An Insight about Point of Care Ultrasound; History, Role, and Interpretation at Respiratory Intensive Care Unit

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Abstract
Point-of-care ultrasound (POCUS) refers to the use of portable ultrasonography at the patient's bedside for diagnostic and therapeutic purposes performed "real time" by the provider. The use of ultrasound has greatly expanded over past years with its increasing usefulness being realized in different clinical areas. It has now become the point-of-care tool in intensive care units (ICU) with varied diagnostic and therapeutic applicability, rightfully earning the nomenclature of 'ultrasound stethoscope. A generation of physicians will need to be trained to view this technology as an extension of their senses, just as many generations have viewed the stethoscope. That development will require the medical education community to embrace and incorporate the technology throughout the curriculum. The importance of ultrasound in ICU can be underscored by its utility in various scenarios. Application of cardiac ultrasound by other clinicians, such as intensivists focused cardiac ultrasound (FOCUS), allows brisk diagnosis of acute cardiovascular pathologies in a noninvasive manner. The key elements during FOCUS in shock patients can be evaluated using SIMPLE approach. Recognizing that POCUS has the potential to be an important tool for diagnosis and clinical management, some medical schools have embraced the technology to augment anatomy lessons, and as an adjunct to the physical examination. In clinical clerkships, students are increasingly familiarized with ultrasound at the POC, either as a part of their training or incidentally in clinical practice. In graduate medical education, ultrasound training is required and fairly standardized in emergency medicine residency programs in the United States.

Keywords: Point of Care, Ultrasound, Respiratory, Intensive care unit

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Introduction:

Point-of-care ultrasound (POCUS) refers to the use of portable ultrasonography at the patient's bedside for diagnostic and therapeutic purposes performed "real time" by the provider. The use of

ultrasound has greatly expanded over past years with its increasing usefulness being realized in different clinical areas. It has now become the point-of-care tool in intensive care units (ICU) with varied diagnostic and therapeutic applicability, rightfully earning the nomenclature of 'ultrasound stethoscope' (1).

Characteristics Of Pocus (2).

1. Aim is a well-defined purpose linked to improving patient outcomes.
2. Examination is focused and goal-directed.
3. Examination findings are easily recognizable.
4. Examination is easily learned.
5. Examination is quickly performed.
6. Examination is performed at the patient's bedside.

History Of Pocus

The history of POCUS dates back to the late 80s when it was first used in ICU and emergency department in 1989. A few years later, there was an increase in ultrasound-guided procedures, during the 1990s. Gradually, POCUS came to be incorporated in academic curriculum like emergency medicine in 1994 followed by US medical school curriculum for the first time in 2005. In 2010, it was integrated in the US residency curriculum. Since then, it has gradually been assimilated in working protocols as well as teaching programs in several countries (2).

Who Uses Pocus

A generation of physicians will need to be trained to view this technology as an extension of their senses, just as many generations have viewed the stethoscope. That development will require the medical education community to embrace and incorporate the technology throughout the curriculum (3).

How To Use Pocus (*2*)?

Point-of-care ultrasound (POCUS) is an integral element to clinical diagnosis and management.
It is a vital link following a history and physical examination, which in turn can help review the initial assessment. It can help determine the further diagnostic work up required as well as carry out many therapeutic procedures as well. POCUS has now come to occupy an indispensable place in all the stages of patient management, i.e. diagnosis, treatment and monitoring. POC ultrasound examinations differ from complete studies in that they are:

• Limited in scope, designed to achieve specific procedural aims (e.g. direct the needle to the correct location) or answer focused questions (e.g. does my patient have ascites?).

• Performed by the same care provider who will be using the information to direct immediate patient care management at the bedside.

The critically ill-patients present with complex clinical problems with the initial pathological process deteriorating into multiorgan involvement over days or even acutely. Whether as, the initial insult or secondary involvement, the cardiorespiratory failure in patients, is a challenging diagnostic dilemma encountered routinely. Similarly, diagnosing the cause of fever, assessing fluid responsiveness, detection of raised intracranial pressure in sedated and ventilated patient, achieving vascular access and insertion of intra-arterial catheter in edematous or injured patients pose challenge to an intensivist.

Even an astute clinician will find this modality useful in overcoming these challenges. Its expanding clinical utility lies in the fact that it is a bedside technique with minimal recurring costs. This has allowed it to be incorporated in critical care set ups. It provides additional advantage for no technique related ionizing radiation exposure. The time is saved due to the obviation of the need to transport the patients, who are usually on multiple life support systems, to the radiology suites.

There is less need for third party referrals. If it is done by the intensivist who is directly involved in the patient management, more clinically relevant and focused examination can be done which will positively influence the management of the patient.

Role of POCUS in ICU

The importance of ultrasound in ICU can be underscored by its utility in various scenarios. These are listed below briefly; an elaborate description follows in the appropriate section:

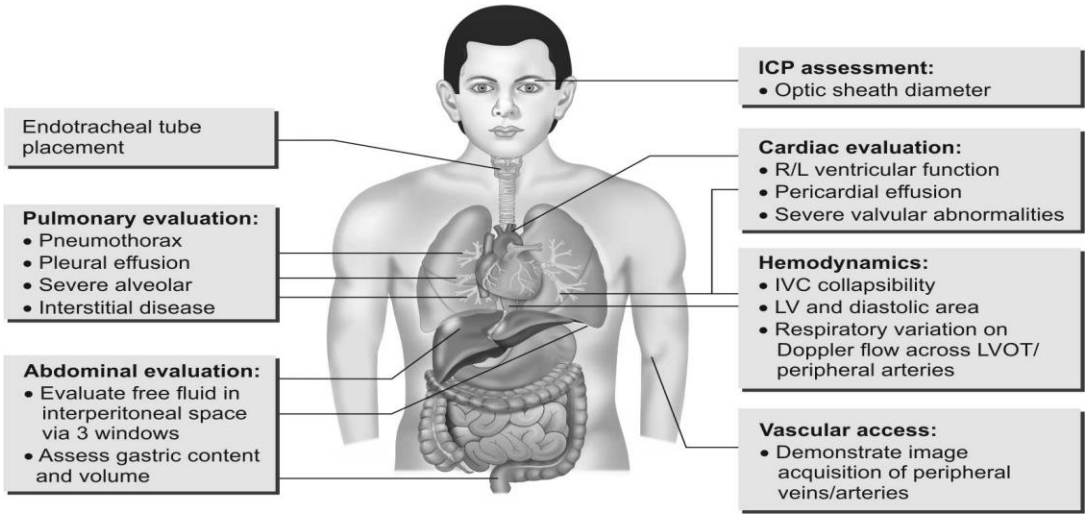

Fig.1: Role of POCUS in ICU: scope of use **(4).**

Abbreviations: ICP: Intracranial pressure; R/L: Right/Left; IVC: Inferior vena cava; LV: Left ventricle; LVOT: Left ventricular outflow tract.

Differential Diagnosis of Acute Respiratory Failure

Critically-ill patients usually suffer from wide spectrum and varied degree of respiratory involvement. The conventionally used roentgenogram has some pitfalls in ICU setting. The sensitivity and specificity of lung ultrasound for detection of pneumothorax has been variously reported but its diagnostic accuracy remains higher than chest X-ray. The pooled sensitivity and specificity of chest ultrasound were 0.87 (95% CI: 0.81–0.92) and 0.99 (95% CI: 0.98–0.99), while those of chest X-ray were 0.46 (95% CI: 0.36–0.56) and 1.0 (95% CI: 0.99–1.0), respectively in a meta-analysis **(5).**

A number of signs like the bat sign, vertical B lines, lung rockets corresponding to tissue fluid interface and interstitial syndrome, quad sign and sinusoid sign, presence of lung point, shred sign and tissue-like sign visualized on lung sonography bear significance **(6).**

In a Ultrasonography (USG) based BLUE protocol (bedside lung ultrasound in emergency) in 2004, describing the application of ultrasound in critically ill, in the differential diagnosis of acute respiratory failure. An intensivist trained in USG can further carry out a more comprehensive examination and maneuvers to understand the pathology, e.g. assessment of lung overinflation, aeration loss and its distribution, assessment of lung recruitment following positive end-expiratory pressure (PEEP), etc **(6).**

Evaluation of Shock and Application in Cardiac Arrest Situation

Application of cardiac ultrasound by other clinicians, such as intensivists focused cardiac ultrasound (FOCUS), allows brisk diagnosis of acute cardiovascular pathologies in a noninvasive manner. The key elements during FOCUS in shock patients can be evaluated using SIMPLE approach **(7).**

Similarly, combination of lung and heart ultrasound in a schematic way, forms the fluid administration limited by lung sonography (FALLS) protocol. This protocol as described by **Lichenstein et al. (6)** serves as a tool for management of acute circulatory failure. Various other protocols like rapid ultrasound for shock and hypotension (RUSH), abdominal and cardiac evaluation with sonography in shock (ACES), undifferentiated hypotension patient (UHP), or focused assessed transthoracic echocardiography (FATE) have been described**.**

Ha et al. (8) explored the combined application of lung and heart ultrasound for shock evaluation by using multi-organ point-of-care (MOPOCUS) strategy. They classified the etiology of shock based on the diffuse interstitial and noninterstitial pattern on lung ultrasound**.**

Various authors have described the application of USG in cardiac arrest settings. Though controversial, when applied in a prompt and focused manner, it can yield valuable information. The efficacy of goal directed or focused echocardiography is highlighted by the study of **Manasia et al. (9)**. In their observational study of 90 patients, they found that intensivists formally trained in handheld echocardiographic system could successfully perform and correctly interpret a limited transthoracic echocardiography (TTE) in critically-ill patients, which could modify their management.

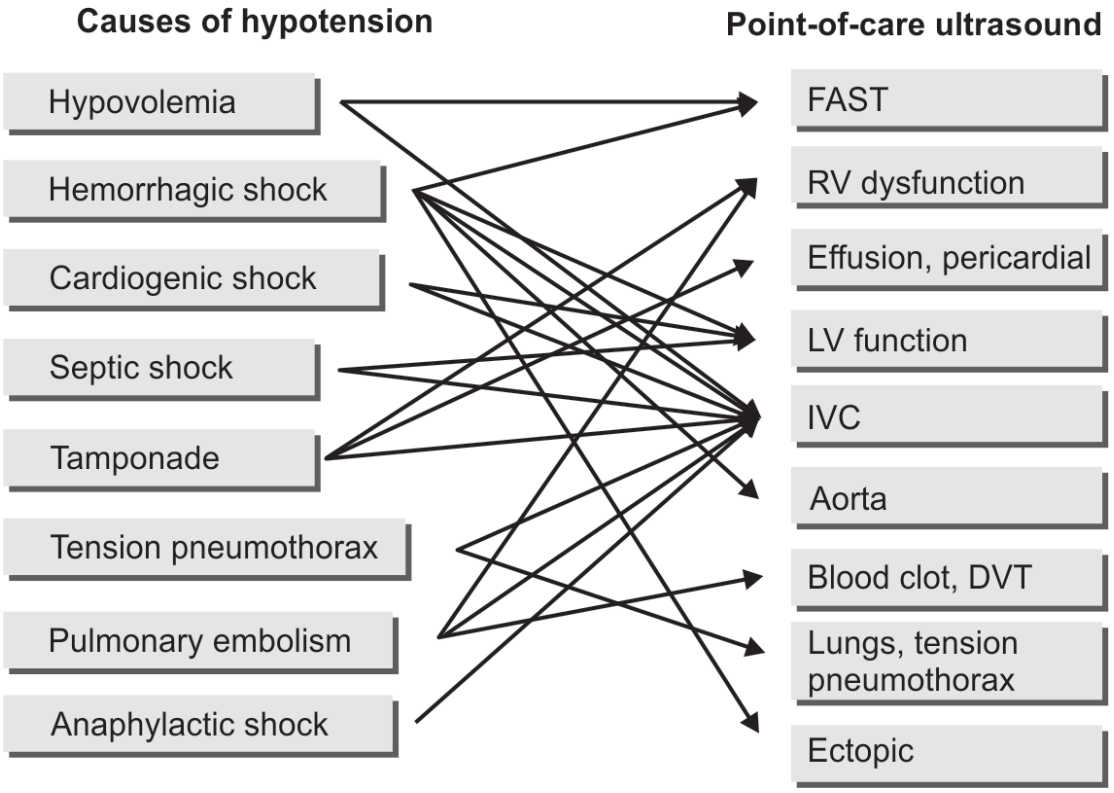

Fig. 2: The causes of hypotension and their ultrasound findings **(2).** Abbreviations: FAST: Focused assessment with sonography in trauma; RV: Right ventricle; LV: Left ventricle; IVC: Inferior vena cava; DVT: Deep vein thrombosis.

Holistic approach to evaluation of heart:

The training in point-of-care echocardiography for noncardiologists, such as intensivists is limited to basic elements. However, there is a new concept of automated speckle tracking echocardiography. **Bagger et al., (10)** found a reasonable agreement between automated and conventional methods to determine left ventricular systolic function.

The recognition of left ventricular diastolic dysfunction (DD) in ICU patients is gaining importance as it might be linked to weaning failure in them. These patients are particularly likely to have DD, due to underlying disease or the applied therapies. However, its exact incidence and prognostic implications are unknown. **Eisen et al., (11)** observed that heart failure with a normal LV ejection fraction (HFNEF) may account for more than 50% of heart failure cases.The recognition of these conditions by a bedside ECHO may in fact become a factor affecting clinical outcome.

Fever in ICU

Fever in the ICU is a diagnostic dilemma that continues to baffle even the best of critical care physicians. The ultrasound can be a useful tool in this regard, by exploring relatively inaccessible locations for hidden abscesses as in deep abdominal, paranasal sinuses, pleural cavity. **Tu et al., (12)** demonstrated that ultrasound was a safe and reliable diagnostic aid for empyema.

The use of ultrasound for necrotizing fasciitis has been described by Kehrl, **(Kehrl T. 2014)** while **Lichenstein (6)** has suggested the possibility of an ultrasound equivalent for fever of unknown origin in the ICU patient.

Raised Intracranial Pressure

The assessment of raised intracranial pressure (ICP) in ICU patients who are sedated and on mechanical ventilation can be facilitated by use of USG. Assessing the diameter of optic nerve sheath (ONSD) by USG guidance can help detect an increase in ICP **(13).**The findings of **Shirodkar et al., (14)** support USG based ONSD estimation as an early test for diagnosing raised ICP.

In a meta-analysis, **Ohle et al., (15)** found a sensitivity and specificity of 95.6% and 92.3% respectively for detection of raised ICP with ocular USG. **Shirodkar et al., (14)** found a good correlation between USG and MRI enabled measurement of ONSD ($r = 0.02$, $P < 0.001$).

Vascular Access

Ultrasound has gained popularity as a guided interventional tool for vascular access in ICU patients. USG based internal jugular venous (IJV) localization for cannulation was described by Ullman and Stoelting as early as the year 1978. It Was described the in-plane approach of USG based IJV cannulation. Since then, USG-guided central venous cannulation has become a standard of care and is widely practiced. A plethora of literature is available comparing alternative approaches and illustrating the advantage of USG-based technique over the landmark-based methods. It Was demonstrated a success rate of 99.9% for USG guided IJV cannulation with 87% first pass attempts.

In a meta-analysis of 27 trials evaluating the outcome of USG-guided central venous cannulation, it was found that USG-guided catheterization was quicker and safer than landmark-based method. A novel 'medial-oblique approach for IJV cannulation, is being explored as it has been shown to provide better visualization of anatomy and minimize the risk of arterial puncture**.** The usefulness in detection of DVT using bedside portable USG is at par with formal duplex sonography with up to 98% agreement with the same. Application of USG for inserting intraarterial lines for invasive monitoring and insertion of dialysis catheters is also noteworthy.

It Was observed a 80% success rate in first attempt with USG-based technique as compared to the palpation method (42%).

Wells score is DVT probability calculation based on clinical findings (4):

-Paralysis, paresis or recent orthopedic casting of lower extremity (1 point)

-Recently bedridden (more than 3days) or major surgery within past 4weeks (1 point)

-Localized tenderness in deep vein system (1 point)
-Swelling of entire leg (1 point)
-Calf swelling 3cm greater than other leg (measured 10 cm below the tibial tuberosity) (1 point)
-Pitting edema greater in the symptomatic leg (1 point)
-Collateral non varicose superficial veins (1 point)
-Active cancer or cancer treated within 6months (1 point)
-Alternative diagnosis more likely than DVT (Baker's cyst, cellulitis, muscle damage, superficial venous thrombosis, post phlebitic syndrome, inguinal lymphadenopathy, external venous compression) (-2 points)

DVT Risk Score Interpretation
3-8 Points: High probability of DVT
1-2 Points: Moderate probability
-2-0 Points: Low Probability.

In a meta-analysis of four trials, It Was found that the first attempt success was likely to be more with USG-guided method for arterial cannulation with a 71% improvement (RR, 1.71; 95% CI, 1.25–2.32) as compared with the palpation method. In a meta-analysis of seven trials evaluating the outcome of ultrasound application for hemodialysis catheter insertion, **Rabindranath et al., (16)** found that the failure risk of catheter placement in the first attempt was reduced significantly with ultrasound guidance, with reduction in risk of inadvertent arterial puncture and subsequent hematoma, as well as time for successful cannulation and the number of attempts required.

Pocus In Medical Education
Recognizing that POCUS has the potential to be an important tool for diagnosis and clinical management, some medical schools have embraced the technology to augment anatomy lessons, and as an adjunct to the physical examination. In clinical clerkships, students are increasingly familiarized with ultrasound at the POC, either as a part of their training or incidentally in clinical practice. In graduate medical education, ultrasound training is required and fairly standardized in emergency medicine residency programs in the United States **(*2*)**

Limitations (*2*):
The limitations of POCUS performed by a critical care physician are mainly related to the clinician and the particular patient. Patient factors, such as obesity, the presence of edema or subcutaneous emphysema, and suboptimal patient position can reduce image quality and make interpretation difficult. This is especially limiting in performing bedside echocardiography where appropriate patient

positioning cannot be achieved and mechanical ventilation frequently hampers image quality. The clinician-related limitations pertain mostly to training and education. This situation may lead to suboptimal care of the patient.

As outlined above, ultrasound has proven to be a modality of immense potential for supporting clinical acumen and guiding the management of ICU patients. While it has established itself as a third eye for an intensivist in management of cardiac and respiratory conditions, it is fast digging its claws into so far unexplored terrain of neurologic monitoring and cardiac arrest situations. As the primary treating physician in the ICU set up is an intensivist, it is an empowering tool to a well-trained intensivist. While all this is said, the approach has to be goal directed or based on focused protocols.

For successful implementation of USG-based strategies, some requirements need to be met. Guidelines must be laid for indications and performance of each examination with adequately trained clinicians who are performing these examinations. The standardized technical specifications of the USG instruments for each examination should be in place. Proper documentation and archiving of cases should be ascertained. An overseer system should be in place to ensure that the prescribed guidelines are met, in terms of providing accreditation or denoting credentials at institutional or individual level.

Key Points

1. POCUS: Disruptive innovation.
2. It is not a substitute, rather an adjunct to physical examination.
3. Done by nonradiologist.
4. Save time, save radiation, save money, save lives.
5. While we have good evidence of literature credentialing the efficacy of POCUS in critical care, outcomes-based research is needed for many areas.

Focused ultrasonography

In the 1970s, radiologists and surgeons started describing the role of US examination for haemoperitoneum in patients who had sustained blunt abdominal trauma. This led to evaluation of US in trauma patients, specifically for the detection of haemoperitoneum and haemopericardium.

This research culminated in the description of the Focused Assessment with Sonography for Trauma (FAST) exam, which has been included as part of the advanced trauma life support course since 1997. FAST examination is an example of a ‘focused ultrasound assessment’, a type of US examination performed in order to answer a specific clinical question, such as ‘is there free fluid in the abdomen?’ or ‘is there a pericardial effusion?’ This differs from traditional US examination where an often time-consuming scan is performed in order to generate a detailed report of the area being examined.

Table 1: The different anatomical areas where a focused US assessment can be performed. When performing the scan, the examiner should try to answer a specific question in order to arrive at a diagnosis **(17)**:

Scan	Questions being asked	Diagnosis
Echocardiography	Is there a pericardial effusion? Are there signs of tamponade? Are the ventricles grossly dilated? Is there adequate ventricular function? Is the right ventricle dilated? Is the IVC fixed and dilated? Is the left ventricle underfilled? Is the IVC collapsing on inspiration? Is there ventricular activity?	Pericardial effusion Myocardial insufficiency Pulmonary embolism Hypovolaemia Confirmation of cardiac arrest
Thoracic ultrasound	Is lung sliding present? Are comet tail artifacts present? Is there fluid in the thorax? Are A lines present? Are B lines present?	Pneumothorax Pleural effusion Pulmonary oedema
Abdominal ultrasound	Is there free fluid/blood in the abdomen? Is the abdominal aorta >3 cm in diameter? Is there hydronephrosis? Is the bladder distended? Is the anterior gallbladder wall thickened? Is the common bile duct dilated? Are there gallstones? Does the patient have a sonographic Murphy sign?	Intraperitoneal fluid Abdominal aortic aneurysm Post-renal obstruction Cholecystitis
Lower extremity	Does the common femoral vein fully compress? Does the popliteal vein fully compress?	Deep venous thrombosis
Ocular ultrasound	Is the optic sheath diameter >5 mm?	Raised intracranial pressure
Transcranial Doppler	What is the flow velocity? What is the pulsatility index?	Cerebral vasospasm or cerebral artery obstruction

Focused echocardiography

Focused echocardiographic examination is significantly shorter in duration than traditional echocardiography. The goal of such an exam is to supplement the physical examination, and in the care of acutely ill patients, an approach that combines both physical examination and bedside echocardiography has proven to improve clinical diagnosis and management. Transthoracic echocardiography (TTE) is noninvasive and more readily available than trans-esophageal echocardiography and should thus be the initial modality of choice **(18).**

Objectives of the examination should include **(17).**

(i) assessment of left ventricular (LV) and right ventricular (RV) function,

(ii) assessment of the pericardial space for effusion and tamponade, and

(iii) assessment of the volume status.

A common use of echo in critical care is to help diagnose the cause of hypotension. Hypovolaemia can often be difficult to diagnose clinically. TTE may demonstrate a hyperdynamic LV, but visualization of the inferior vena cava (IVC) may be more helpful. The IVC can be visualized in the abdomen as it travels behind the liver. In a healthy subject breathing spontaneously, an inspiratory decrease in an IVC diameter of 50% can be observed as a result of cyclic changes in pleural pressure. This cyclic change in the vena cava diameter is abolished, when the vessel is dilated, for example, in cardiac tamponade, pulmonary embolism, and severe RV failure. In a mechanically ventilated patient, the respiratory changes in the IVC diameter are reversed, with an inspiration causing an increase in the diameter. Cyclic respiratory changes in the IVC diameter during mechanical ventilation can be observed only with a normal or low volume status **(17).**

Conclusion

Point of care ultrasonography (POCUS) is advanced diagnostic ultrasonography that is performed and interpreted by the attending physician as a bedside test. POCUS has been widely used in many disciplines as a rapid diagnostic tool, especially in emergency medicine. POCUS has been used to aid the diagnosis of multiple medical conditions ranging from acute appendicitis, airway compromise, abdominal aortic aneurysm, traumatic injury assessment. The relatively fast use has made it a potential option in situations where a formal radiological investigation may delay the diagnosis. Additionally, the ever-increasing demands of other diagnostic imaging and interventional radiological procedures have underscored the importance of non-radiologists physicians' contribution to radiological diagnosis through POCUS.

There are several advantages of incorporating POCUS in daily clinical practice, with the major one being integrating sonographic findings with history and clinical examination at the patient's bedside. In addition, POCUS performed by the primary clinician reduces the need to involve a second clinician and avoids the need for patient transfer to a separate ultrasonography room. POCUS is a cost-effective

approach that directly and indirectly saves healthcare expenses at both national and international scales.

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