



Integrating Point-of-Care Ultrasound in Emergency and Rehabilitation Settings: Radiological, Emergency and Nursing Perspectives from the Saudi Health System

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Abstract

Point-of-care ultrasound has emerged as a transformative diagnostic modality enabling real-time clinical decision-making at the patient bedside across diverse healthcare settings. This systematic review examines the integration of point-of-care ultrasound technology within emergency and rehabilitation contexts of the Saudi Arabian health system, with particular attention to radiological and nursing perspectives. A comprehensive literature search identified peer-reviewed publications addressing POCUS implementation, training frameworks, clinical applications, and interprofessional collaboration models. Analysis of 51 included studies revealed that point-of-care ultrasound enhances diagnostic accuracy, reduces time to treatment, and improves patient outcomes when implemented within structured governance frameworks. Radiologists contribute through protocol development, quality assurance, and competency verification while navigating evolving professional boundaries. Nurses and emergency medical services technicians expand clinical capabilities through focused ultrasound examinations supporting triage, procedural guidance, and therapeutic monitoring. Implementation barriers include training infrastructure limitations, equipment accessibility, credentialing ambiguities, and resistance stemming from traditional professional role definitions. The Saudi healthcare context presents unique challenges including workforce composition diversity, geographic resource disparities, and cultural considerations influencing technology adoption. Evidence supports phased implementation approaches emphasizing multidisciplinary collaboration, standardized competency frameworks, and continuous quality improvement. This review synthesizes current knowledge and proposes recommendations for advancing point-of-care ultrasound integration to optimize emergency care delivery and rehabilitation outcomes within Saudi healthcare environments.

Keywords: point-of-care ultrasound, emergency medicine, rehabilitation, radiology, nursing practice

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1. Introduction

Point-of-care ultrasound represents a paradigm shift in medical imaging from centralized radiology departments to bedside diagnostic capabilities enabling immediate clinical decision-making. Unlike traditional comprehensive ultrasonography performed by specialized radiologists or sonographers, POCUS comprises focused examinations conducted by treating clinicians to answer specific clinical questions during patient encounters (Moore & Copel, 2011). This distributed imaging model fundamentally alters diagnostic workflows, temporal relationships between imaging and clinical decisions, and professional boundaries regarding who performs and interprets ultrasound examinations. The proliferation of portable ultrasound devices with enhanced image quality, intuitive interfaces, and decreasing costs has accelerated POCUS adoption across diverse clinical specialties and practice settings globally (Dietrich et al., 2016).

Emergency medicine has emerged as a primary domain for POCUS integration, with applications spanning trauma assessment, cardiac evaluation, respiratory pathology identification, procedural guidance, and undifferentiated shock evaluation. The FAST examination for detecting free fluid in trauma patients, focused cardiac ultrasound for pericardial effusion and gross ventricular function assessment, and lung ultrasound for pneumothorax or pulmonary edema diagnosis represent foundational emergency POCUS applications supported by extensive validation research (Atkinson et al., 2009). These examinations enable rapid bedside diagnosis potentially altering management decisions before formal radiological imaging completion, particularly valuable in unstable patients where transport to radiology departments poses clinical risks.

Rehabilitation settings present emerging opportunities for POCUS application that remain comparatively underexplored in published literature. Physical therapists utilize musculoskeletal ultrasound for evaluating soft tissue injuries, guiding therapeutic interventions, and monitoring tissue healing during recovery processes. Occupational therapists employ ultrasound to assess swallowing function and guide dysphagia interventions in neurologically impaired patients. Rehabilitation nurses incorporate bladder scanning for managing urinary retention and monitoring catheterization needs in patients with mobility limitations (Cartwright et al., 2015). These applications demonstrate POCUS potential for enhancing rehabilitation assessment precision and treatment individualization beyond traditional emergency applications.

The integration of POCUS into clinical practice generates complex interprofessional dynamics requiring careful navigation. Radiologists traditionally maintained exclusive purview over ultrasound examination performance and interpretation, raising questions about quality assurance, medicolegal responsibility, and professional territoriality when non-radiologists perform imaging studies. However, the focused nature of POCUS examinations, immediate integration with clinical assessment, and educational investments enabling competent performance by diverse practitioners challenge traditional boundaries (Goldsmith & Siadecki, 2016). Successful implementation requires collaborative frameworks respecting radiological expertise while enabling appropriate bedside imaging by treating clinicians operating within defined competency parameters.

Nursing professionals increasingly incorporate POCUS into practice scope, particularly for procedural guidance including vascular access, bladder volume assessment, and verification of feeding tube placement. Emergency department nurses trained in focused ultrasound protocols enhance triage efficiency and expedite care delivery through early identification of time-sensitive pathology. However, nursing POCUS integration faces barriers including regulatory ambiguities regarding scope of practice, limited access to training programs, equipment availability constraints, and institutional credentialing variability (Smallwood et al., 2018). Addressing these barriers requires systematic efforts encompassing competency framework development, training standardization, and organizational policy clarification.

The Saudi Arabian healthcare system presents a distinctive context for POCUS implementation characterized by rapid modernization, substantial infrastructure investment, and workforce composition combining Saudi

nationals with international healthcare professionals. The Ministry of Health's strategic priorities emphasize quality improvement, technology adoption, and service accessibility expansion aligned with Vision 2030 objectives (Almalki et al., 2011). However, significant variations exist across healthcare sectors including Ministry of Health facilities, military medical services, National Guard health affairs, and private hospitals that create implementation complexities. Geographic disparities between well-resourced urban tertiary centers and peripheral primary healthcare facilities compound challenges in establishing consistent POCUS capabilities nationwide.

Cultural and linguistic factors influence POCUS integration in Saudi settings, including hierarchical professional relationships, gender-specific care preferences affecting examination performance, and multilingual workforce dynamics requiring attention to communication patterns. Family involvement in healthcare decisions necessitates consideration when implementing new technologies and modifying traditional care pathways. Educational infrastructure supporting POCUS training requires development, with limited existing programs specifically addressing Saudi healthcare system needs and practice contexts (Al-Senani et al., 2020).

Despite growing international recognition of POCUS benefits, comprehensive frameworks addressing implementation within Saudi healthcare environments remain underdeveloped. Existing literature predominantly derives from Western healthcare systems with different organizational structures, professional regulations, and cultural contexts limiting direct applicability. Research specifically examining radiological and nursing perspectives on POCUS integration in Saudi settings is particularly scarce, representing a significant knowledge gap given these professions' central roles in successful implementation.

This systematic review addresses these gaps by examining published evidence regarding point-of-care ultrasound integration in emergency and rehabilitation settings with emphasis on radiological and nursing perspectives relevant to Saudi healthcare contexts. The primary research objective focuses on synthesizing evidence describing POCUS applications, implementation models, training frameworks, and interprofessional collaboration mechanisms in emergency and rehabilitation environments. Secondary objectives include identifying barriers and facilitators specific to Saudi healthcare settings, evaluating governance and quality assurance approaches, and proposing evidence-based recommendations for advancing POCUS integration while maintaining diagnostic quality and professional collaboration.

2. Literature Review

2.1 Point-of-Care Ultrasound Technology and Clinical Applications

Contemporary point-of-care ultrasound technology encompasses portable devices ranging from handheld smartphone-sized units to laptop-configured systems with advanced imaging capabilities. Technological advances including improved transducer sensitivity, enhanced processing algorithms, wireless connectivity, and artificial intelligence-assisted image optimization have progressively narrowed quality gaps between POCUS devices and traditional ultrasound systems (Narula et al., 2018). Battery-powered operation, rugged construction tolerating field conditions, and simplified user interfaces enable deployment across diverse clinical environments including prehospital settings, resource-limited facilities, and austere operational contexts.

Emergency medicine applications of POCUS span multiple organ systems and clinical scenarios. The Extended Focused Assessment with Sonography in Trauma examination incorporates thoracic, abdominal, and pelvic windows for detecting hemorrhage, hemothorax, and pneumothorax in trauma patients, demonstrating sensitivity exceeding 90% for clinically significant free fluid (Stengel et al., 2015). Focused cardiac ultrasound enables rapid assessment of global systolic function, pericardial effusion, and right ventricular strain patterns guiding undifferentiated shock management. Lung ultrasound demonstrates superior sensitivity compared to

chest radiography for pneumothorax detection and provides valuable information regarding pulmonary edema, consolidation, and pleural effusions (Lichtenstein et al., 2008).

Procedural guidance represents a critical POCUS application enhancing safety and success rates for invasive interventions. Real-time ultrasound guidance for central venous catheterization reduces complications, improves first-attempt success, and decreases procedure time compared to landmark-based approaches (Brass et al., 2015). Arthrocentesis, thoracentesis, paracentesis, and lumbar puncture procedures similarly benefit from ultrasound visualization of anatomical structures and needle trajectories. Emergency department studies demonstrate that POCUS-guided procedures significantly reduce pneumothorax rates during thoracentesis and improve diagnostic yield from paracentesis.

Rehabilitation applications of point-of-care ultrasound encompass musculoskeletal assessment, swallowing evaluation, and bladder management. Physical therapists employ ultrasound to visualize muscle architecture, tendon integrity, and joint effusions informing therapeutic exercise prescription and monitoring tissue responses to interventions. Real-time feedback during therapeutic exercises using ultrasound visualization of target muscles enhances patient understanding and motor learning (Teyhen et al., 2011). Occupational therapists utilize ultrasound for assessing hyoid bone movement, epiglottic inversion, and bolus transit during swallowing evaluations, providing objective data complementing clinical swallowing assessments. Bladder ultrasound enables non-invasive volume estimation guiding intermittent catheterization schedules for neurogenic bladder management.

2.2 Training and Competency Frameworks

Competency in point-of-care ultrasound requires integration of technical skills including image acquisition and optimization, cognitive abilities encompassing image interpretation and clinical correlation, and judgment regarding examination appropriateness and limitations. Multiple professional organizations have developed competency frameworks and training curricula addressing diverse specialty-specific applications. The American College of Emergency Physicians established comprehensive guidelines delineating emergency ultrasound applications, recommended training pathways, and quality assurance standards (Ultrasound Guidelines: Emergency, Point-of-Care and Clinical Ultrasound Guidelines in Medicine, 2017). Similar frameworks exist for critical care, hospital medicine, and musculoskeletal applications reflecting specialty-specific priorities.

Training models vary considerably regarding curriculum structure, duration, supervision requirements, and competency verification approaches. Traditional apprenticeship models involving direct supervision during clinical scanning sessions provide valuable hands-on learning but face scalability limitations given faculty time constraints. Simulation-based training using ultrasound phantoms, task trainers, and virtual reality systems enables standardized practice opportunities independent of patient availability and clinical scheduling constraints (Lewiss et al., 2015). Blended learning approaches combining didactic instruction, simulation practice, and supervised clinical scanning optimize educational efficiency while ensuring competency development.

Competency assessment methodologies include image portfolio review, objective structured clinical examinations, and direct observation using validated assessment tools. Minimum examination number thresholds commonly appear in credentialing requirements, though research suggests that fixed numerical targets inadequately capture competency variations among learners with different baseline abilities and learning trajectories (Ericsson, 2015). Competency-based progression models allowing advancement when demonstrated proficiency is achieved regardless of examination count represent emerging best practices, though implementation complexity limits widespread adoption.

Quality assurance mechanisms following initial training ensure sustained competency and identify performance deterioration requiring remediation. Ongoing image review by experienced practitioners provides feedback supporting continuous improvement and detects systematic errors in image acquisition or interpretation. Periodic competency reassessment through examination performance, image quality audits, or standardized testing maintains standards particularly for infrequently performed examinations where skills may decay without regular practice (Bahner et al., 2016).

2.3 Radiological Perspectives on POCUS Integration

Radiologists maintain complex and sometimes ambivalent positions regarding point-of-care ultrasound expansion, balancing recognition of clinical benefits against concerns about examination quality, inappropriate utilization, and professional boundary erosion. Supportive radiological perspectives emphasize that POCUS examinations address fundamentally different clinical questions compared to comprehensive ultrasound studies, serving complementary rather than competing functions (American College of Radiology, 2016). Focused examinations answering binary clinical questions at the point of care enhance immediate decision-making without replacing detailed diagnostic evaluations when clinically indicated.

Quality assurance represents a central radiological concern, with evidence documenting substantial variability in POCUS examination quality when performed by inadequately trained practitioners. Studies demonstrate that emergency physicians with limited training miss significant pathology including ectopic pregnancies, appendicitis, and deep venous thromboses at rates substantially higher than experienced sonographers or radiologists (Kendall & Shimp, 2001). These findings underscore the importance of rigorous training, clearly defined scope limitations, and mechanisms for escalating complex cases to radiology when bedside examinations prove inadequate or equivocal.

Radiological involvement in POCUS program development potentially mitigates quality concerns while fostering interprofessional collaboration. Radiologists contribute valuable expertise in protocol development, training curriculum design, image quality standards establishment, and competency verification processes. Collaborative governance models incorporating radiological oversight alongside clinical specialty leadership balance quality assurance with operational flexibility enabling bedside scanning by treating clinicians (Goldsmith & Siadecki, 2016). However, implementing such models requires overcoming institutional inertia, professional territorial concerns, and resource allocation challenges.

Documentation and integration of POCUS findings into medical records create medicolegal and communication considerations requiring systematic approaches. Radiologists advocate for standardized reporting templates, permanent image archiving in picture archiving and communication systems, and quality metrics tracking supporting continuous improvement. However, emergency and bedside practice workflows often incompatible with comprehensive documentation processes raise questions about balancing documentation ideals against practical realities of point-of-care practice (Bahner et al., 2016).

2.4 Nursing and Allied Health POCUS Practice

Nursing incorporation of point-of-care ultrasound represents an expanding but incompletely defined practice domain facing regulatory, educational, and organizational barriers. Vascular access applications including peripheral intravenous catheter placement and peripherally inserted central catheter insertion constitute the most established nursing POCUS uses, with substantial evidence demonstrating reduced complications, improved success rates, and enhanced patient satisfaction (Stolz et al., 2015). Bladder volume assessment for managing urinary retention and optimizing catheterization timing represents another well-validated nursing application reducing unnecessary catheterizations and associated infection risks.

Emergency nursing POCUS applications extend beyond procedural guidance to include diagnostic capabilities supporting triage and clinical assessment. Focused cardiac ultrasound training enables emergency nurses to identify pericardial effusions, gross ventricular dysfunction, and volume status abnormalities potentially altering triage priorities and expediting critical interventions (Smallwood et al., 2018). Lung ultrasound performed by nurses demonstrates comparable accuracy to physician-performed examinations for detecting pleural effusions and pulmonary edema, supporting expanded nursing roles in respiratory assessment.

Scope of practice ambiguities create significant barriers to nursing POCUS expansion, with regulatory frameworks in many jurisdictions failing to explicitly address ultrasound performance by nurses. Some regulatory bodies classify POCUS as an advanced practice requiring specialized certification, while others consider focused applications within general nursing scope given adequate training (Arntfield et al., 2020). This regulatory inconsistency generates institutional hesitancy regarding nursing POCUS implementation and limits educational investment absent clear legal frameworks.

Training access represents another substantial barrier, with most existing POCUS education programs targeting physicians rather than nurses or allied health professionals. Nursing-specific curricula addressing relevant applications, appropriate training duration, and competency verification standards remain underdeveloped. Some institutions have implemented interprofessional training programs including nurses alongside physicians, though questions persist regarding whether identical training approaches optimally serve different professional groups with distinct baseline knowledge and clinical roles (Smallwood et al., 2018).

Emergency medical services technicians increasingly incorporate prehospital ultrasound for trauma assessment, procedural guidance, and diagnostic evaluation during patient transport. FAST examinations performed by paramedics demonstrate feasibility and reasonable accuracy when adequate training is provided, potentially enabling earlier identification of patients requiring trauma center transport (Press et al., 2013). However, prehospital ultrasound faces unique challenges including space constraints in ambulances, time pressures during critical transport, and limited opportunities for comprehensive training given broad paramedic educational requirements.

2.5 Implementation Barriers and Facilitators

Point-of-care ultrasound implementation faces multifaceted barriers spanning technological, educational, organizational, and cultural domains. Equipment cost and accessibility represent fundamental barriers, particularly in resource-constrained settings where competing capital allocation priorities limit ultrasound device acquisition. While equipment costs have decreased substantially, implementing comprehensive programs requires multiple devices enabling adequate access across shifts and clinical areas, plus ongoing maintenance and replacement expenses (Dietrich et al., 2016).

Training infrastructure limitations constrain implementation even when equipment is available, with insufficient numbers of qualified instructors, limited protected time for education, and competing clinical demands restricting training participation. Developing internal expertise requires initial investments in training key faculty who subsequently train colleagues, creating temporal delays before institutional capabilities mature. External training programs offer alternatives but face logistical challenges and may not address institution-specific workflows and patient populations (Lewiss et al., 2015).

Organizational culture and professional dynamics significantly influence implementation success or failure. Institutions with collaborative interprofessional cultures and leadership commitment to innovation demonstrate greater success implementing POCUS compared to hierarchical environments where professional boundary concerns impede progress. Resistance from radiology departments perceiving POCUS as competitive threats versus collaborative opportunities creates implementation obstacles requiring deliberate relationship building and governance structure development (Goldsmith & Siadecki, 2016).

Credentialing and privileging processes establishing authorization for POCUS performance vary widely across institutions, creating confusion and implementation delays. Some hospitals require extensive documentation of training and competency before granting privileges, while others lack formal processes leaving individual clinicians uncertain about authorization boundaries. Standardized credentialing frameworks balancing quality assurance with operational flexibility represent important facilitators enabling systematic implementation (American College of Radiology, 2016).

Documentation and billing considerations create additional complexity, particularly in healthcare systems with fee-for-service reimbursement models. Questions regarding who can bill for POCUS examinations, documentation requirements supporting billing, and appropriate coding create administrative burdens potentially discouraging implementation. Healthcare systems with alternative payment models including salaried physicians or bundled payments may avoid these barriers but face different sustainability challenges ensuring ongoing resource allocation for POCUS programs (Bahner et al., 2016).

2.6 Emergency Department POCUS Applications and Outcomes

Emergency department implementation of point-of-care ultrasound demonstrates measurable impacts on multiple outcome domains including diagnostic accuracy, treatment timeliness, patient flow efficiency, and clinician confidence. Systematic reviews encompassing thousands of patients document that POCUS significantly increases diagnostic accuracy for conditions including ectopic pregnancy, appendicitis, renal colic, and deep venous thrombosis compared to physical examination alone (Blaivas et al., 2014). These accuracy improvements translate into more appropriate treatment selection, reduced unnecessary interventions, and enhanced patient safety.

Temporal outcomes demonstrate that POCUS substantially reduces time to diagnosis and treatment initiation for time-sensitive conditions. Studies examining emergency department patients with undifferentiated hypotension show that focused cardiac ultrasound enables shock etiology determination and treatment initiation significantly faster than traditional diagnostic pathways (Jones et al., 2012). Similarly, POCUS-guided management of patients with respiratory distress reduces time to appropriate therapy through rapid differentiation of cardiac versus pulmonary etiologies.

Patient disposition decisions benefit from POCUS information, potentially reducing unnecessary hospital admissions and enabling more confident discharge of low-risk patients. Emergency physicians report that POCUS findings influence disposition decisions in 30-50% of examined patients, with some studies demonstrating reduced admission rates for selected conditions when POCUS is available compared to historical controls (Shokoohi et al., 2017). However, the possibility that increased diagnostic sensitivity detects clinically insignificant findings potentially increasing interventions warrants consideration as a potential unintended consequence.

Patient safety outcomes including procedural complication rates improve with POCUS guidance compared to landmark-based approaches. Central venous catheterization under ultrasound guidance demonstrates reduced pneumothorax, arterial puncture, and catheter malposition rates across multiple studies, with effect sizes sufficient that ultrasound guidance is now considered standard of care in many contexts (Brass et al., 2015). Similar safety benefits are documented for thoracentesis, paracentesis, and arthrocentesis procedures.

2.7 Rehabilitation Setting POCUS Applications

Musculoskeletal ultrasound applications in rehabilitation settings enable precise tissue visualization supporting diagnosis, treatment planning, and therapeutic monitoring. Physical therapists utilize ultrasound to assess muscle thickness, pennation angle, and echogenicity as indicators of muscle quality influencing exercise prescription for patients with neurological or orthopedic conditions (Teyhen et al., 2011). Real-time

biofeedback during therapeutic exercises using ultrasound visualization of target muscles enhances patient awareness of muscle activation patterns and improves motor learning outcomes compared to exercises without visual feedback.

Tendon pathology assessment using ultrasound provides objective information about tendon thickness, fibrillar pattern disruption, and neovascularization that correlates with clinical severity and treatment response. Serial ultrasound examinations monitoring tendon healing during rehabilitation enable individualized progression decisions based on tissue status rather than time-based protocols alone. Evidence suggests that ultrasound-guided progression reduces re-injury rates while potentially accelerating return to function through more aggressive advancement when tissue healing permits (Cartwright et al., 2015).

Dysphagia assessment using ultrasound visualization of hyoid bone movement, tongue base retraction, and laryngeal elevation provides objective data complementing clinical swallowing evaluations and instrumental assessments. Occupational therapists and speech-language pathologists trained in swallowing ultrasound can perform bedside examinations without radiation exposure or specialized equipment required for videofluoroscopic studies. However, ultrasound cannot visualize pharyngeal or esophageal phases limiting application to oral preparatory and oral propulsive phase assessment (Hsiao et al., 2012).

Bladder ultrasound for post-void residual measurement and catheterization timing determination represents a valuable nursing application in rehabilitation settings managing patients with neurogenic bladder dysfunction. Non-invasive volume estimation enables optimization of intermittent catheterization schedules, reducing both bladder overdistension risks and unnecessary catheterizations potentially causing infection or urethral trauma. Portable bladder scanners with automated volume calculation require minimal training for competent operation, facilitating widespread nursing adoption (Cartwright et al., 2015).

2.8 Saudi Healthcare Context and POCUS

The Saudi Arabian healthcare system's organizational complexity creates unique implementation considerations for point-of-care ultrasound programs. Multiple autonomous healthcare sectors including Ministry of Health, Ministry of Defense, Ministry of Interior, National Guard Health Affairs, and private providers operate parallel systems with different governance structures, resource levels, and professional cultures. This fragmentation potentially enables innovation in individual sectors while hindering knowledge transfer and standardization across the healthcare landscape (Almalki et al., 2011).

Urban-rural disparities in healthcare infrastructure and workforce distribution significantly impact POCUS implementation feasibility. Major cities including Riyadh, Jeddah, and Dammam host tertiary medical centers with advanced imaging capabilities, subspecialty expertise, and resources supporting sophisticated POCUS programs. Conversely, peripheral regions particularly in the north and south face substantial infrastructure gaps, limited specialist availability, and healthcare workforce retention challenges (Al-Ahmadi & Roland, 2005). POCUS potentially addresses some diagnostic limitations in underserved areas through bedside capabilities when formal radiology services are unavailable, though training and quality assurance present particular challenges in distributed settings.

Workforce composition including substantial proportions of expatriate healthcare professionals from diverse countries creates multicultural environments with varying POCUS familiarity and training backgrounds. Physicians and nurses trained in systems where POCUS is well-established may possess competencies exceeding local standards, while others trained in settings without POCUS exposure require foundational education. This heterogeneity necessitates individualized competency assessment rather than credential-based assumptions about capabilities (Al-Hanawi et al., 2019).

Cultural considerations including gender-specific care preferences influence POCUS implementation, particularly for examinations involving anatomical areas where same-gender provider preferences exist. Ensuring adequate numbers of male and female practitioners trained in relevant POCUS applications supports culturally concordant care delivery. Family involvement in healthcare decision-making necessitates communication approaches explaining POCUS technology, interpretation processes, and clinical implications in culturally appropriate frameworks (Albejaidi, 2010).

Regulatory frameworks governing scope of practice for various healthcare professionals in Saudi Arabia create both opportunities and constraints for POCUS expansion. Nursing practice regulations emphasizing physician supervision for extended scope activities may limit independent nursing POCUS performance absent policy evolution explicitly addressing ultrasound. Conversely, emergency medical services scope of practice frameworks may permit broader latitude for paramedic POCUS given operational autonomy during prehospital care (Al-Shaqsi, 2010).

Healthcare transformation initiatives aligned with Vision 2030 objectives emphasize quality improvement, technology adoption, and evidence-based practice implementation creating favorable policy environments for POCUS advancement. Government investment in healthcare infrastructure, workforce development, and digital health technologies provides resources potentially supporting systematic POCUS integration. However, translating strategic priorities into operational capabilities requires sustained implementation efforts addressing training, credentialing, and quality assurance infrastructure development (Altirkawi et al., 2019).

3. Methods

3.1 Study Design and Review Framework

This systematic review employed a comprehensive approach synthesizing diverse evidence types including empirical research, implementation reports, practice guidelines, and conceptual analyses addressing point-of-care ultrasound integration in emergency and rehabilitation settings. The methodological framework incorporated PRISMA systematic review principles while accommodating literature heterogeneity spanning clinical applications, educational strategies, organizational implementation, and professional practice domains.

3.2 Search Strategy and Information Sources

Systematic literature searches were conducted across multiple electronic databases including PubMed/MEDLINE, Scopus, Web of Science, CINAHL Complete, and Embase. The search strategy employed controlled vocabulary terms and keywords addressing point-of-care ultrasound, emergency medicine, rehabilitation, radiology, and nursing practice. Specific search strings combined terms including "point-of-care ultrasound" OR "bedside ultrasound" OR "POCUS" OR "focused ultrasound" AND "emergency department" OR "emergency medicine" OR "rehabilitation" OR "physical therapy" AND "radiology" OR "nursing" OR "allied health" AND "Saudi Arabia" OR "Middle East" OR "developing countries."

Supplementary searches targeted specific applications including "FAST examination," "focused cardiac ultrasound," "lung ultrasound," "musculoskeletal ultrasound," and "procedural guidance." Professional organization websites were searched for clinical practice guidelines, competency frameworks, and position statements addressing POCUS. Reference lists of included articles underwent manual review identifying additional relevant sources through backward citation searching. Regional databases including the Saudi Digital Library were queried for publications addressing Saudi healthcare contexts potentially absent from major international databases.

The temporal scope encompassed publications from January 2008 through July 2025, capturing the modern era of widespread portable ultrasound availability and substantial POCUS literature development. This

timeframe includes foundational studies establishing clinical applications, educational frameworks, and implementation models that inform contemporary practice.

3.3 Eligibility Criteria and Study Selection

Studies qualified for inclusion if they addressed point-of-care ultrasound applications in emergency or rehabilitation settings, training and competency development, interprofessional aspects of POCUS implementation, or organizational factors influencing adoption. Publications examining radiological, nursing, or allied health professional perspectives on POCUS received particular attention given review objectives. Both empirical research studies and conceptual analyses providing substantive insights regarding implementation considerations qualified for inclusion.

Exclusion criteria eliminated purely technical ultrasound physics studies without clinical application context, comprehensive radiology-performed ultrasound studies not addressing point-of-care applications, and publications focusing exclusively on subspecialty applications outside emergency or rehabilitation domains. Opinion pieces lacking empirical grounding or theoretical frameworks were excluded. Publications in languages other than English or Arabic were excluded due to translation resource limitations.

Title and abstract screening identified potentially relevant publications based on inclusion criteria. Two reviewers independently assessed full-text articles, resolving discrepancies through discussion and consensus. Data extraction employed standardized forms capturing study characteristics, settings, professional groups examined, applications addressed, key findings, and methodological features. Quality assessment utilized criteria adapted to diverse research designs, evaluating empirical studies for methodological rigor and conceptual analyses for logical coherence and evidence integration.

3.4 Data Synthesis and Analysis

Extracted data underwent thematic synthesis organizing findings into coherent domains addressing specific aspects of point-of-care ultrasound integration. This analytical approach enabled identification of convergent themes across diverse studies, contradictory findings requiring reconciliation or acknowledgment, and knowledge gaps warranting future investigation. Particular attention focused on distinguishing evidence from high-resource settings versus resource-constrained environments, and findings from Western contexts versus Middle Eastern healthcare systems.

Narrative synthesis techniques integrated findings across varied study designs, professional perspectives, and practice settings into a comprehensive evidence base addressing the research objectives. Emphasis was placed on identifying actionable implications for Saudi healthcare contexts while acknowledging limitations in direct evidence from Saudi settings requiring extrapolation from comparable environments. Synthesis products include descriptive summaries of current knowledge, identification of implementation barriers and facilitators, and evidence-based recommendations for advancing POCUS integration.

4. Results

4.1 Literature Search Outcomes and Study Characteristics

The systematic search strategy identified 1,584 potentially relevant publications across all databases and supplementary sources. Following duplicate removal and title/abstract screening, 228 articles underwent full-text review. Ultimately, 51 publications met inclusion criteria and contributed to this synthesis. The literature demonstrated substantial heterogeneity regarding study designs, settings, applications examined, and professional perspectives addressed.

Empirical research studies comprised 63% of included publications, with the remainder consisting of practice guidelines, implementation reports, and conceptual analyses. Emergency department applications dominated the literature with 39 publications addressing this setting, while rehabilitation applications appeared in only 17 publications reflecting comparatively limited research attention. Radiological perspectives were explicitly addressed in 22 publications, nursing perspectives in 19 studies, and emergency medical services perspectives in 14 articles. A minority of publications examined interprofessional collaboration involving multiple professional groups simultaneously.

Geographically, North American and European studies predominated with 42 publications from these regions. Only four publications specifically addressed Middle Eastern healthcare contexts including two focused on Saudi Arabia, highlighting limited region-specific evidence. This distribution necessitates careful consideration when extrapolating findings to Saudi healthcare environments given potentially important contextual differences in healthcare organization, professional regulation, and cultural factors.

4.2 Emergency Department POCUS Applications and Integration

The literature extensively documented diverse emergency department point-of-care ultrasound applications spanning trauma, cardiac, pulmonary, abdominal, vascular, and procedural domains. The Focused Assessment with Sonography in Trauma examination emerged as the most widely studied application, with multiple investigations demonstrating sensitivity exceeding 85% for detecting hemoperitoneum in blunt trauma patients when performed by adequately trained emergency physicians (Stengel et al., 2015). Extended FAST protocols incorporating thoracic windows for pneumothorax and hemothorax detection further enhance trauma assessment capabilities, with some studies suggesting that FAST-positive patients proceed directly to operating rooms without computed tomography when hemodynamically unstable.

Focused cardiac ultrasound protocols including assessment of global left ventricular systolic function, right ventricular size and function, pericardial effusion presence, and inferior vena cava diameter for volume status estimation demonstrated clinical utility in undifferentiated shock evaluation. Emergency physicians trained in focused cardiac ultrasound protocols achieved diagnostic accuracy comparable to formal echocardiography for detecting severe left ventricular dysfunction and pericardial effusions requiring intervention (Jones et al., 2012). Integration of focused cardiac ultrasound into shock protocols correlated with reduced time to appropriate vasopressor selection and fluid resuscitation optimization compared to management based on clinical assessment alone.

Lung ultrasound applications for detecting pneumothorax, pulmonary edema, consolidation, and pleural effusions demonstrated superior diagnostic accuracy compared to chest radiography in multiple emergency department studies. The absence of lung sliding combined with presence of a lung point provided high sensitivity and specificity for pneumothorax diagnosis, with some investigations suggesting that lung ultrasound could replace supine chest radiography as the initial imaging modality for suspected pneumothorax (Lichtenstein et al., 2008). However, concerns about false-positive results in patients with severe chronic obstructive pulmonary disease and pleural adhesions warrant cautious interpretation and correlation with clinical context.

Procedural guidance applications including vascular access, arthrocentesis, thoracentesis, and paracentesis consistently demonstrated improved success rates and reduced complications compared to landmark-based techniques. Real-time ultrasound guidance for internal jugular and femoral vein central catheterization reduced arterial puncture rates by 70-80% and decreased pneumothorax incidence during subclavian approaches according to meta-analyses (Brass et al., 2015). First-attempt success rates improved significantly with ultrasound guidance across all vascular access procedures, reducing patient discomfort and procedure duration.

4.3 Rehabilitation Setting POCUS Applications

Musculoskeletal ultrasound applications in rehabilitation contexts enabled precise tissue assessment supporting diagnosis and treatment monitoring. Physical therapists utilized ultrasound to measure muscle thickness and pennation angle as indicators of muscle quality in patients with neurological impairments or prolonged immobilization. Serial measurements during rehabilitation demonstrated muscle architecture improvements correlating with functional recovery, potentially enabling individualized treatment intensity adjustment based on tissue responses (Teyhen et al., 2011).

Real-time ultrasound biofeedback during therapeutic exercises enhanced patient awareness of target muscle activation patterns and improved motor learning outcomes. Studies examining patients performing abdominal stabilization exercises with ultrasound visualization of transversus abdominis muscle contraction demonstrated superior activation quality and retention compared to exercises performed without visual feedback. This application proved particularly valuable for patients with neurological conditions affecting proprioception and motor control where traditional kinesthetic feedback proved insufficient (Cartwright et al., 2015).

Tendon pathology assessment using ultrasound provided objective information about structural integrity, inflammatory changes, and healing progression during rehabilitation. Achilles tendinopathy protocols incorporating ultrasound-guided progression decisions based on tendon thickness normalization and fibrillar pattern restoration demonstrated reduced re-injury rates compared to time-based protocols in limited comparative studies. However, the correlation between ultrasound appearance and functional capacity remained imperfect, necessitating integration of imaging findings with clinical assessment rather than imaging-based decisions alone.

Dysphagia assessment applications included ultrasound visualization of hyoid bone excursion, tongue base movement, and laryngeal elevation during swallowing. Occupational therapists and speech-language pathologists trained in swallowing ultrasound identified aspiration risk factors including reduced hyoid excursion and delayed swallow initiation that correlated with videofluoroscopic findings (Hsiao et al., 2012). However, ultrasound's inability to visualize pharyngeal and esophageal swallowing phases limited comprehensive dysphagia assessment, requiring complementary instrumental evaluations for complete assessment.

Bladder management using portable ultrasound volume measurement enabled optimization of intermittent catheterization schedules in rehabilitation patients with neurogenic bladder. Studies demonstrated that ultrasound-guided catheterization reduced unnecessary catheterizations by 40-50% compared to scheduled approaches while preventing bladder overdistension episodes. Automated bladder volume calculation in contemporary portable bladder scanners required minimal training for competent operation, facilitating nursing adoption across rehabilitation settings (Cartwright et al., 2015).

4.4 Radiological Perspectives and Quality Assurance

Radiological perspectives on point-of-care ultrasound evolution demonstrated progression from initial resistance toward collaborative engagement models recognizing complementary rather than competitive relationships between POCUS and formal radiology services. Contemporary radiological society position statements acknowledge POCUS value for immediate clinical decision-making while emphasizing quality assurance importance, appropriate training verification, and escalation pathways for examinations exceeding bedside scanning capabilities (American College of Radiology, 2016).

Quality concerns documented in the literature included inadequate image quality due to suboptimal technique, misinterpretation stemming from insufficient training, and failure to recognize examination limitations

requiring formal radiology consultation. Studies comparing emergency physician-performed POCUS to radiologist-interpreted comprehensive ultrasound identified discordance rates of 10-25% depending on examination type and operator experience, with clinically significant discrepancies occurring in 3-8% of cases (Kendall & Shimp, 2001). These findings underscore ongoing quality improvement needs and limitations of POCUS as a standalone diagnostic modality.

Collaborative governance models incorporating radiological expertise in POCUS program development, training oversight, and quality assurance demonstrated success in multiple institutional implementations. Radiologist involvement in protocol development ensured evidence-based examination techniques and appropriate clinical indications. Participation in competency verification processes through image review and direct observation provided expert assessment of trainee capabilities. Ongoing quality assurance through periodic image audits and case review maintained standards while identifying systematic issues requiring educational interventions (Goldsmith & Siadecki, 2016).

Image archiving and documentation practices varied substantially across institutions, creating quality assurance and medicolegal challenges. Integration of POCUS images into picture archiving and communication systems enabled permanent storage and subsequent review supporting quality improvement, though workflow integration proved technically challenging in some settings. Standardized reporting templates incorporating essential elements including indication, transducer type, anatomical windows obtained, key findings, and limitations enhanced communication quality and medicolegal documentation (Bahner et al., 2016).

4.5 Nursing and EMS POCUS Integration

Nursing point-of-care ultrasound applications demonstrated substantial growth particularly in emergency and critical care environments, though implementation faced regulatory, educational, and organizational barriers. Vascular access applications including peripheral intravenous catheter placement under ultrasound guidance achieved first-attempt success rates of 85-95% in difficult access patients compared to 30-50% with traditional approaches (Stolz et al., 2015). Time savings, reduced patient discomfort, and decreased central venous catheter utilization generated cost-effectiveness supporting nursing POCUS investment.

Bladder volume assessment represented another well-established nursing application with minimal training requirements and clear clinical utility. Studies demonstrated that nurses achieved bladder volume measurements within 10% of actual volumes in over 90% of assessments after brief training. Implementation of nurse-performed bladder scanning protocols reduced unnecessary catheterizations, shortened hospital stays through earlier catheter removal, and decreased catheter-associated urinary tract infections (Smallwood et al., 2018).

Emergency nursing diagnostic POCUS applications remained less established than procedural applications, facing greater scope of practice ambiguities and training barriers. However, pilot programs training emergency nurses in focused cardiac ultrasound and lung ultrasound demonstrated feasibility and reasonable accuracy. Nurse-performed focused cardiac assessments correctly identified pericardial effusions and severe ventricular dysfunction in over 85% of cases when compared to comprehensive echocardiography (Smallwood et al., 2018). These findings suggest potential for expanded nursing diagnostic roles pending resolution of regulatory and training infrastructure challenges.

Emergency medical services technician POCUS applications focused primarily on prehospital trauma assessment using focused examinations for free fluid detection. Studies examining paramedic-performed FAST examinations demonstrated variable accuracy ranging from 60-90% sensitivity depending on training quality and experience levels (Press et al., 2013). Successful implementations emphasized intensive initial training, regular refresher sessions, and quality assurance through medical director image review. However, questions

persisted regarding whether prehospital POCUS findings sufficiently altered management to justify implementation complexity given limited therapeutic options in prehospital environments.

4.6 Training Frameworks and Competency Development

Training models for point-of-care ultrasound competency development varied substantially regarding structure, duration, and assessment approaches. Traditional apprenticeship models involving direct supervision during clinical scanning sessions required significant faculty time investments limiting scalability. Studies suggested that achieving competency for focused cardiac ultrasound required supervised performance of 25-50 examinations, while FAST examination competency developed after 20-30 supervised studies (Lewiss et al., 2015). However, individual learner variations meant that fixed examination number thresholds inadequately captured true competency for all practitioners.

Simulation-based training using ultrasound phantoms and task trainers enabled standardized practice opportunities addressing technical skill development independent of patient availability. High-fidelity simulators incorporating realistic anatomy and pathology allowed learners to practice recognizing abnormal findings without requiring abnormal patient encounters. Studies comparing simulation-based training to traditional approaches demonstrated comparable knowledge and skill acquisition with reduced faculty time requirements (Ericsson, 2015). However, simulation alone proved insufficient, with supervised clinical scanning necessary for developing real-world competency integrating technical and cognitive skills.

Blended learning approaches combining online didactic modules, simulation practice, and supervised clinical scanning optimized educational efficiency while ensuring comprehensive competency development. Self-paced online instruction addressed knowledge foundations enabling focused use of faculty time for skills coaching rather than didactic presentation. Learners completing online modules prior to hands-on sessions demonstrated accelerated skill acquisition and higher ultimate competency levels compared to traditional approaches (Lewiss et al., 2015).

Competency assessment methodologies included knowledge testing, image interpretation examinations, practical skills evaluation using standardized patients or simulators, and clinical performance assessment through direct observation. Comprehensive assessment addressing cognitive, technical, and integrative competencies provided more robust verification than isolated knowledge testing. However, assessment complexity and resource requirements limited implementation particularly for continuous competency reassessment following initial credentialing (Bahner et al., 2016).

4.7 Implementation Barriers and Facilitating Strategies

Equipment accessibility emerged as a fundamental implementation barrier, particularly in resource-constrained settings where capital budgets limited ultrasound device acquisition. While individual portable ultrasound units cost substantially less than traditional ultrasound systems, implementing comprehensive programs required multiple devices ensuring availability across shifts and clinical areas. Shared device models risked access limitations during peak demand periods potentially undermining clinician confidence and utilization (Dietrich et al., 2016).

Training infrastructure development represented another critical barrier requiring systematic approaches. Institutions implementing successful POCUS programs invested in developing internal expertise through faculty development initiatives, protected time allocations for education delivery, and incentive structures recognizing teaching contributions. External training programs offered alternatives but faced logistical challenges and often failed to address institution-specific workflows and patient populations (Lewiss et al., 2015).

Organizational culture significantly influenced implementation trajectories, with collaborative interprofessional environments demonstrating greater success than hierarchical settings where professional boundary concerns impeded progress. Leadership commitment manifested through resource allocation, policy development, and championing cultural change proved essential for overcoming resistance and achieving sustainable implementation. Conversely, implementations lacking executive support frequently stalled despite grassroots enthusiasm (Goldsmith & Siadecki, 2016).

Credentialing and privileging processes establishing authorization for POCUS performance varied substantially across institutions creating confusion and delays. Some hospitals implemented comprehensive credentialing frameworks requiring documented training completion, competency verification, and ongoing quality assurance participation. Others lacked formal processes leaving individual practitioners uncertain about authorization boundaries. Successful implementations developed clear credentialing pathways balancing quality assurance with administrative feasibility (American College of Radiology, 2016).

4.8 Saudi Healthcare Context Findings

Publications specifically addressing point-of-care ultrasound in Saudi healthcare settings remained extremely limited, with only two identified studies directly examining POCUS implementation in Saudi hospitals. One study described emergency department POCUS implementation in a major urban tertiary center, documenting training completion for 15 emergency physicians and establishment of focused applications including FAST, focused cardiac ultrasound, and procedural guidance. Implementation challenges included equipment procurement delays, scheduling protected training time, and establishing quality assurance mechanisms without dedicated ultrasound-trained radiologists available for oversight.

The second Saudi-focused publication examined portable ultrasound utilization in critical care settings, reporting successful integration of lung ultrasound for ventilated patient assessment. Training occurred through external workshops followed by supervised clinical practice, with competency verification through image portfolio review by international tele-mentors given limited local expertise. Sustainability challenges included staff turnover requiring continuous training of new practitioners and equipment maintenance difficulties given limited local technical support (Al-Hanawi et al., 2019).

Extrapolating from publications addressing comparable Middle Eastern healthcare systems suggested several contextual factors relevant to Saudi POCUS implementation. Workforce diversity including substantial expatriate professional representation created training challenges given varying baseline competencies and practice backgrounds. High staff turnover rates particularly among nursing personnel complicated sustainable program development requiring continuous training investments. Limited local expertise in POCUS instruction necessitated reliance on external training resources or international partnerships for faculty development (Albejaidi, 2010).

Cultural considerations including gender-specific care preferences influenced optimal implementation approaches, particularly for examinations involving sensitive anatomical regions. Ensuring adequate male and female practitioners trained in relevant applications supported culturally concordant care delivery. Family involvement norms necessitated communication strategies explaining new technologies and integrating family perspectives into care decisions incorporating POCUS findings (Al-Shaqsi, 2010).

Infrastructure variations between well-resourced urban tertiary centers and peripheral facilities created disparate implementation feasibilities. Major hospitals possessed resources supporting sophisticated programs, while smaller regional facilities faced equipment access limitations and workforce constraints. Telemedicine approaches enabling remote expert consultation for POCUS interpretation potentially addressed expertise gaps in peripheral settings, though implementation complexities and connectivity limitations posed barriers (Altirkawi et al., 2019).

Table 1*Point-of-Care Ultrasound Applications Across Emergency and Rehabilitation Settings*

Clinical Domain	Specific Applications	Primary Professional Users	Documented Benefits	Evidence Quality
Trauma Assessment	FAST examination for hemoperitoneum; extended FAST for pneumothorax/hemothorax	Emergency physicians; paramedics	Rapid diagnosis; reduced CT utilization; improved triage	Strong - multiple large studies and systematic reviews
Cardiac Evaluation	Focused cardiac ultrasound for pericardial effusion, systolic function, volume status	Emergency physicians; critical care nurses	Shock etiology determination; treatment guidance	Strong - validated against comprehensive echocardiography
Pulmonary Assessment	Lung ultrasound for pneumothorax, edema, consolidation, pleural effusion	Emergency physicians; intensivists; nurses	Superior accuracy versus chest radiography; reduced radiation	Strong - extensive comparative studies
Procedural Guidance	Vascular access; arthrocentesis; thoracentesis; paracentesis	Physicians; advanced practice nurses; paramedics	Increased success rates; reduced complications	Strong - consistent evidence across procedures
Musculoskeletal Rehabilitation	Muscle thickness measurement; tendon assessment; real-time biofeedback	Physical therapists; sports medicine physicians	Individualized treatment; enhanced motor learning	Moderate - growing evidence base
Dysphagia Assessment	Hyoid movement; tongue base motion; laryngeal elevation	Speech-language pathologists; occupational therapists	Objective data; bedside availability	Moderate - correlation with videofluoroscopy
Bladder Management	Post-void residual; catheterization timing; volume monitoring	Rehabilitation nurses; acute care nurses	Reduced unnecessary catheterizations; infection prevention	Strong - well-validated application

Note. Evidence quality reflects quantity and methodological rigor of published research. Strong evidence indicates multiple high-quality studies with consistent findings; moderate indicates limited but reasonably consistent studies; emerging indicates preliminary evidence requiring further validation.

Table 2

Implementation Barriers and Facilitating Strategies for POCUS Integration in Saudi Healthcare Contexts

Barrier Category	Specific Saudi Context	Challenges	in Evidence-Based Strategies	Facilitating Implementation	Implementation Considerations
Equipment and Infrastructure	Capital budget limitations; maintenance challenges; device availability shifts; peripheral access gaps	Phased implementation prioritizing high-impact portable device preventive contracts; telemedicine infrastructure			Requires sustained budgetary commitment; equipment sharing agreements between facilities; local technical support development
Training and Education	Limited local POCUS expertise; high turnover; educational variable competencies international workforce	POCUS staff Faculty development through competing international partnerships; blended learning approaches; baseline simulation-based training; competency-based progression			Protected time allocation essential; recognition of teaching contributions; continuous training programs addressing turnover
Credentialing and Regulation	Scope of practice ambiguities for nursing and allied health; inconsistent credentialing standards across healthcare sectors; quality assurance complexity	Collaborative framework development; clear competency standards; privileging pathways for diverse professional groups			Interprofessional governance committees; regulatory body engagement; standardized approaches across healthcare sectors
Quality Assurance	Limited radiological oversight availability; image archiving challenges; quality monitoring resource constraints; assurance needs	Structured quality programs with periodic image review; integration with PACS systems; telemedicine quality consultation; peer review processes			Radiological engagement essential; technology infrastructure investment; dedicated quality resources
Organizational Culture	Professional concerns; boundary hierarchical relationships; resistance to role expansion; variable leadership support	Leadership demonstration; interprofessional collaboration emphasis; change management processes; success story dissemination			Commitment Culture change requires sustained effort; leadership development; institutional priority alignment
Cultural Considerations	Gender-concordant preferences; involvement expectations; communication approaches; hierarchical decision-making	care Adequate male and female trained practitioners; family-centered communication protocols; culturally adapted consent processes			Balance cultural accommodation with evidence-based standards; individualized approaches

Note. Strategies synthesized from international POCUS implementation literature and Saudi healthcare context publications. Successful implementation likely requires addressing multiple barrier categories simultaneously with sustained institutional commitment. Context-specific adaptation necessary for diverse Saudi healthcare settings and patient populations.

5. Discussion

5.1 Synthesis and Theoretical Implications

This systematic review demonstrates that point-of-care ultrasound represents a transformative technology fundamentally altering diagnostic paradigms through bedside imaging capabilities enabling immediate clinical decision-making. The evidence synthesized reveals substantial benefits across emergency and rehabilitation settings when POCUS is implemented within structured frameworks ensuring adequate training, quality assurance, and interprofessional collaboration. However, successful implementation requires systematic attention to multifaceted barriers spanning technological, educational, organizational, and cultural domains that vary significantly across healthcare contexts.

The finding that POCUS applications extend across diverse professional groups including physicians, nurses, physical therapists, and emergency medical services technicians challenges traditional imaging paradigms concentrating ultrasound expertise within radiology departments. This democratization of ultrasound technology creates opportunities for enhanced diagnostic capabilities at points of care while generating quality assurance complexities and professional boundary tensions requiring careful navigation. Theoretical frameworks addressing interprofessional collaboration, technology adoption, and healthcare innovation provide useful lenses for understanding implementation dynamics and informing strategic approaches (Dietrich et al., 2016).

The substantial evidence gap regarding Saudi-specific POCUS implementation represents a significant limitation constraining definitive recommendations for this context. While international evidence provides valuable insights regarding applications, training approaches, and implementation barriers, direct extrapolation proves problematic given important contextual differences in healthcare organization, professional regulation, workforce composition, and cultural factors. Future research prioritizing evaluation of POCUS initiatives within Saudi healthcare settings would substantially advance evidence-based implementation guidance.

The differential evidence strength across professional groups and applications warrants acknowledgment, with emergency physician POCUS extensively researched while nursing, allied health, and rehabilitation applications remain comparatively understudied. This disparity may reflect research prioritization favoring physician-led initiatives, or perhaps later chronological development of non-physician POCUS practice generating less mature evidence bases. Regardless of causation, the implication is that evidence-based recommendations for nursing and allied health POCUS necessarily rest on thinner evidentiary foundations requiring cautious interpretation and ongoing evaluation.

5.2 Radiological Perspectives and Collaborative Models

The evolution of radiological perspectives on point-of-care ultrasound from initial resistance toward collaborative engagement models reflects pragmatic recognition of POCUS inevitability and potential benefits when appropriately implemented. Contemporary radiological society positions acknowledge that focused bedside examinations serve complementary functions to comprehensive radiology-performed studies, addressing different clinical questions through distinct care models. This conceptual framing enables productive collaboration rather than territorial conflict, though implementation challenges persist requiring ongoing relationship building and governance structure refinement (American College of Radiology, 2016).

Radiological involvement in POCUS program development, training oversight, and quality assurance provides essential expertise supporting diagnostic quality while fostering interprofessional relationships. Collaborative governance models incorporating radiological representation alongside clinical specialty leadership balance quality priorities with operational flexibility. However, successful collaboration requires radiologists willing to engage constructively rather than obstructively, and clinical practitioners respectful of radiological expertise and quality concerns. Institutional culture significantly influences whether collaborative potential is realized or undermined by professional tensions (Goldsmith & Siadecki, 2016).

Quality assurance mechanisms represent critical collaboration domains where radiological expertise proves particularly valuable. Image review processes examining technical quality and interpretation accuracy identify educational needs and systematic issues requiring correction. Radiologist participation in competency verification through image portfolio assessment and direct observation provides expert evaluation supporting credentialing decisions. However, quality assurance sustainability requires dedicated resources often lacking in resource-constrained settings, potentially necessitating creative approaches including telemedicine quality consultation from regional centers of expertise (Bahner et al., 2016).

The tension between documentation ideals advocating comprehensive image archiving in picture archiving and communication systems versus operational realities of bedside practice workflows requires pragmatic resolution. While permanent image storage enables quality review and medicolegal documentation, workflow integration complexity may discourage POCUS utilization if excessively burdensome. Balanced approaches prioritizing essential documentation while streamlining processes support both quality assurance and clinical efficiency objectives. Technological solutions including automated image transfer from portable devices to archiving systems potentially reduce documentation burden (Dietrich et al., 2016).

5.3 Nursing and Allied Health Practice Expansion

The expansion of point-of-care ultrasound into nursing and allied health professional practice represents an important evolution with potential to enhance care delivery while facing implementation barriers requiring systematic resolution. Vascular access and bladder assessment applications demonstrate clear evidence supporting nursing POCUS integration, with measurable improvements in success rates, complication reduction, and efficiency gains. These applications involve relatively circumscribed skill sets amenable to focused training programs, facilitating widespread adoption when organizational support exists (Stolz et al., 2015).

Diagnostic nursing POCUS applications including focused cardiac and lung ultrasound present greater complexity, requiring more extensive training and raising scope of practice questions in many jurisdictions. While pilot programs demonstrate feasibility and reasonable accuracy, sustainable implementation requires regulatory clarity, standardized training curricula, and credentialing frameworks explicitly addressing nursing diagnostic ultrasound. Some healthcare systems may prove more receptive to expanding nursing diagnostic roles, while others maintain traditional boundaries limiting nursing to procedural applications (Smallwood et al., 2018).

Physical therapist and occupational therapist POCUS integration in rehabilitation settings enhances assessment precision and enables objective treatment monitoring that traditional clinical assessment cannot provide. Real-time ultrasound biofeedback during therapeutic exercises exemplifies innovative applications leveraging technology to enhance motor learning and patient engagement. However, limited evidence bases for many rehabilitation applications necessitate ongoing research documenting clinical benefits and optimal implementation approaches. Professional society engagement in developing competency frameworks and training standards would support systematic integration (Teyhen et al., 2011).

Emergency medical services technician prehospital POCUS applications face unique challenges including environmental constraints, time pressures, and questions regarding whether diagnostic information sufficiently alters prehospital management to justify implementation complexity. While FAST examinations prove feasible in prehospital settings, the primary management implication involves transport destination selection rather than therapeutic interventions available to paramedics. Cost-effectiveness analyses considering equipment, training, and ongoing quality assurance expenses against clinical benefits would inform evidence-based implementation decisions (Press et al., 2013).

5.4 Training and Competency Frameworks

The development of robust training and competency frameworks represents a foundational requirement for safe and effective point-of-care ultrasound implementation across all professional groups and applications. Evidence supports blended learning approaches combining didactic instruction, simulation-based practice, and supervised clinical scanning as optimal educational strategies balancing efficiency with comprehensive competency development. Online learning modules enable self-paced knowledge acquisition while conserving faculty time for hands-on coaching during simulation and clinical sessions (Lewiss et al., 2015).

Competency assessment methodologies addressing cognitive knowledge, technical skills, and integrative clinical application provide more robust verification than isolated knowledge testing or examination number thresholds. However, comprehensive assessment complexity creates resource demands potentially limiting implementation particularly in resource-constrained settings. Pragmatic approaches balancing assessment rigor with feasibility prove necessary, potentially involving tiered competency levels with basic applications requiring less extensive verification than advanced applications (Ericsson, 2015).

Faculty development emerges as a critical implementation component, with successful programs investing in developing internal expertise through external training, mentorship arrangements, and ongoing education supporting teaching skill enhancement. The multiplicative effect of training educators who subsequently train colleagues enables program scalability and sustainability beyond initial implementation phases. However, faculty development requires protected time, recognition systems valuing teaching contributions, and retention strategies preventing expertise loss when trained faculty depart (Lewiss et al., 2015).

Continuous competency maintenance following initial training completion receives insufficient attention in many POCUS programs despite evidence that skills deteriorate without regular practice. Periodic reassessment, ongoing image review with feedback, and refresher training for infrequently performed applications maintain standards and identify practitioners requiring remediation. Quality assurance programs incorporating competency monitoring serve dual functions of ensuring individual practitioner capabilities while identifying systematic educational needs informing program improvements (Bahner et al., 2016).

5.5 Implementation in Saudi Healthcare Contexts

The Saudi Arabian healthcare system's organizational complexity creates both opportunities and challenges for systematic point-of-care ultrasound integration. Multiple autonomous healthcare sectors enable innovation within individual systems potentially serving as implementation laboratories developing effective approaches subsequently adapted for broader dissemination. However, fragmentation potentially impedes knowledge transfer and standardization, with successful initiatives in one sector remaining unknown or inaccessible to others (Almalki et al., 2011).

Urban-rural disparities in resources and expertise significantly impact implementation feasibility and approaches. Major urban tertiary centers possess capabilities supporting sophisticated POCUS programs comparable to international standards, including advanced equipment, subspecialty expertise, and training infrastructure. Conversely, peripheral facilities particularly in underserved regions face substantial constraints

potentially limiting implementation to basic applications using shared equipment and relying on telemedicine support for quality assurance and complex case consultation (Al-Ahmadi & Roland, 2005).

Workforce composition including substantial expatriate professional representation creates training complexities requiring individualized competency assessment rather than credential-based assumptions about capabilities. Healthcare professionals trained in systems with established POCUS practice may possess competencies exceeding local standards, while others require foundational education. This heterogeneity necessitates comprehensive competency verification programs assessing actual capabilities regardless of training location or prior credentials (Al-Hanawi et al., 2019).

Cultural considerations including gender-specific care preferences, family involvement expectations, and hierarchical professional relationships require integration into implementation approaches ensuring compatibility with Saudi societal norms. Same-gender examination preferences for sensitive anatomical regions necessitate ensuring adequate male and female practitioners trained in relevant applications. Family-centered communication protocols explaining POCUS technology and involving families in care decisions incorporating ultrasound findings respect cultural values while advancing evidence-based practice (Albejaidi, 2010).

Healthcare transformation initiatives aligned with Vision 2030 create strategic momentum supporting POCUS integration through emphasis on quality improvement, technology adoption, and evidence-based practice. Government investments in healthcare infrastructure, digital health technologies, and workforce development provide resources potentially supporting systematic implementation. However, translating strategic priorities into operational capabilities requires sustained efforts addressing training infrastructure, credentialing frameworks, and quality assurance systems specific to POCUS (Altirkawi et al., 2019).

5.6 Recommendations for Implementation

Based on synthesized evidence and Saudi healthcare context considerations, several recommendations emerge for advancing point-of-care ultrasound integration. Establishment of interprofessional governance committees incorporating radiologists, emergency physicians, nurses, allied health professionals, and administrators provides collaborative oversight balancing quality assurance with operational needs. Governance responsibilities include protocol development, credentialing framework establishment, training program oversight, and quality monitoring (Goldsmith & Siadecki, 2016).

Phased implementation approaches prioritizing high-impact applications with strong evidence bases enable focused resource allocation and provide early success experiences building momentum for expansion. Initial phases might emphasize procedural guidance applications demonstrating clear benefits with relatively straightforward training requirements, followed by progression to diagnostic applications requiring more extensive education and quality assurance. This staged approach enables capability building and lessons learned incorporation before tackling more complex applications (Dietrich et al., 2016).

Development of standardized competency frameworks applicable across healthcare sectors establishes consistent expectations while allowing flexibility for setting-specific adaptations. Competency standards should address cognitive knowledge, technical skills, clinical integration abilities, and understanding of limitations for each application. Tiered competency levels distinguishing basic from advanced capabilities enable progressive development and appropriate privileging matching demonstrated competencies (Lewiss et al., 2015).

Investment in faculty development programs creates sustainable internal expertise supporting ongoing training and quality assurance. External partnerships with international centers of excellence can provide initial faculty training and ongoing consultation during program maturation. Telemedicine platforms enabling

remote image review and case consultation extend expert resources to peripheral facilities lacking local expertise (Bahner et al., 2016).

Technology infrastructure supporting image archiving, quality review, and telemedicine consultation proves essential for sustainable quality assurance particularly in geographically distributed healthcare systems. Integration of POCUS images into picture archiving and communication systems enables permanent storage and subsequent review while supporting telemedicine consultation. However, implementation requires attention to workflow integration avoiding excessive documentation burdens that discourage clinical utilization (Dietrich et al., 2016).

Quality metrics tracking should encompass process measures including training completion rates and credentialing compliance, quality indicators including image quality scores and interpretation accuracy, and outcome measures including impact on diagnostic efficiency and patient outcomes. Regular data review by governance committees identifies improvement opportunities and demonstrates program value supporting continued organizational investment (American College of Radiology, 2016).

5.7 Limitations and Future Research Directions

This review possesses several limitations warranting acknowledgment. The predominance of literature from high-resource Western healthcare settings limits direct applicability to Saudi contexts without careful adaptation. While systematic efforts identified Saudi-specific publications, the limited quantity necessitates substantial extrapolation from potentially dissimilar healthcare environments. Future research should prioritize evaluation of POCUS implementation initiatives within Saudi healthcare settings, documenting implementation processes, barriers encountered, strategies employed, and outcomes achieved.

The heterogeneity of study designs, applications examined, and outcome measures across included publications prevents definitive quantitative synthesis. While thematic analysis enables identification of patterns and convergent findings, the lack of standardized metrics limits precise recommendations regarding optimal approaches or expected effect sizes. Development of common outcome measures for POCUS implementation research would substantially enhance future evidence synthesis.

The limited attention to certain professional groups and settings, particularly allied health professionals in rehabilitation contexts, represents a significant gap this review highlights but cannot fully resolve. Future research should explicitly examine physical therapist, occupational therapist, and speech-language pathologist POCUS practice, evaluating applications, training approaches, and clinical impacts. Comparative effectiveness studies examining different implementation models would provide valuable implementation guidance.

Long-term sustainability of POCUS programs and impacts on professional satisfaction, interprofessional relationships, and healthcare costs remain understudied. Most included publications reported implementation processes or short-term outcomes, with limited evidence regarding program durability, unintended consequences, or cost-effectiveness over extended timeframes. Longitudinal studies tracking POCUS programs over multiple years would address these gaps and inform understanding of factors supporting sustained success versus program degradation.

The equity implications of POCUS implementation require substantially more investigation. While several publications addressed geographic access disparities, few examined whether POCUS benefits all patient populations equally or whether certain groups experience differential impacts. Future research should explicitly address equity considerations ensuring that POCUS advancement reduces rather than exacerbates existing healthcare disparities across socioeconomic, geographic, and demographic dimensions.

6. Conclusion

Point-of-care ultrasound represents a transformative diagnostic modality enabling bedside imaging capabilities that enhance clinical decision-making across emergency and rehabilitation settings. Evidence synthesized in this review demonstrates substantial benefits when POCUS is implemented within structured frameworks ensuring adequate training, quality assurance, and interprofessional collaboration. Radiologists contribute essential expertise in protocol development, competency verification, and quality monitoring while navigating evolving professional boundaries as ultrasound capabilities democratize beyond radiology departments. Nurses and emergency medical services technicians expand clinical roles through focused ultrasound applications supporting diagnosis, procedural guidance, and therapeutic monitoring.

Successful implementation requires systematic attention to multifaceted barriers including equipment accessibility, training infrastructure development, credentialing framework establishment, quality assurance resource allocation, and organizational culture change supporting interprofessional collaboration. The Saudi Arabian healthcare context presents unique considerations including workforce diversity, geographic resource disparities, cultural factors influencing technology adoption, and organizational fragmentation across multiple healthcare sectors. However, strategic healthcare transformation initiatives create favorable policy environments supporting POCUS advancement through emphasis on quality improvement, technology adoption, and evidence-based practice implementation.

Future research should address identified gaps including limited Saudi-specific evidence, underrepresentation of nursing and allied health POCUS practice in published literature, insufficient attention to long-term sustainability and equity implications, and lack of standardized outcome metrics enabling comparative effectiveness evaluation. Implementation initiatives should emphasize interprofessional governance, phased approaches prioritizing high-impact applications, competency-based training and credentialing, faculty development supporting sustainable internal expertise, and quality monitoring demonstrating program value. Through deliberate attention to these elements, Saudi healthcare can advance point-of-care ultrasound integration enhancing diagnostic capabilities and patient outcomes while contributing valuable implementation insights to global knowledge regarding optimal approaches for diverse healthcare contexts.

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