurysm (AAA) in non-obese patients. When POCUS screening is used instead of just abdominal palpation, results show improved sensitivity (93%) and specificity (97%) for AAA. Given the high death rate linked to AAA, guidelines suggest a one-time test for men who have smoked in the past and for those who are 65 to 80 years old. Primary care visits are usually prompted by widespread stomach pain. NPs need to be on the lookout for warning signs that call for urgent care or surgery. Integrating POCUS into primary care has been successful in ruling out acute abdomen, a condition that frequently necessitates an immediate referral to a higher level of care. Emergencies associated with stomach discomfort frequently include renal colic, AAA, intestinal blockage, acute appendicitis, and acute cholecystitis. An authorized POCUS practitioner can effectively evaluate these critical disorders by looking for hydronephrosis, anatomic anomalies, free air, and other worrisome findings. Certified NPs in rural primary care settings can use POCUS to assess possible warning signs, determine required transportation expenses, and predict patient difficulties [64].

POCUS Role in Gynecology:

In obstetric and gynecologic treatment, ultrasound has become a common diagnostic procedure, especially when performed at the patient's bedside. Doig et al. pointed out that antenatal care services are extremely difficult to access in rural and isolated areas. In this situation, POCUS becomes an important diagnostic tool for assessing intrauterine pregnancy and ruling out potentially dangerous conditions like stillbirth, ectopic pregnancy, or fetal difficulties. This technology is especially helpful for isolated and rural areas, as it reduces healthcare costs and improves the outcomes of patients who are pregnant or nursing a baby. Moreover, POCUS makes it easier to estimate gestational age, determine fetal number, and diagnose defects early in the prenatal stage. POCUS is essential in reducing maternal and fetal risk factors and raising overall morbidity and death rates because it facilitates prompt ultrasound screening and bedside assessment. When it comes to primary care, nurse practitioners have the ability to improve obstetric assessments by using timely bedside ultrasound imaging sparingly [65-66].

Role of Nursing in POCUS:

Bowra et al. (2010) conducted a prospective study in Australia to assess the accuracy of nurse-performed Focused Assessment with Sonography for Trauma (FAST) examinations in trauma patients. The study involved a convenience sample of 242 scans performed by 8 senior trauma registered nurses (RNs) who underwent a 3-hour theory and 3-hour practical workshop followed by the use of a logbook. The training was based on Australasian College of Emergency Medicine (ACEM) guidelines. The results showed that "*RNs performed FAST with a sensitivity of 84.4% (95% CI 72.1-92.2) and specificity of 98% (95% CI 94.9–99.6), achieving an overall accuracy of 95%. These findings demonstrated that RNs could perform FAST with similar accuracy to previously published doctor-performed examinations*". [67]

Gundersen et al. (2016) conducted a study in Norway to evaluate the clinical impact of focused ultrasound (US) examinations of pleural cavities and

the inferior vena cava (IVC) performed by registered nurses (RNs) to assess volume status in heart failure outpatient clinics. The study, which utilized a cross-over design, involved 119 scans performed by 2 ICU/Cardiovascular RNs with previous ultrasound experience. The RNs underwent practical training for one month, including 15-20 supervised assessments of pleural cavities and IVC. The results indicated that "*RN-performed ultrasound assessments influenced clinical decisions regarding dosing adjustments of diuretics, particularly in predicting volume status. However, there were variations in diuretic dosing between the teams, highlighting the need for standardized guidelines in this context*". [68]

Henderson et al. (2010) conducted a two-part prospective study in the USA to assess the adequacy and accuracy of emergency department nurse practitioners' (NPs) point-of-care ultrasound (POCUS) examinations following training courses and clinical instruction. The study involved 227 ultrasound exams performed by 5 ED NPs who underwent an 8-hour theory and 8-hour practical course, supervision, evaluation of images, and logbook documentation. The results showed that "*NPs were able to perform POCUS with a high degree of accuracy, with a sensitivity of 93%, specificity of 98%, positive predictive value of 89%, and negative predictive value of 99%".* [69]

Mumoli et al. (2014) conducted a prospective evaluation in Italy to assess the diagnostic accuracy of RN-performed compression ultrasonography (CUS) for symptomatic proximal deep vein thrombosis (DVT) of the lower limb. The study involved 697 scans performed by 4 Vascular Lab RNs who underwent 12 hours of theory and 48 hours of practical training. The results demonstrated that "*nurse-performed CUS had a diagnostic accuracy of 94.8% (95% CI 93.2%–96.5%), with a sensitivity of 84.4% and specificity of 97.0%, highlighting the effectiveness of RNs in detecting symptomatic proximal DVT*". [70]

Partovi-Deilami et al. (2016) conducted a prospective observational study in Denmark to evaluate the quality of care in patients with difficult intravenous access (DIVA) before and after the implementation of ultrasound-guided peripheral venous catheter (PVC) placement by nurse anesthetists. The study involved two phases: Phase 1 with no ultrasound use and Phase 2 post-ultrasound training, where ultrasound was used to guide PVC placement in 70 patients by 10 RN anesthetists. The results showed "*a success rate of 83% for ultrasound-guided PVC placement in patients with DIVA, with improvements observed in procedure time, number of skin punctures, and patient discomfort*". [71]

Steinwandel et al. (2018) conducted a cross-sectional interrater study in Australia to determine if a renal RN could reliably perform point-of-care ultrasound (POCUS) of the inferior vena cava (IVC) to assess volume in hemodialysis patients. The study involved 60 ultrasound scans performed by 1 Renal RN who underwent 4 hours of theory, 4 hours of practical training, and 100 self-directed training sessions. The results demonstrated good interrater reliability, with the nurse showing agreement with an expert sonographer in estimating intravascular volume. [72].

In the context of an intensive care unit (ICU), Alexandra (2018) evaluated nurse practitioners' (NPs') proficiency in obtaining and interpreting point-of-care ultrasound (POCUS) pictures. According to the findings, NPs were able to capture 86% of certain POCUS images and interpret 80.6% of those photos correctly. Notably, NPs correctly collected 93.1% of POCUS images and correctly evaluated 73.9% of them for images that achieved 100% agreement among all three reviewers. NPs in the ICU context performed similarly to those in the emergency department (ED), with an acquisition accuracy of 86%, according to a comparison with a similar study by Henderson et al. A significant distinction was the degree of preparation, as ICU NPs were only given a 30-minute information session for the project while ED NPs were given a full 16-hour ultrasound course and a year of supervised clinical instruction.

The study's generalizability based on the wide variety of NP expertise, the use of three different blinded reviewers, and its capacity to fill a large vacuum in the literature about NP performance of POCUS in the ICU setting were among its strong points. The small sample size obtained by convenience sampling, the modification of the original approach according to reviewer expertise, and the difficulty to ascertain the quantity of images obtained by each NP were among the drawbacks. Future ramifications emphasize the significance of POCUS education and training in NP programs and practice, along with the necessity of more research to evaluate the effects of various educational philosophies on POCUS performance [73].

Recent studies have delved into the development of novel educational programs aimed at equipping nurses with point-of-care ultrasound (POCUS) skills. These initiatives reflect a growing recognition of the pivotal role nurses play in leveraging POCUS technology to enhance patient care. For instance, Lai, (2022) conducted a comprehensive needs assessment to identify the specific educational requirements of nurses in mastering POCUS techniques. Building on this foundation, Matsumoto *et al* (2021) designed a tailored curriculum integrating theoretical knowledge with hands-on training to ensure proficiency in ultrasound image acquisition and interpretation among nursing professionals. Also, Yoshida et al., (2020) explored innovative teaching methodologies, such as simulation-based learning and online modules, to optimize the effectiveness and accessibility of POCUS education for nurses. These studies underscore the importance of tailored

educational strategies in empowering nurses to harness the full potential of POCUS in clinical practice, ultimately enhancing patient outcomes and healthcare delivery [74-76].

New Technologies in POCUS:

Point-of-care ultrasound (POCUS) technology has transformed the sector by providing healthcare providers with portable, affordable options. One noteworthy invention is the ultrasound-on-chip technology, which uses a two-dimensional array of microsensors in place of conventional piezoelectric crystals. With the use of this technique, transducers with curved, linear, and phased arrays can be emulated, and a broad frequency range can be covered without the use of additional probes. Voltage generation through a membrane enables the emission of ultrasonic waves, simplifying communication and enabling picture display on mobile devices through the use of capacitive micromachined ultrasound transducers. Furthermore, POCUS functionality is improved by new features like augmented reality (AR) and artificial intelligence (AI). AI helps to improve image quality by guaranteeing consistency, giving real-time feedback, and making it easier for even inexperienced users to acquire images. In the meantime, augmented reality (AR) facilitates remote teleguidance, which lets professionals help beginners with image interpretation and probe placement from a distance. AR makes it possible for numerous physicians to see examinations in real time without having direct patient contact, which is very useful in situations with transmissible disorders like COVID-19. These developments have potential uses in telemedicine and remote education outside of clinical settings, which could increase the effect and reach of POCUS technology [77].

Barriers and Challenges of POCUS:

Barriers to the widespread use of point-of-care ultrasound (POCUS) are multifaceted and include factors related to equipment availability, training, funding, skill maintenance, lack of quality assurance, and infrastructure limitations [78-79].

1. **Lack of Equipment**: The availability of ultrasound machines in rural emergency departments (EDs) varies widely. Surveys conducted in different regions, including Ontario, Newfoundland, Quebec, and various U.S. states, reveal discrepancies in access to POCUS equipment. In some areas, as many as 40% of physicians do not have access to ultrasound machines in their EDs. Factors contributing to this disparity include funding sources and healthcare infrastructure.
2. **Lack of Training**: Many rural physicians express interest in POCUS but report inadequate access to formal training programs. Survey data from different regions, including Ontario, Newfoundland, Quebec, and the U.S., consistently highlight the gap between the perceived importance of POCUS and the availability of training opportunities. Lack of training contributes to low competency levels and hinders the integration of POCUS into clinical practice.
3. **Lack of Funding**: Cost is a significant barrier to POCUS training, as physicians often have to pay for courses out of pocket. Additionally, there is a lack of funding for ultrasound equipment in some regions, further limiting access to POCUS. Survey data from various studies indicate that a significant percentage of physicians identify cost as a barrier to both training and equipment acquisition.
4. **Inability to Maintain Skills**: Skill maintenance in POCUS is challenging, particularly in rural settings with lower patient volumes. Physicians may struggle to achieve and sustain competency due to limited opportunities for practice. Survey data from different regions highlight the difficulty physicians face in maintaining POCUS skills, with many reporting infrequent use and low scan volumes.
5. **Lack of Quality Assurance**: The absence of formal quality assurance programs in EDs using POCUS is a significant concern. Physicians may be hesitant to use POCUS due to fears of litigation and lack of feedback on scan quality. Survey data from various regions, including the U.S., indicate that a substantial percentage of rural EDs lack formal quality assurance processes for POCUS.
6. **Other Barriers**: Several barriers to the widespread adoption of point-of-care ultrasound (POCUS) in healthcare settings have been identified. Training barriers encompass a shortage of trained providers, with limited access to formal education and certification opportunities due to insufficient funding and training opportunities. Equipment barriers highlight the inadequacy of ultrasound machines, resulting from both a shortage of equipment and insufficient funding for their acquisition and maintenance. Infrastructure barriers include the absence of a clinician champion to advocate for POCUS integration, as well as challenges related to image archiving, support staff funding, standard reporting forms, privileged criteria, and facility leadership support. Additionally, a lack of funding for simulation space hinders hands-on training opportunities. Other barriers such as the perceived lack of benefit and the absence of identified barriers among some

respondents further complicate efforts to implement POCUS effectively. These multifaceted challenges underscore the need for comprehensive strategies to address training, equipment, and infrastructure limitations in order to promote the widespread use of POCUS in clinical practice.

Conclusion:

Point-of-care ultrasonography, or POCUS, has become a highly useful diagnostic instrument with a wide range of uses in many medical specialties. Because of its adaptability, it can quickly examine and diagnose a variety of conditions, which makes it very helpful in emergency and critical care situations. POCUS procedures are reasonably simple to learn and can be applied at the patient's bedside by qualified medical personnel, promoting prompt decision-making and enhancing patient outcomes. POCUS has many advantages over other diagnostic tools, such as cost-effectiveness, mobility, and the potential to minimize the need for more invasive treatments. Research has shown that nurses are essential to the application and use of POCUS because of their proficiency in obtaining and interpreting ultrasound images in a variety of clinical contexts. However, there are a number of obstacles that prevent POCUS from being widely used, such as difficult infrastructure in healthcare facilities, restricted access to training, and insufficient financing for teaching and equipment. In order to overcome these obstacles, healthcare organizations, academic institutions, and legislators must work together to improve training opportunities, raise money for infrastructure and equipment, and encourage interdisciplinary collaboration. Notwithstanding these difficulties, POCUS has the potential to improve patient care, which makes continued attempts to remove obstacles and incorporate this useful technology into standard clinical practice justified. POCUS offers the ability to transform diagnostic and therapeutic techniques, ultimately leading to improved patient outcomes and improved healthcare delivery. This can be achieved by utilizing the experience of healthcare professionals, particularly nurses, and putting complete policies in place to remove barriers.

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