POINT-OF-CARE ULTRASOUND IN INTERNAL MEDICINE: CLINICAL APPLICATIONS, HEMODYNAMIC ASSESSMENT, AND IMPLEMENTATION- A Review

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Abstract

Point-of-care ultrasound (POCUS) has become an essential tool in the internal medicine setting, enabling rapid, focused and non-invasive evaluation and supplementing traditional clinical evaluations. This narrative review aims to highlight the state-of-the-art knowledge on the clinical use, hemodynamic evaluation, implementation strategies and future perspectives of POCUS in internal medicine. The review highlights 4 high-yield applications: Lung ultrasound, Focused Cardiac Ultrasound (FoCUS), Rapid Ultrasound in Shock (RUSH) protocol, Venous Excess Ultrasound (VExUS) framework for venous congestion assessment. These methods allow clinician to quickly assess patients with dyspnea, hypotension, heart failure, acute kidney injury and undifferentiated shock, which increases the diagnostic accuracy, helps guide therapy, and simplifies serial bedside evaluation. It also addresses how POCUS has become more integrated into outpatient and ward-based settings, competency-based training, credentialing, documentation, quality assurance, and the new technologies, including handheld ultrasound, tele-ultrasound, and artificial intelligence image analysis. While highly operator dependent and not a replacement for comprehensive diagnostic

imaging, POCUS can be incorporated into the routine practice of internal medicine to help inform clinical decisions at the bedside, effectively using resources, and improving outcomes for the patient through timely and evidence-based decision-making.

Keywords: Point-of-Care Ultrasound (POCUS); Internal Medicine; Lung Ultrasound; Focused Cardiac Ultrasound (FoCUS); Rapid Ultrasound in Shock (RUSH); Venous Excess Ultrasound (VExUS)

Introduction

Point-of-care ultrasound (POCUS) has become one of the most important innovations of bedside assessment and has revolutionized the delivery of care in internal medicine by giving clinicians immediate, focused, and non-invasive diagnostic information (Chelikam et al., 2023). POCUS is different from traditional ultrasonography, which could be done in an imaging department by radiologists or sonographers (Leidi et al., 2020). It is used mainly to provide the answer to a specific clinical question which might occur during patient evaluation, enabling rapid decision making and timely therapeutic interventions. POCUS is NOT a substitute for full diagnostic imaging, but is used as a tool to complement the clinical history and physical exam, to enhance the diagnostic process and the management of the patient (Alfoti et al., 2024).

As ultrasound technology has evolved, more and more compact, portable, and handheld ultrasound devices that offer high quality imaging at relatively low cost have become available, leading to the widespread use of POCUS (Chelikam et al., 2023). These innovations have made ultrasound accessible to more than just emergency departments and intensive care units, and onto general internal medicine wards, outpatient clinics, and even the resource-challenged healthcare environments (Baribeau et al., 2020). The growing focus on timely diagnosis, cost effectiveness and patient-centred care in healthcare has created a great need for POCUS as a bedside tool that facilitates evidence-based clinical decision making and decreases reliance on more costly and time-consuming imaging modalities (Hsieh et al., 2022; Malik et al., 2021).

It is not uncommon for the internal medicine physician to see a patient with unexplained complaints like dyspnea, hypotension, chest pain, peripheral edema, abdominal pain, and acute kidney injury (Gri et al., 2023). These are often complex clinical situations where multiple potential diagnoses have to be quickly differentiated to begin treatment. POCUS is a technique that allows the clinician to quickly and efficiently conduct focused examinations of the lungs, heart, inferior vena cava, abdomen, and vascular system within minutes, thereby helping to limit differential diagnosis and influence clinical management in real time (Talle et al., 2022). This can also be repeated serially, enabling physicians to track disease progression and evaluate therapeutic response without irradiating the patient or sending him or her to an imaging area for repeated exams (Chandramohan et al., 2023).

Lung ultrasound has proven to be a highly sensitive and specific diagnostic modality in the assessment of pulmonary edema, pneumonia, pleural effusion and pneumothorax among the many applications of POCUS. In a similar fashion, focused cardiac ultrasound (FoCUS) can assess global left ventricular systolic function, right ventricular enlargement, pericardial effusion and gross valvular abnormalities, and is especially useful in the patient with heart failure, shock and unexplained

hypotension (Kameda et al., 2024). Bedside Lung Ultrasound in Emergency (BLUE) protocol and Rapid Ultrasound in Shock (RUSH) examination are structured bedside approaches that combine pulmonary, cardiac, vascular, and abdominal findings for the critically ill patient (Lau & See, 2022). A novel approach to systemically venous congestion grading and fluid management, namely "Venous Excess Ultrasound" (VExUS) grading system, has come to the fore more recently, especially in the context of patients with acute kidney injury and decompensated HF (Sartini et al., 2024).

POCUS is not just for diagnosis, but is also a critical assistant in procedural guidance for internal medicine. Procedures guided by ultrasound, like central venous catheterization, thoracentesis and paracentesis, vascular access, etc., increase the safety of the procedure and increase the success rate due to the ability to visualize the anatomical structures directly and avoid procedure-related complications (Chelikam et al., 2023). In addition, serial bedside ultrasound can help evaluate volume status, cardiac function, and pulmonary congestion which can guide treatment decisions and reduce unnecessary invasive investigations.

Although it holds many benefits, there are still some challenges associated with implementing POCUS. Acquisition and interpretation of images are still very much operator dependent, and demand structured education, supervised training, competency assessment and ongoing quality assurance (Alfoti et al., 2024). The lack of uniformity of training, credentialing, image documentation, and governance continues to affect the uniformity and reliability of POCUS in healthcare facilities. Additionally, physicians need to be aware of the restrictions of focused ultrasound examination and know when to send patients for more in-depth imaging or refer them to a specialist to prevent diagnostic mistakes (Alfoti et al., 2024).

As more evidence emerges of its clinical utility, POCUS is growing in importance as an essential tool in contemporary internal medicine practice. The aim of this review is to give a broad overview of the main roles of point-of-care ultrasound in internal medicine, focusing on lung ultrasound, focused cardiac ultrasound, shock assessment, venous congestion assessment (VExUS), procedural guidance and outpatient applications (Adeniran et al., 2026). The review also covers the latest research on implementation strategies, physician training, credentialing, documentation standards, quality assurance, new technologies, and future research directions (Chelikam et al., 2023). This review aims to summarize the current literature and emphasize the growing importance of POCUS as a valuable, effective, and evidence-based bedside imaging tool that has the potential to increase diagnostic accuracy, facilitate clinical decision-making and to provide better patient care in a variety of internal medicine settings (Leidi et al., 2020).

Methods and Scope of This Review

This manuscript aims to review, in a focused way and according to the literature from the last 10 years, the current knowledge about point-of-care ultrasound (POCUS) in internal medicine, highlighting its diagnostic, hemodynamic and procedural applications in the clinical routine (Leidi et al., 2020). This review aimed to provide a summary of the existing data, discuss clinically relevant uses, and discuss practical implications for applying POCUS in inpatient and ambulatory internal medicine (Chelikam et al., 2023). This narrative review synthesizes the evidence from selected, key clinical guidelines, consensus statements, review articles, observational studies, and landmark research that have shaped the development of bedside ultrasound in internal medicine, rather than

relying on quantitative analysis of evidence from predetermined studies, as is typical with systematic reviews (Qaseem et al., 2021).

Peer-reviewed papers from well-known medical journals, professional society recommendations and evidence-based clinical practice guidelines were all reviewed. Specific focus was placed on the publications of various societies including the American College of Physicians (ACP), Society of Hospital Medicine (SHM), American College of Emergency Physicians (ACEP) and other international societies that have contributed to the evolution of POCUS education, competency standards and clinical use (Nickols & Douthit, 2026; Lau & See, 2022). Recent studies that assessed the diagnostic accuracy, clinical value and implementation of bedside ultrasound were also taken into account as a way of providing an up-to-date perspective of current practice.

This review narrowed its scope intentionally to four high yield domains which have shown significant clinical relevance to internal medicine doctors. They include lung ultrasound to diagnose and assess pulmonary edema, pneumonia, pleural effusion, and pneumothorax; focused cardiac ultrasound (FoCUS) to rapidly assess ventricular function, pericardial effusion, and right heart disease at the bedside; or ultrasound-based evaluation of undifferentiated shock using structured approaches such as the Rapid Ultrasound in Shock (RUSH) protocol; and assessment of systemic venous congestion using the Venous Excess Ultrasound (VExUS) framework (Fan et al., 2023; Maringelli et al., 2025; Muller et al., 2026). These applications have been chosen due to the high frequency of their occurrence and have demonstrated a high potential to enhance the confidence in diagnostic decisions and to support sequential patient monitoring and early decision making in the therapeutic pathway in general internal medicine practice.

Beyond clinical uses, this review explores key considerations in POCUS adoption that will be vital to the safe and effective use of POCUS in everyday practice. This includes competency-based training, documentation requirements, image archiving requirements, physician education and training, infection prevention, and quality assurance (Romero-González et al., 2023). POCUS is operator dependent and these governance elements are essential for standardizing image acquisition, interpretation and patient safety. Future research priorities, the role of artificial intelligence in image interpretation, handheld ultrasound technology and tele-ultrasound are also discussed to offer a wider context to the changing landscape of the use of POCUS in contemporary internal medicine (Recker et al., 2023; Frid et al., 2025).

The aim of this review is not to supplant in-depth evidence syntheses or formal imaging guidelines, but to offer a succinct and thorough overview to clinicians, educators and trainees of the most clinically relevant uses of POCUS. This review seeks to incorporate the best available evidence and implementation strategies and provide a foundation for the responsible use of bedside ultrasound as a valuable addition to the physical examination and patient-centered clinical care.

Core Principles of POCUS in Internal Medicine

Point of Care Ultrasound (POCUS) is a vital part of modern internal medicine, by giving the clinician rapid information at the bedside to augment the clinical exam. POCUS is a 'point of care' diagnostic ultrasound examination performed by the treating physician for limited diagnostic questions to address during patient evaluation, as opposed to a comprehensive examination performed by a

radiologist or cardiologist (Chelikam et al., 2023). Not to provide a thorough anatomical evaluation, but to give immediate information that is useful for diagnosis, therapeutic decision making and treatment response monitoring. Therefore, POCUS should be seen as a complement to the physical examination, and not as a substitute for formal imaging tests (Radonjić et al., 2022).

POCUS is a hypothesis-driven process that starts with the clinician having a clear clinical question derived from the history, symptoms, physical findings, and initial lab data. Combined with clinical judgement, doctors can quickly distinguish between common conditions such as pulmonary oedema and pneumonia, and quickly assess gross cardiac function, the volume status, or the cause of circulatory shock (LoPresti et al., 2019). Ultrasound can also be repeated many times without being harmful by radiation, making it an excellent means for tracking disease progression and evaluating therapeutic response, especially in patients being treated in a critical care setting.

The portability and accessibility of POCUS is one of the key benefits. Handheld ultrasound devices allow for fast assessment in emergency departments, hospital wards, outpatient clinics and in resource limited areas where access to a full imaging system might be delayed (Maw et al., 2020). Early diagnosis with POCUS can help minimise unnecessary investigations, shorten time to treatment, aid patient flow and improve overall clinical efficiencies.

While these benefits are apparent, POCUS is very operator reliant. Conditions such as examiner experience, probe selection, patient's body habitus, subcutaneous emphysema, bowel gas, and examination conditions affect image quality (Alfoti et al., 2024). Also, there are several sonographic features that are not specific (may occur in many other diseases) and should always be taken into consideration with clinical findings (Leidi et al., 2020). For instance, the measurement of the IVC can be normal in chronic right heart disease, and in patients who are mechanically vented, the measurement may not accurately reflect intravascular volume status, diffuse B lines can be seen in interstitial lung disease or viral pneumonia, and so on (Su et al., 2025).

Implementing POCUS, therefore, requires a structured training program, competency assessment, documentation, image archiving, and continuous quality assurance (Shah & Patel, 2023). Physicians are advised to be aware of the advantages and drawbacks of bedside ultrasound and to know when more in-depth echocardiographic, computed tomography or formal ultrasonography is necessary (Pandompatam, 2025). When used correctly in clinical practice, POCUS can increase confidence in the ability to diagnose, aid in evidence-based decision making, and assist with quality of patient-centered care in internal medicine (Osterwalder et al., 2023).

Major Clinical Applications

Point-of-care ultrasound (POCUS) is used in a variety of clinical situations in IM, allowing for rapid assessment at the bedside and effective decision making. The targeted use can help the physician assess a number of common medical conditions efficiently without delaying treatment. The most common applications are in lung ultrasound for the evaluation of respiratory disorders, Focused Cardiac Ultrasound (FoCUS) for cardiac evaluation, Rapid Ultrasound in Shock (RUSH) for circulatory shock, and Venous Excess Ultrasound (VExUS) for systemic venous congestion (Maw et al., 2020). These applications contribute to a better diagnosis, therapeutic decision-making and the ongoing monitoring of patients in both emergency and outpatient/ambulatory care.

Table 1. Core point-of-care ultrasound applications in internal medicine

Domain	Common Clinical Questions	Key Sonographic Findings	Clinical Significance
Lung Ultrasound	Pulmonary edema? Pneumonia? Pleural effusion? Pneumothorax?	A-lines, B-lines, lung sliding, consolidation, pleural effusion, lung point	Rapid bedside differentiation of common respiratory conditions and guidance of fluid management
Focused Cardiac Ultrasound (FoCUS)	Is ventricular function reduced? Is there right ventricular strain or pericardial effusion?	Qualitative LV systolic function, RV enlargement, pericardial effusion, tamponade physiology	Supports evaluation of heart failure, hypotension, dyspnea, and hemodynamic instability
Shock Assessment (RUSH Protocol)	What is the underlying cause of shock?	Cardiac function, IVC assessment, abdominal free fluid, aortic pathology, deep vein thrombosis	Facilitates rapid differentiation of cardiogenic, hypovolemic, obstructive, and distributive shock
Venous Congestion (VExUS)	Is systemic venous congestion contributing to acute kidney injury or fluid overload?	Dilated IVC with abnormal hepatic, portal, and intrarenal venous Doppler waveforms	Assesses organ congestion, guides decongestive therapy, and supports fluid management decisions

Lung Ultrasound

Point of care ultrasound (POCUS) is one of the most useful and well validated uses of point of care ultrasound (POCUS) in the internal medicine setting. LUS is highly accurate, readily available at the bedside, non-ionizing and provides an 'on-line' assessment of the patient with acute respiratory symptoms and has significantly enhanced the evaluation of these patients (Volpicelli et al., 2026). It is helpful in patients with acute dyspnea when distinguishing pulmonary edema from pneumonia, pleural effusion, pneumothorax, chronic obstructive pulmonary disease (COPD), and interstitial lung disease is difficult based on clinical exam and chest radiograph (Lo Cricchio et al., 2024). Many studies have shown that lung ultrasound has high sensitivity for a number of pulmonary diseases, with advantages over conventional chest radiography, increasingly playing an important role in clinical assessment at the bedside.

Lung ultrasound interpretation focuses on the assessment of the movement of the pleura and the typical ultrasound artefacts that occur at the pleura-lung interface. A normal aerated lung has a bright hyperechoic pleural line which shows a rhythmic movement of the lung during respiration (lung sliding) (Cid et al., 2020). A-lines are also called horizontal reverberation artifacts and represent normal air-filled lung tissue, and are usually seen in normal people or patients with obstructive

airway diseases like asthma and COPD. When lung sliding is preserved and A-lines are visible, pneumothorax is unlikely to be present at that site.

B-lines are vertical, hyperechoic reverberation artifacts that extend to the bottom of the ultrasound window without fading, whereas C-lines are hyperechoic, vertical lines that start at the pleural line that fade trailing toward the bottom of the ultrasound window (Rocca et al., 2023). Multiple bilateral B-lines are seen in the presence of increased extravascular lung water and are often seen with pulmonary edema caused by acute heart failure. B-lines are a good way of assessing pulmonary congestion and can be helpful in assessing response to diuretic treatment (Rice et al., 2021). B-lines are not specific to any disease, however, and can be seen in other interstitial/non-respiratory diseases such as pulmonary fibrosis, viral pneumonia, acute respiratory distress syndrome (ARDS). Thus, the ultrasound diagnosis should always be evaluated in the clinical setting.

Lung ultrasound is also very useful in the diagnosis of pneumonia. The sonographic features are usually B-lines visible in the focus or spots, subpleural consolidations, tissue-like hepatization of the lungs, dynamic air bronchograms and localized pleural irregularities. These findings are frequently identified before an abnormality is seen on chest radiography and allow for early diagnosis and the early institution of antimicrobial therapy (Abid et al., 2024). Likewise, pneumothorax can be easily detected as anechoic or hypoechoic fluid collection above the diaphragm, and the amount of fluid can be precisely estimated and reduce procedural complications by performing ultrasound-guided thoracentesis.

Pneumothorax is diagnosed by multiple characteristic sonographic findings. The absence of lung sliding, the disappearance of B-lines and the presence of the lung point (the zone between normal lung sliding and no sliding) is very suggestive of pneumothorax (Chelikam et al., 2023). In this regard, among the findings, the lung point is deemed to be very specific and can help the clinician confirm the diagnosis quickly, especially in the emergency and critical care sectors where rapid interventions may be required (Volpicelli et al., 2026).

There are a number of standardized scanning protocols designed to increase the consistency of diagnostics. One of the most widely used algorithms for the acutely ill patient with respiratory failure is the Bedside Lung Ultrasound in Emergency (BLUE) protocol (Tierney et al., 2023). The BLUE protocol allows for quick differentiation between cardiogenic pulmonary edema, pneumonia, pulmonary embolism, COPD, asthma and pneumothorax by combining lung ultrasound with focused cardiac ultrasound and venous assessment. This systematic approach increases diagnostic confidence, reduces time to definitive therapy and facilitates evidence based bedside decision making (Rocca et al., 2023).

Overall, lung ultrasound has been an indispensable part of the modern internal medicine due to its portability, reproductivity, diagnostic accuracy, and dynamic evaluation of lung pathology. In addition to clinical data, LUS is a highly valuable tool to aid in the assessment and treatment of patients with acute and chronic respiratory diseases when used by trained clinicians and when interpreted in conjunction with clinical data, and helps to avoid the use of more costly or time-consuming imaging modalities (Chelikam et al., 2023).

Focused Cardiac Ultrasound (FoCUS)

Focused Cardiac Ultrasound (FoCUS) is a goal directed application of point-of-care ultrasound (POCUS) which allows clinicians to perform a rapid bedside assessment of cardiac structure and function. FoCUS is not a full transthoracic echocardiogram, but is intended to provide answers to specific clinical questions (Koratala & Kazory, 2021). In the field of internal medicine its main applications are estimating global left ventricular (LV) systolic function, detecting right ventricular (RV) enlargement, assessing the size of inferior vena cava (IVC), and identifying signs of cardiac tamponade and gross hemodynamic dysfunction. FoCUS enables timely clinical decisions and early diagnosis since it brings information up to the bedside (Tarantini et al., 2025).

The standard four chambers of the heart view of the echocardiogram include the parasternal long-axis (PLAX), parasternal short axis (PSAX), apical four-chamber (A4C) and subcostal views. These imaging windows are combined to give qualitative data on ventricular size, myocardial contractility, chamber dimensions, pericardial fluid and gross structural abnormalities (Maheshwari & Dagor, 2024). FoCUS is not used for routine echocardiography but provides useful clinical information in addition to the clinical examination, blood pressure readings, electrocardiography, lung ultrasound findings and lab investigations.

FoCUS may be helpful in patients with hypotension, acute dyspnea, chest pain, or suspected heart failure. It is rapid in differentiating cardiogenic shock due to impaired myocardial contractility from the obstructive shock (such as cardiac tamponade or massive pulmonary embolus) and thus indicates the correct therapeutic approach in patients with circulatory shock (Luong et al., 2019). Severe LV dysfunction may signal the need to commence inotropic support, while detection of pericardial effusion with tamponade physiology will warrant immediate specialist intervention (Johri et al., 2023).

Serial FoCUS exams are also very helpful to track changes in cardiac function during hospitalization. Repeated bedside evaluations will be useful to assess response to IV fluids, vasopressors, inotropic agents and diuretics, and to optimize haemodynamic management (Yamada et al., 2022). FoCUS is an invaluable tool to increase diagnostic confidence, speed up clinical decision making at the bedside and optimize the management of critically ill patients in the inpatient and emergency room internal medicine settings when performed by trained physicians in the clinical context (Adeniran et al., 2026).

Shock Assessment and the RUSH Framework

Rapid Ultrasound in Shock (RUSH) is a point-of-care ultrasound (POCUS) approach that allows for a quick identification of the underlying cause of circulatory shock and allows for timely management. The protocol divides bedside assessment into three major areas: pump, tank, and pipes. The pump assesses left ventricular contractility, right ventricular enlargement, presence of pericardial effusion and cardiac tamponade (Stickles et al., 2019). The tank evaluates intravascular volume status by looking at the inferior vena cava (IVC), and for free fluid in the thoracic or abdominal cavity that can represent hemorrhage or significant fluid loss (Nguyen et al., 2024). The pipes examine the vascular system, looking for any bulging, or ruptures, of the abdominal aorta, and for deep vein thrombosis in the veins of the lower leg, a sign of possible pulmonary embolism (Chen et al., 2026).

The RUSH acronym helps the clinician quickly distinguish between the four main types of shock: cardiogenic, hypovolemic, obstructive and distributive (Kosiń et al., 2025). A combination of cardiac, vascular and volume evaluation at the bedside results in a significantly reduced differential diagnosis and facilitates early and cause-directed therapy (Su et al., 2025). RUSH has proven to be an excellent tool used to rapidly assess patients with undifferentiated hypotension in the ED, I.C.U. and medical wards. The RUSH protocol, with clinical findings, lab studies and other POCUS applications, results in improved hemodynamics management, overall patient outcomes and greater diagnostic accuracy, which in turn advances therapeutic decision-making. (Boella et al., 2025)

Venous Congestion and the VExUS Score

Venous congestion assessment is a major development of the bedside hemodynamic evaluation, and has moved the point of view from static evaluation of intravascular volume to dynamic assessment of organ congestion (Giangregorio et al., 2025). The use of the inferior vena cava (IVC) diameter and the change in IVC diameter during respiration has been traditionally used to estimate the volume status. IVC assessment has, however, a few limitations as it is affected by mechanical ventilation, elevated intra-abdominal pressure, obesity, right ventricular dysfunction and chronic pulmonary disease (Koratala et al., 2024). Therefore, isolated IVC measurements may not be a reliable indicator of systemic venous congestion or be useful for fluid management in the complex medical patient (Noor et al., 2025).

The Venous Excess Ultrasound (VExUS) grading system was created to offer a more powerful assessment of venous congestion, by incorporating IVC assessment with Doppler evaluation of the hepatic, portal and intrarenal veins (Bitar et al., 2025). This multiparametric approach allows the identification of abnormal venous flow patterns corresponding to increased right atrial pressure and venous return dysfunction. Increased severity of systemic venous congestion is accompanied by progressive Doppler abnormalities which could reflect inadequate perfusion of the organs (Leyba et al., 2024).

The clinical importance of VExUS is particularly evident in patients with acute kidney injury (AKI), decompensated heart failure, fluid overload, and diuretic resistance (Chandra et al., 2025). Even without the presence of overt hypovolemia, persistent venous congestion has been identified as an important factor in the deterioration of renal function. The VExUS score enables clinicians to identify early signs of congestion, thereby avoiding unnecessary fluid administration, optimizing diuretic therapy and individualizing hemodynamic management (Leyba et al., 2026; Biuzzi et al., 2026). The serial VExUS examinations also help to monitor response to treatment and the resolution of venous congestion over time (Chanda et al., 2026; Policastro, 2026). While further validation studies are currently being conducted, the VExUS model is a potential bedside tool to assess the cardiorenal interaction and aid evidence-based fluid therapy in internal medicine (Li et al., 2026; Patel et al., 2024).

Table 2. Practical comparison of major internal medicine POCUS protocols

Protocol	Primary purpose	Key views or measurements	Best use case
BLUE	Rapid diagnosis of	Lung zones, pleural	Acute respiratory

Protocol	Primary purpose	Key views or measurements	Best use case
	common causes of acute dyspnea	line, lung sliding, B-lines, pleural effusion, limited cardiac assessment	failure, pulmonary edema, pneumonia, pneumothorax
FoCUS	Focused bedside cardiac evaluation	Parasternal long-axis (PLAX), parasternal short-axis (PSAX), apical four-chamber (A4C), subcostal views	Heart failure, hypotension, chest pain, dyspnea, suspected pericardial effusion
RUSH	Rapid evaluation of undifferentiated shock	Assessment of pump (heart), tank (IVC and free fluid), and pipes (aorta and deep veins)	Cardiogenic, hypovolemic, obstructive, and distributive shock
VExUS	Assessment of systemic venous congestion	IVC diameter with hepatic, portal, and intrarenal venous Doppler	Acute kidney injury, fluid overload, decompensated heart failure, monitoring diuretic response

Outpatient and Ward-Based Internal Medicine

Point of care ultrasound (POCUS) has often traditionally been the domain of the emergency department and critical care, but has grown in the outpatient departments and general internal medicine wards over recent years (Martocchia et al., 2022). With new portable and handheld ultrasound equipment, physicians can bring imaging to the bedside to enhance the efficiency of diagnosis and aid rapid clinical decisions (Ranasinghe et al., 2024). In ambulatory care, POCUS can be used as an important tool to supplement history taking and physical examination, giving immediate information to help narrow down the differential diagnosis and aid further management.

Lung ultrasound is especially helpful in the assessment of patients with dyspnea, chronic cough, and patients with suspected pulmonary congestion. It helps to identify the early signs of pulmonary edema, pleural effusion, interstitial lung diseases, and pneumonia, which will help to assess the patient with chronic heart failure or respiratory disease (Cid et al., 2020). Focused cardiac ultrasound (FoCUS) can be used to help with this evaluation, and can be performed very quickly for assessment of global ventricular function, pericardial effusion, chamber enlargement, and gross valvular abnormalities (Haji-Hassan et al., 2023). Venous compression ultrasound can help diagnose deep vein thrombosis in selected patients and limited abdominal ultrasound can detect ascites, abdominal aortic aneurysm, urinary retention, hydronephrosis and pleural effusions.

In hospital wards, POCUS allows for repeated checks on the haemodynamic status, fluid responsiveness, pulmonary congestion and treatment outcomes, without repeated referrals for formal imaging. This is especially helpful in patients with acute kidney injury, heart failure, sepsis, and complex multisystem disease, as frequent assessment can help tailor therapy to patients (Noor et al.,

2025). In addition, ultrasound-guided bedside procedures (thoracentesis, paracentesis, and vascular access) increase the safety of and decrease the incidence of complications.

The use of POCUS in out-patient and ward-based care is particularly advantageous in healthcare environments where access to extensive imaging services is constrained or delayed (Lau & See, 2022). POCUS can help to decrease unnecessary referrals, streamline diagnostic pathways, and enable timely therapeutic interventions, which can lead to improved patient care and outcomes (Jarsania et al., 2025). To achieve this, however, it requires the standardized training, correct documentation, image archiving, and periodic quality assurance for the correct interpretation and safe clinical use.

Training, Credentialing, and Quality Assurance

Along with access to ultrasound equipment, the effective use of POCUS in internal medicine practice requires a detailed training, credentialing, and ongoing quality assurance (QA) program (LoPresti et al., 2019). POCUS is very operator dependent and requires physicians to become proficient in image acquisition, optimization, interpretation, and the incorporation of ultrasound findings into patient care before they can use these skills on their own and autonomously in patient management (Soni et al., 2019). It requires structured educational programs, including theory lessons, simulation-based learning, supervised bedside scanning and competency evaluation, to develop and maintain the skills.

There is a need to focus on both technical and clinical skills in training. Doctors not only learn the standard scanning procedures, but they also learn when it is appropriate, when it isn't, and when it has the potential to fail.Physicians not only learn the basics of the scanning procedures but also the indications, contraindications and potential problems of POCUS and when an extensive scan should be performed (Conner et al., 2025). Use of a logbook or electronic portfolio to record supervised examinations, image quality, and clinical interpretation allows students to have a record that shows progress during learning. Us ultrasound technology and clinical use continue to change, and periodic refresher courses and continuing medical education are other aids to keeping clinicians up to date (Waldman & Pino, 2024).

The “ownership” of devices and participation in short workshops should not determine credentialing, but rather competency demonstrated. Healthcare institutions should develop standardized credentialing processes that have a minimum number of scans required, in-person evaluation of practical skills, image review, and an assessment conducted by knowledgeable faculty (Waldman et al., 2025). This competency-based certification leads to uniform practice and improved patient safety.

Another key component of a sustainable POCUS program is quality assurance (QA). The frequent assessment of the ultrasound images and reports by experienced clinicians’ aids in the detection of the incorrect image interpretation, assures the technical standards of the images and reports, and supplies constructive feedback for continual enhancement (Phillips et al., 2024). All clinical notes should be standardized and should include clinical indication, examination technique, findings, interpretation and limitations during the acquisition of images. Internal archiving of images in institutional databases helps with peer review, quality improvement programs, research and the documentation for medico-legal matters (Carroll, 2024; Amaral et al., 2020).

Infection prevention also needs to be taken into account, especially where ultrasound equipment is used in various clinical areas. Appropriate cleaning and disinfection of probes, cables, and touch surfaces after examination help to prevent healthcare-associated infections (Fox et al., 2020). Lastly, there should be governance policies agreed upon by institutions regarding the extent and type of POCUS examinations, acceptance of referral to full imaging, reporting standards, and integration of ultrasound information into electronic medical record (Phillips et al., 2024). Together, these measures provide for the safe, consistent, and effective implementation of POCUS, and for the delivery of high-quality patient care (Smalley et al., 2023).

Table 3. Core implementation requirements for an internal medicine POCUS program

Domain	Minimum standard	Why it matters
Training	Structured education with supervised scanning, competency assessment, and documented logbook	Develops technical skills, improves diagnostic accuracy, and minimizes operator-related errors
Credentialing	Competency-based certification with objective assessment and periodic re-evaluation	Ensures standardized practice, professional accountability, and patient safety
Documentation	Standardized report including indication, examination technique, findings, interpretation, and limitations	Facilitates clinical communication, continuity of care, quality improvement, and medico-legal documentation
Image Archiving	Secure storage of representative still images and video clips within institutional systems	Supports peer review, quality assurance, education, audit, and future clinical reference
Quality Assurance (QA)	Regular expert review of examinations, performance feedback, and continuing competency assessment	Maintains diagnostic consistency, identifies errors, and promotes continuous professional development

Emerging Directions

Point-of-care ultrasound (POCUS) is an ever-changing modality that is rapidly evolving in terms of technological advancements and clinical use, and will continue to play an important role in internal medicine in the future. A major innovation is the use of handheld ultrasound devices, which are portable, inexpensive, and provide high-quality imaging (Deivayanai et al., 2025). These small systems can be used in a hospital ward, outpatient clinic, community health facility, and in areas where there is no healthcare facility for the first time, allowing patients to be managed appropriately and timely, and improving access to diagnostic imaging (Ashby, 2022).

The use of tele-ultrasound and distance mentoring is another promising development. Experienced sonographers or specialists can assist clinicians with ultrasound examinations in remote locations by transmitting images in real-time and providing guidance (Adams et al., 2021). This method improves

the training process, allows for standardized scanning techniques, and creates access to specialized knowledge and experience, especially in low-resource health care settings where formal ultrasound services might not be available (Britton et al., 2019).

The use of artificial intelligence (AI) in the future is also foreseen to have a growing importance in POCUS. Computer-based software with AI capabilities can help the clinician by automatically localizing landmarks, optimizing the image, determining and recognizing the standard imaging views, and giving preliminary measurements of cardiac function or an abnormality in the lungs (Salerno et al., 2020). These technologies can be useful for enhancing workflow efficiency and decrease operator variability, but should not be used as an alternative to clinical judgment and physician expertise (Recker et al., 2022).

Future studies need to go beyond the measurement of diagnostic accuracy to look at patient-centred outcomes such as reduction in morbidity and mortality, hospital stay, health care costs and the number of unnecessary imaging investigations (Anderson & Theophanous, 2025). In addition to this, there is a need for large multicenter studies to create standardized competency frameworks, validate emerging ultrasound protocols and understand the long-term effects of POCUS on clinical decision making and healthcare delivery (Kariman et al., 2025). The integration of innovation and the use of high-quality education, quality assurance and evidence-based practice will be critical as technology continues to progress to ensure safe and effective use of POCUS throughout all aspects of internal medicine (Lobo et al., 2024).

Table 4. Emerging Trends and Future Directions of Point-of-Care Ultrasound (POCUS) in Internal Medicine

Emerging Trend	Description	Potential Benefits	Current Challenges
Handheld Ultrasound Devices	Portable, lightweight ultrasound systems that enable bedside imaging across diverse clinical settings.	Improved accessibility, rapid diagnosis, lower equipment costs, and increased use in outpatient and rural healthcare.	Variable image quality, battery limitations, and the need for adequate user training.
Artificial Intelligence (AI)-Assisted POCUS	AI algorithms assist with image acquisition, view recognition, automated measurements, and quality assessment.	Reduces operator variability, shortens examination time, enhances diagnostic confidence, and supports novice users.	Limited validation across diverse patient populations, regulatory concerns, and dependence on high-quality datasets.
Tele-Ultrasound and Remote Mentorship	Real-time transmission of ultrasound images for expert guidance and interpretation from remote locations.	Expands access to specialist expertise, improves education, and supports healthcare delivery in underserved	Internet connectivity requirements, data security, and implementation costs.

		regions.	
Competency-Based Digital Training	Integration of simulation, online learning platforms, virtual reality, and digital assessment tools for ultrasound education.	Standardizes training, enhances learning efficiency, and facilitates continuous professional development.	Requires institutional investment and standardized competency frameworks.
Advanced Hemodynamic Monitoring	Expansion of protocols such as FoCUS and VExUS for comprehensive bedside cardiovascular and volume assessment.	Enables individualized fluid management, early recognition of congestion, and improved monitoring of critically ill patients.	Requires advanced Doppler skills and further multicenter validation studies.
Integration with Electronic Health Records (EHRs)	Automated storage of ultrasound images and structured reports within electronic medical records.	Improves documentation, continuity of care, quality assurance, research, and clinical auditing.	Interoperability issues, storage requirements, and cybersecurity concerns.
Future Research Priorities	Large multicenter clinical studies evaluating the long-term impact of POCUS on patient outcomes and healthcare systems.	Establishes evidence-based guidelines, improves standardization, and supports widespread adoption in internal medicine.	Need for high-quality prospective studies and standardized outcome measures.

Conclusion

Point-of-care ultrasound (POCUS) is an essential part of the internal medicine practice of today, providing rapid, non-invasive, and bedside diagnostic information that complements the traditional clinical assessment. It has greatly improved the assessment of patients with dyspnea, circulatory shock, heart failure and systemic venous congestion, with a variety of applications such as lung ultrasound, Focused Cardiac Ultrasound (FoCUS), the Rapid Ultrasound in Shock (RUSH) protocol, and the Venous Excess Ultrasound (VExUS) framework. These targeted ultrasound methods allow physicians to make timely, evidence-based clinical decisions, track treatment results, and lead to safer, image-guided procedures with a reduction of unnecessary delays in diagnosis and treatment.

ROUTINE clinical use of POCUS will require structured training of physicians, competency based credentialing, standardizing documentation, archiving of images and ongoing quality assurance. Handheld ultrasound devices, AI-aided image analysis and tele-ultrasound technologies are still in

development, and the use of POCUS is projected to grow even more in various inpatient, outpatient, and resource-constrained healthcare environments. However, bedside ultrasound should always be used in addition to and not in place of full anatomic assessment with comprehensive diagnostic imaging when detailed anatomical assessment is needed. Further studies aimed at patient-centered outcomes, cost-effectiveness, and the lack of a standardized educational program will add to the value of POCUS as an integral component of the physical examination and a vital and valuable resource for patient-centered, high-quality internal medicine practice.

References

Abid, I., Qureshi, N., Lategan, N., Williams, S., & Shahid, S. (2024). Point-of-care lung ultrasound in detecting pneumonia: A systematic review. *Canadian Journal of Respiratory Therapy: CJRT= Revue Canadienne De La Therapie Respiratoire: RCTR*, *60*, 37.

Adams, S. J., Burbridge, B., Obaid, H., Stoneham, G., Babyn, P., & Mendez, I. (2021). Telerobotic sonography for remote diagnostic imaging: narrative review of current developments and clinical applications. *Journal of Ultrasound in Medicine*, *40*(7), 1287-1306.

Adeniran, A. K., Oyetola, E. O., Jagunmolu, H. A., Adeyemo, R. O., Salami, S. O., Oyetola, O. T., ... & Ayanleke, D. (2026). The Role of Point-of-Care Ultrasound (POCUS) Powered by Artificial Intelligence in Trauma and Cardiac Arrest Assessment: A Narrative Review. *SN Comprehensive Clinical Medicine*, *8*(1), 92.

Alfoti, B. O. O., Alfoti, F. O. O., Alothman, S. T. H., Al-Dhafiri, T. M. A., Al-Harbi, N. H. M., Al-Khalidi, A. M., ... & Alotaibi, N. F. A. (2024). Utilization of Point-of-Care Ultrasound (POCUS) in Emergency and Critical Care: Role of Nursing for Enhancing Diagnostic Accuracy and Efficiency-Systematic Review. *Egyptian Journal of Chemistry*, *67*(13), 705-716.

Amaral, C. B., Ralston, D. C., & Becker, T. K. (2020). Prehospital point-of-care ultrasound: A transformative technology. *SAGE Open Medicine*, *8*, 2050312120932706.

Anderson, A., & Theophanous, R. G. (2025). Identifying enablers and barriers to teleultrasound use for remote settings: A scoping review. *Australasian Journal of Ultrasound in Medicine*, *28*(1), e12415.

Ashby, A. E. (2022, June). *A novel cough audio pre-processing and segmentation algorithm for COVID-19 detection*.

Baribeau, Y., Sharkey, A., Chaudhary, O., Krumm, S., Fatima, H., Mahmood, F., & Matyal, R. (2020). Handheld point-of-care ultrasound probes: the new generation of POCUS. *Journal of cardiothoracic and vascular anesthesia*, *34*(11), 3139-3145.

Bitar, Z. I., Maadarani, O. S., & Bitar, M. (2025). Ultrasound indicators of organ venous congestion: a narrative review. *Annals of Intensive Care*, *15*(1), 184.

Biuzzi, C., Modica, E., Pondrelli, L., Raimondi, A., Cavenago, M., Marianello, D., ... & Scolletta, S. (2026). Central Venous Pressure Revisited: Physiology, Pitfalls, Misconceptions, and Modern Clinical Interpretation in Critical Care. *Journal of Clinical Medicine*, *15*(11), 4227.

Boella, L., Zar, A., & Dachsel, M. (2025). Ultrasound as the New Stethoscope: A Journey From Just Locating Fluid to Assessing Haemodynamics and Venous Congestion. *British Journal of Hospital Medicine*, *86*(12), 1-18.

Britton, N., Miller, M. A., Safadi, S., Siegel, A., Levine, A. R., & McCurdy, M. T. (2019). Tele-ultrasound in resource-limited settings: a systematic review. *Frontiers in public health*, *7*, 244.

Carroll, L. K. (2024). A Qualitative Phenomenological Study of Quality Standards for Practicing Credentialed Sonographers and Their Interpretation of an Advanced Ultrasound Practitioner Credential to Increase Patient Safety Outcomes.

Chanda, A. H., Idayathulla, S., Zulfiqar, H., Fatima, M., Balal, A., & Alhussein, M. M. K. (2026). POCUS (Point of Care Ultrasound): Hemodynamic Monitoring of Future.

Chandra, N. C., Bhattacharya, D., & Koratala, A. (2025). Point-of-care ultrasound: Uniting cardiology and nephrology at the bedside. *World Journal of Cardiology*, *17*(12), 112047.

Chandramohan, D., García, J. J. C., Kata, M., Naik, R., Bali, A., Shaik, B. F., ... & Avula, S. (2023). Acute kidney injury. *Advances in Renal Diseases and Dialysis*, 2-18.

Chelikam, N., Vyas, A., Desai, R., Khan, N., Raol, K., Kavarthapu, A., ... & Patel, U. K. (2023). Past and present of point-of-care ultrasound (PoCUS): a narrative review. *Cureus*, *15*(12), e50155.

Chen, L., Li, J., Chen, X., Huang, J., Liang, J., Qu, C., ... & Chen, W. (2026). Point-of-care ultrasound during trauma and critical care transport: a practical, safety-gated review. *Frontiers in Public Health*, *14*, 1816318.

Cid, X., Canty, D., Royse, A., Maier, A. B., Johnson, D., El-Ansary, D., ... & Royse, C. (2020). Impact of point-of-care ultrasound on the hospital length of stay for internal medicine inpatients with cardiopulmonary diagnosis at admission: study protocol of a randomized controlled trial—the IMFCU-1 (Internal Medicine Focused Clinical Ultrasound) study. *Trials*, *21*(1), 53.

Conner, S. M., Anstey, J. E., Thomas, M. K., Carney, P. A., Fiore, M. D., Little, C. E., ... & Piro, K. M. (2025). Perspectives on Point-of-Care Ultrasonography Credentialing and Privileging: A Qualitative Study. *JAMA Network Open*, *8*(10), e2538759.

Deivayanai, V. C., Swaminaathanan, P., Vickram, A. S., Saravanan, A., Bibi, S., Aggarwal, N., ... & Abdel-Daim, M. M. (2025). Transforming healthcare: the impact of artificial intelligence on diagnostics, pharmaceuticals, and ethical considerations–a comprehensive review. *International Journal of Surgery*, *111*(7), 4666-4693.

Fan, X., Bian, Y., Wang, G., Liu, W., Gao, L., Pan, Y., ... & Chen, Y. (2023). Trends in point-of-care ultrasound protocols in the emergency department and intensive care unit: a review. *Emergency and Critical Care Medicine*, *3*(2), 64-69.

Fox, S., Fleshner, M., Flanagan, C., Robertson, T., Fujita, A. W., Bhamidipati, D., ... & Bui, T. (2020). Developing and evaluating a remote quality assurance system for point-of-care ultrasound for an internal medicine residency global health track. *POCUS journal*, *5*(2), 46.

Frid, H., Bilder, A., Hija, A., & Emodi, O. (2025). Diagnostic Accuracy and Clinical Impact of Handheld Point-of-Care Ultrasound in Pediatric Odontogenic Infections: A Prospective Cohort Study. *Children*, *12*(10), 1392.

Giangregorio, F., Centenara, E., Mazzocchi, S., Gerra, L., Tursi, F., Imberti, D., & Aschieri, D. (2025). Assessing Venous Congestion in Acute and Chronic Heart Failure: A Review of Splanchnic, Cardiac and Pulmonary Ultrasound: Part 1: Conventional B-Mode, Colordoppler, and Vexus Protocol. *Journal of Clinical Medicine*, *14*(22), 8147.

Gri, N., Longhitano, Y., Zanza, C., Monticone, V., Fuschi, D., Piccioni, A., ... & Savioli, G. (2023). Acute Oncologic complications: clinical–therapeutic management in critical Care and Emergency Departments. *Current Oncology*, *30*(8), 7315-7334.

Haji-Hassan, M., Capraș, R. D., & Bolboacă, S. D. (2023). Efficacy of handheld ultrasound in medical education: a comprehensive systematic review and narrative analysis. *Diagnostics*, *13*(24), 3665.

Hsieh, A., Baker, M. B., Phalen, J. M., Mejias-Garcia, J., Hsieh, A., Hsieh, A., & Canelli, R. (2022). Handheld point-of-care ultrasound: safety considerations for creating guidelines. *Journal of Intensive Care Medicine*, *37*(9), 1146-1151.

Jarsania, D. M., Breunig, M. J., Kolar, G. J., Issa, M., Kingsley, R., Bhuiyan, M. N., ... & Kirchoff, R. W. (2025). Role of Point-of-Care Ultrasound in Inpatient Perioperative Medical Management: A Systematic Review. *Journal of Clinical Medicine*, *14*(20), 7429.

Johri, A. M., Glass, C., Hill, B., Jensen, T., Puentes, W., Olusanya, O., ... & Galen, B. T. (2023). The evolution of cardiovascular ultrasound: a review of cardiac point-of-care ultrasound (POCUS) across specialties. *The American Journal of Medicine*, *136*(7), 621-628.

Kameda, T., Ishii, H., Oya, S., Katabami, K., Kodama, T., Sera, M., ... & Kimura, A. (2024). Guidance for clinical practice using emergency and point-of-care ultrasonography. *Acute Medicine & Surgery*, *11*(1), e974.

Kariman, S. S., van den Heuvel, J. F., Adriaanse, B. M., Oepkes, D., & Bekker, M. N. (2025). The Potential of Tele-Ultrasound, Handheld and Self-Operated Ultrasound in Pregnancy Care: A Systematic Review. *Prenatal diagnosis*, *45*(7), 906-920.

Koratala, A., & Kazory, A. (2021). Point of care ultrasonography for objective assessment of heart failure: integration of cardiac, vascular, and extravascular determinants of volume status. *Cardiorenal Medicine*, *11*(1), 5-17.

Koratala, A., Romero-González, G., Soliman-Aboumarie, H., & Kazory, A. (2024). Unlocking the potential of VExUS in assessing venous congestion: the art of doing it right. *Cardiorenal Medicine*, *14*(1), 350-374.

Kosiń, K., Polak, A., Kiwior, J., Liszka, W., & Malina, M. (2025). The role of point-of-care ultrasound in emergency medicine: A contemporary narrative review. *Emergency Medical Service*, *12*(4), 464-471.

Lau, Y. H., & See, K. C. (2022). Point-of-care ultrasound for critically-ill patients: a mini-review of key diagnostic features and protocols. *World Journal of Critical Care Medicine*, *11*(2), 70.

Leidi, A., Rouyer, F., Marti, C., Reny, J. L., & Grosgurin, O. (2020). Point of care ultrasonography from the emergency department to the internal medicine ward: current trends and perspectives. *Internal and emergency medicine*, *15*(3), 395-408.

Leyba, K., Longino, A., Ormesher, R., Krienke, M., Van Ochten, N., Zimmerman, K., ... & Gill, E. (2024). Venous excess ultrasonography (VExUS) captures dynamic changes in volume status surrounding hemodialysis: A multicenter prospective observational study. *Research Square*, rs-3.

Leyba, K., Longino, A., Ormesher, R., Krienke, M., Van Ochten, N., Zimmerman, K., ... & Gill, E. (2026). VExUS Point-of-Care Ultrasound Tool to Detect Changes in Volume Status: A Prospective Observational Study. *JACC: Advances*, *5*(3), 102538.

Li, L., Xu, Y., Chen, X., & Huang, W. (2026). Assessing venous congestion in critical illness: advantages of the inferior vena cava shape change index over diameter. *Annals of Intensive Care*, *16*, 100032.

Lo Cricchio, A., Storelli, A., Bertoletti, I., Ciuti, G., Fabbri, A., Martinelli, E., ... & Bandini, G. (2024). Accuracy of lung ultrasound performed with handheld ultrasound device in internal medicine: an observational study. *Journal of Ultrasound*, *27*(4), 825-830.

Lobo, M. D., Miravent, S., & de Almeida, R. P. P. (2024). Emerging trends in ultrasound education and healthcare clinical applications: a rapid review. *Emerging Technologies for Health Literacy and Medical Practice*, 263-287.

LoPresti, C. M., Jensen, T. P., Dversdal, R. K., & Astiz, D. J. (2019). Point-of-care ultrasound for internal medicine residency training: a position statement from the alliance of academic internal medicine. *The American journal of medicine*, *132*(11), 1356-1360.

Luong, C. L., Ong, K., Kaila, K., Pellikka, P. A., Gin, K., & Tsang, T. S. (2019). Focused cardiac ultrasonography: current applications and future directions. *Journal of Ultrasound in Medicine*, *38*(4), 865-876.

Maheshwari, S., & Dagor, H. (2024). Evolving the scope of cardiac point-of-care ultrasound in the current era. *Cureus*, *16*(2).

Malik, A. N., Rowland, J., Haber, B. D., Thom, S., Jackson, B., Volk, B., & Ehrman, R. R. (2021). The use of handheld ultrasound devices in emergency medicine. *Current Emergency and Hospital Medicine Reports*, *9*(3), 73-81.

Maringelli, G., Prota, L., Ferrari, C., Laterza, C., Arcamone, E., Marsico, P., ... & Vetrugno, L. (2025). Ultrasound management in the emergency department: a narrative review. *Journal of Public Health and Emergency*, *9*, 17.

Martocchia, A., Bentivegna, E., Sergi, D., Luciani, M., Barlattani, M., Notarangelo, M. F., ... & Martelletti, P. (2022). The point-of-care ultrasound (POCUS) by the handheld ultrasound

devices (HUDs) in the COVID-19 scenario: a review of the literature. *SN Comprehensive Clinical Medicine*, *5*(1), 1.

Maw, A. M., Huebschmann, A. G., Mould-Millman, N. K., Dempsey, A. F., & Soni, N. J. (2020). Point-of-care ultrasound and modernization of the bedside assessment. *Journal of graduate medical education*, *12*(6), 661-665.

Muller, L., Volpicelli, G., Mongodi, S., Girard, M., Fraccalini, T., Gargani, L., ... & Zieleskiewicz, L. (2026). Bedside thoracic echography in ICU: new insights for acute circulatory and respiratory failure. *Intensive Care Medicine*, *52*(1), 76-88.

Nguyen, C., Parfianowicz, D., & Bennett, C. (2024). Point of care ultrasound and shock: The value in bedside diagnosis and hemodynamic assessment in undifferentiated shock patients. *Journal of Translational Critical Care Medicine*, *6*(3), e24-00010.

Nickols, J., & Douthit, N. (2026). Point-of-Care Ultrasound Guidelines From Family Medicine, Emergency Medicine, and Internal Medicine for Curriculum Development: A Narrative Review. *Journal of Graduate Medical Education*, *18*(3), 292-300.

Noor, A., Liu, M., Jarman, A., Yamanaka, T., & Kaul, M. (2025). Point-of-care ultrasound use in hemodynamic assessment. *Biomedicines*, *13*(6), 1426.

Osterwalder, J., Polyzogopoulou, E., & Hoffmann, B. (2023). Point-of-care ultrasound—history, current and evolving clinical concepts in emergency medicine. *Medicina*, *59*(12), 2179.

Pandompatam, G. (2025). Basics of point of care ultrasonography. *Journal of Translational Critical Care Medicine*, *7*(4), e25-00001.

Patel, S., Ashokkumar, S., & Green, A. (2024). Modern tools for optimizing fluid management in dialysis patients: a comprehensive review. *BMC nephrology*, *25*(1), 464.

Phillips, L., Maclean, A., Monester, J., Douglas, J., Davidson, S., & King, G. (2024). Recommendations for developing a comprehensive point-of-care ultrasound (POCUS) program in the emergency department: an Emergency Medicine Ultrasound Group advocacy statement. *Emergency Medicine Australasia*, *36*(6), 956-963.

Policastro, P. (2026). Integrative Assessment of Cardiovascular Volume Status: Automated Inferior Vena Cava Imaging and Cardiorespiratory Signal Analysis.

Qaseem, A., Etxeandia-Ikobaltzeta, I., Mustafa, R. A., Kansagara, D., Fitterman, N., Wilt, T. J., & Clinical Guidelines Committee of the American College of Physicians. (2021). Appropriate use of point-of-care ultrasonography in patients with acute dyspnea in emergency department or inpatient settings: a clinical guideline from the American College of Physicians. *Annals of internal medicine*, *174*(7), 985-993.

Radonjić, T., Popović, M., Zdravković, M., Jovanović, I., Popadić, V., Crnokrak, B., ... & Branković, M. (2022). Point-of-care abdominal ultrasonography (POCUS) on the way to the right and rapid diagnosis. *Diagnostics*, *12*(9), 2052.

Ranasinghe, M. P., Koh, Y., Vogrin, S., Nelson, C. L., Cohen, N. D., Voskoboinik, A., ... & Costello, B. (2024). Early discharge to clinic-based therapy of patients presenting with decompensated heart failure (EDICT-HF): study protocol for a multi-centre randomised controlled trial. *Heart, Lung and Circulation*, *33*(1), 78-85.

Recker, F., Höhne, E., Damjanovic, D., & Schäfer, V. S. (2022). Ultrasound in telemedicine: a brief overview. *Applied sciences*, *12*(3), 958.

Recker, F., Schäfer, V. S., Holzgreve, W., Brossart, P., & Petzinna, S. (2023). Development and implementation of a comprehensive ultrasound curriculum for medical students: The Bonn internship point-of-care-ultrasound curriculum (BI-POCUS). *Frontiers in medicine*, *10*, 1072326.

Rice, J. A., Brewer, J., Speaks, T., Choi, C., Lahsaei, P., & Romito, B. T. (2021). The POCUS consult: how point of care ultrasound helps guide medical decision making. *International journal of general medicine*, 9789-9806.

Rocca, E., Zanza, C., Longhitano, Y., Piccolella, F., Romenskaya, T., Racca, F., ... & Mongodi, S. (2023). Lung ultrasound in critical care and emergency medicine: clinical review. *Advances in respiratory medicine*, *91*(3), 203-223.

Romero-González, G., Manrique, J., Slon-Roblero, M. F., Husain-Syed, F., De la Espriella, R., Ferrari, F., ... & Ronco, C. (2023). PoCUS in nephrology: a new tool to improve our diagnostic skills. *Clinical Kidney Journal*, *16*(2), 218-229.

Salerno, A., Kuhn, D., El Sibai, R., Levine, A. R., & McCurdy, M. T. (2020). Real-time remote tele-mentored echocardiography: a systematic review. *Medicina*, *56*(12), 668.

Sartini, S., Ferrari, L., Cutuli, O., Castellani, L., Bagnasco, M., Moisio Corsello, L., ... & Sartini, M. (2024). The role of pocus in acute respiratory failure: a narrative review on airway and breathing assessment. *Journal of Clinical Medicine*, *13*(3), 750.

Shah, P., & Patel, U. K. (2023). Past and Present of Point-of-Care Ultrasound (PoCUS): A Narrative Review.

Smalley, C. M., Simon, E. L., Muir, M. R., & Fertel, B. S. (2023). A real-world experience: retrospective review of point-of-care ultrasound utilization and quality in community emergency departments. *Western Journal of Emergency Medicine*, *24*(4), 685.

Soni, N. J., Schnobrich, D., Mathews, B. K., Tierney, D. M., Jensen, T. P., Dancel, R., ... & Lucas, B. P. (2019). Point-of-care ultrasound for hospitalists: a position statement of the Society of Hospital Medicine. *Journal of hospital medicine*, *14*(1), E1-E6.

Stickles, S. P., Carpenter, C. R., Gekle, R., Kraus, C. K., Scoville, C., Theodoro, D., ... & Raio, C. (2019). The diagnostic accuracy of a point-of-care ultrasound protocol for shock etiology: a systematic review and meta-analysis. *Canadian Journal of Emergency Medicine*, *21*(3), 406-417.

Su, J., Tie, X., Wei, Y., Zhou, R., Zou, T., Qin, Y., ... & Yin, W. (2025). Critical care ultrasound: development, evolution, current and evolving clinical concepts in critical care medicine. *Frontiers in Medicine*, *12*, 1622604.

Talle, M. A., Ngarande, E., Doubell, A. F., & Herbst, P. G. (2022). Cardiac complications of hypertensive emergency: classification, diagnosis and management challenges. *Journal of Cardiovascular Development and Disease*, *9*(8), 276.

Tarantini, P., Cei, F., Longhi, F., Fici, A., Tupputi, S., Solitro, G., ... & Mumoli, N. (2025). Heart at hand: the role of Point-of-Care cardiac ultrasound in internal medicine. *Journal of Cardiovascular Development and Disease*, *12*(10), 379.

Tierney, D. M., Rosborough, T. K., Sipsey, L. M., Hanson, K., Smith, C. S., Boland, L. L., & Miner, R. (2023). Association of internal medicine point of care ultrasound (POCUS) with length of stay, hospitalization costs, and formal imaging: a prospective cohort study. *POCUS journal*, *8*(2), 184.

Volpicelli, G., Gargani, L., Zieleskiewicz, L., Tuinman, P. R., Kimura, B. J., Zisis, G., ... & Oveland, N. P. (2026). International evidence-based recommendations for point-of-care lung ultrasound. *Intensive care medicine*, 1-32.

Waldman, D., & Pino, C. (2024). Roadmap to success: Blueprint for enterprise-wide deployment of a point-of-care ultrasound platform, inclusive of governance, policy, education, credentialing, and quality assurance. *Journal of Clinical Imaging Science*, *14*, 35.

Waldman, D., Doughton, J., & Pino, C. (2025). Roadmap to success: Blueprint for enterprise-wide deployment of a point-of-care ultrasound platform, inclusive of governance, policy, education, credentialing, and quality assurance (Part 2). *Journal of Clinical Imaging Science*, *15*, 28.

Yamada, H., Ito, H., & Fujiwara, M. (2022). Cardiac and vascular point-of-care ultrasound: current situation, problems, and future prospects. *Journal of Medical Ultrasonics*, *49*(4), 601-608.