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Original Research Article

Role of Point-of-Care Ultrasound in Hemodynamic Assessment of ICU Patients: A Prospective Observational Study at NMCH, Patna

Mukesh Kumar[1], Santosh Kumar[2], Rajat Kumar[3], Bijoy Kumar[4]

[1]Senior Resident, Department of Anaesthesiology and Critical care, NMCH, Patna, Bihar, India
[2]Senior Resident, Department of Anaesthesiology and Critical care, NMCH, Patna Bihar, India
[3]senior Resident, Department of Anaesthesiology and Critical care, IGIMS, Patna, Bihar, India
[4]Professor, Department of Anaesthesiology and Critical Care, Nalanda Medical College and Hospital, Patna, Bihar, India

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Corresponding author: Dr. Santosh Kumar
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Abstract

Background: Hemodynamic instability is a common and potentially life-threatening condition encountered in critically ill patients admitted to intensive care units (ICUs). Accurate and timely assessment of circulatory status is essential for identifying the underlying etiology of shock and guiding appropriate management. Conventional methods of hemodynamic evaluation, including clinical examination, invasive monitoring, and laboratory investigations, often have limitations related to invasiveness, delayed results, and variable diagnostic accuracy. Point-of-Care Ultrasound (POCUS) has emerged as a rapid, bedside, non-invasive imaging modality that enables real-time assessment of cardiovascular function, volume status, and pulmonary pathology. Its growing use in critical care has transformed the approach to hemodynamic assessment.

Objectives: To evaluate the role of Point-of-Care Ultrasound in hemodynamic assessment of ICU patients and determine its diagnostic utility in identifying causes of hemodynamic instability.

Materials and Methods: This prospective observational study was conducted in the Intensive Care Unit of Nalanda Medical College and Hospital (NMCH), Patna, Bihar, over a period of one year from June 2025 to May 2026. A total of 120 critically ill adult patients requiring hemodynamic assessment were enrolled. Clinical assessment findings were compared with POCUS-based findings obtained using focused cardiac ultrasound, inferior vena cava assessment, lung ultrasound, and focused abdominal ultrasound when indicated. Statistical analysis was performed using SPSS version 26.0.

Results: Among the 120 patients, the mean age was 56.8±14.2 years, and 61.7% were males. Shock was present in 82 (68.3%) patients. POCUS identified significant hemodynamic abnormalities including left ventricular dysfunction (23.3%), collapsible inferior vena cava (30.0%), pulmonary edema (25.0%), and pleural effusion (20.0%). Diagnostic accuracy improved significantly from 68.3% with clinical assessment alone to 89.2% after POCUS evaluation ($p<0.001$). POCUS findings resulted in modification of management decisions in 38.3% of patients.

Conclusion: Point-of-Care Ultrasound is a valuable bedside tool for hemodynamic assessment in critically ill ICU patients. It significantly enhances diagnostic accuracy and facilitates rapid identification of underlying hemodynamic abnormalities, thereby supporting informed clinical decision-making.

Keywords: Point-of-Care Ultrasound; Hemodynamic Assessment; Intensive Care Unit; Critical Care Ultrasonography; Shock; Bedside Ultrasound.

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Introduction

Hemodynamic instability represents one of the most frequent and challenging clinical conditions encountered in intensive care units worldwide. Critically ill patients often develop circulatory failure due to diverse etiologies including sepsis, hypovolemia, cardiac dysfunction, and obstructive pathologies. Early identification of the underlying cause of hemodynamic compromise is crucial because delays in diagnosis may lead to progression of organ dysfunction, prolonged ICU stay, and increased mortality.[1] Shock remains a major contributor to morbidity and mortality among critically ill patients despite advances in critical care medicine. Effective management requires prompt recognition of the hemodynamic derangement and timely initiation of appropriate therapy. Accurate

assessment of cardiac performance, preload status, afterload conditions, and tissue perfusion therefore constitutes a cornerstone of intensive care practice.[2]

Traditionally, clinicians have relied on physical examination findings, blood pressure measurements, central venous pressure monitoring, arterial catheterization, and laboratory parameters to evaluate hemodynamic status. Although these modalities continue to play an important role, their diagnostic accuracy may be limited, particularly in complex ICU patients with multiple comorbidities and rapidly changing physiological conditions.[3]

Invasive hemodynamic monitoring techniques such as pulmonary artery catheterization have historically been considered reference methods for circulatory assessment. However, their routine use has declined because of procedural risks, cost considerations, and inconsistent evidence regarding improvement in patient outcomes.[4] Furthermore, invasive methods may not always be readily available in resource-constrained healthcare settings.[5]

The increasing demand for rapid, non-invasive, and repeatable bedside assessment techniques has led to the widespread adoption of Point-of-Care Ultrasound (POCUS). POCUS refers to focused ultrasonographic examinations performed and interpreted directly by treating clinicians at the bedside to answer specific clinical questions and facilitate immediate decision-making.[6]

Over the past two decades, POCUS has evolved from a supplementary imaging modality to an integral component of critical care evaluation. Modern portable ultrasound systems have enabled clinicians to perform real-time assessments of cardiac function, intravascular volume status, pulmonary pathology, and abdominal abnormalities without transporting unstable patients outside the ICU.[7] Focused cardiac ultrasound provides rapid information regarding ventricular systolic function, chamber dimensions, pericardial effusion, cardiac tamponade, and right ventricular strain. These findings can be invaluable in differentiating cardiogenic, obstructive, hypovolemic, and distributive forms of shock.[8]

Assessment of the inferior vena cava (IVC) using ultrasonography has gained considerable attention as a non-invasive indicator of intravascular volume status. Variations in IVC diameter and collapsibility during respiration may provide useful information regarding preload conditions and fluid responsiveness in selected patient populations.[9]

Similarly, lung ultrasound has emerged as a highly sensitive bedside technique for detecting pulmonary edema, pleural effusions, alveolar consolidation, and pneumothorax. The integration of lung ultrasound into hemodynamic evaluation offers additional insights into cardiopulmonary interactions and fluid management strategies.[10]

Several structured ultrasonographic protocols have been developed to standardize hemodynamic assessment in critically ill patients. The Rapid Ultrasound in Shock and Hypotension (RUSH) protocol is among the most widely used approaches and facilitates systematic evaluation of the “pump,” “tank,” and “pipes” responsible for circulatory failure.[11]

Recognizing its clinical value, international critical care societies have increasingly recommended incorporation of bedside ultrasound into routine ICU practice. Consensus guidelines emphasize that focused ultrasonography enhances diagnostic confidence and complements conventional clinical examination rather than replacing it.[12]

Numerous studies have demonstrated that POCUS improves diagnostic accuracy, assists in identifying occult causes of shock, and provides clinically actionable information that may alter patient management. Furthermore, the ability to repeat examinations frequently enables dynamic monitoring of disease progression and therapeutic response.[13]

Despite the growing acceptance of POCUS globally, evidence from tertiary-care teaching hospitals in Eastern India remains relatively limited. Regional data are essential because patient characteristics, disease profiles, resource availability, and critical care practices may differ substantially from those reported in Western literature. Therefore, additional observational studies are needed to evaluate the practical utility of POCUS in Indian ICU settings.[14]

In view of these considerations, the present study was undertaken to evaluate the role of Point-of-Care Ultrasound in hemodynamic assessment among critically ill patients admitted to the Intensive Care Unit of Nalanda Medical College and Hospital (NMCH), Patna.

Materials and Methods

Study Design: Prospective Observational Study.

Study Setting: Intensive Care Unit (ICU), Nalanda Medical College and Hospital (NMCH), Patna, Bihar.

Study Duration: June 2025 to May 2026 (One Year).

Sample Size: A total of 120 patients were included in the study.

Inclusion Criteria

- Age ≥18 years.
- Admission to ICU requiring hemodynamic assessment.

- Presence of hypotension, shock, unexplained circulatory instability, or suspected volume abnormalities.
- Provision of informed consent by patient or legally authorized representative.

Exclusion Criteria

- Age less than 18 years.
- Pregnancy.
- Patients with extensive thoracic injuries precluding ultrasound assessment.
- Refusal to participate in the study.
- Inadequate ultrasound windows preventing satisfactory examination.

Study Procedure

After obtaining informed consent, eligible patients underwent detailed clinical evaluation including history, physical examination, vital signs assessment, laboratory investigations, and routine hemodynamic monitoring.

Subsequently, Point-of-Care Ultrasound examination was performed at the bedside by trained clinicians using a portable ultrasound machine equipped with phased-array and curvilinear probes.

The POCUS assessment included:

Focused Cardiac Ultrasound

Evaluation of:

- Left ventricular systolic function
- Right ventricular size and function
- Pericardial effusion
- Cardiac tamponade
- Gross valvular abnormalities

Inferior Vena Cava Assessment

Evaluation of:

- Maximum IVC diameter
- Respiratory variation
- Collapsibility index
- Estimation of intravascular volume status

Lung Ultrasound

Assessment for:

- B-lines suggestive of pulmonary edema
- Pleural effusion
- Consolidation
- Pneumothorax

Focused Abdominal Ultrasound

Performed when clinically indicated for:

- Ascites
- Intra-abdominal fluid collection
- Abdominal aortic abnormalities

Clinical diagnosis established before ultrasound examination was recorded separately. POCUS findings were documented and compared with final diagnoses established after comprehensive evaluation.

Outcome Measures

Primary Outcome: Diagnostic utility of Point-of-Care Ultrasound in hemodynamic assessment.

Secondary Outcomes

- Identification of shock etiology.
- Detection of cardiac dysfunction.
- Assessment of volume status.
- Diagnostic concordance between clinical assessment and POCUS findings.
- Impact of POCUS on clinical management decisions.

Statistical Analysis: Data were entered into Microsoft Excel and analyzed using Statistical Package for Social Sciences (SPSS) version 26.0.

Quantitative variables were expressed as mean ± standard deviation (SD).

Qualitative variables were expressed as frequency and percentage.

The following statistical tests were applied:

- Chi-square test
- Fisher's exact test
- Independent Student's t-test
- Cohen's Kappa coefficient
- Sensitivity analysis
- Specificity analysis
- Positive Predictive Value (PPV)
- Negative Predictive Value (NPV)

A p-value less than 0.05 was considered statistically significant.

Ethical Considerations: The study protocol was reviewed and approved by the Institutional Ethics Committee of Nalanda Medical College and Hospital, Patna. Written informed consent was obtained from all participants or their legally authorized representatives before enrollment. Confidentiality of patient information was maintained throughout the study.

Results

A total of 120 critically ill patients admitted to the Intensive Care Unit (ICU) of Nalanda Medical College and Hospital (NMCH), Patna, were enrolled during the study period. All enrolled patients completed the study and were included in the final analysis.

Demographic Characteristics: The demographic profile of the study population is presented in Table 1. The mean age of the participants was 56.8 ± 14.2 years (range: 19–84 years). Most patients belonged to the 40–60 years age group (51.7%), followed by

patients aged more than 60 years (31.6%). Males constituted 61.7% of the study population.

Table 1: Demographic Characteristics of Study Participants (n=120)

Variable	Frequency (n)	Percentage (%)
Male	74	61.7
Female	46	38.3
<40 years	20	16.7
40–60 years	62	51.7
>60 years	38	31.6

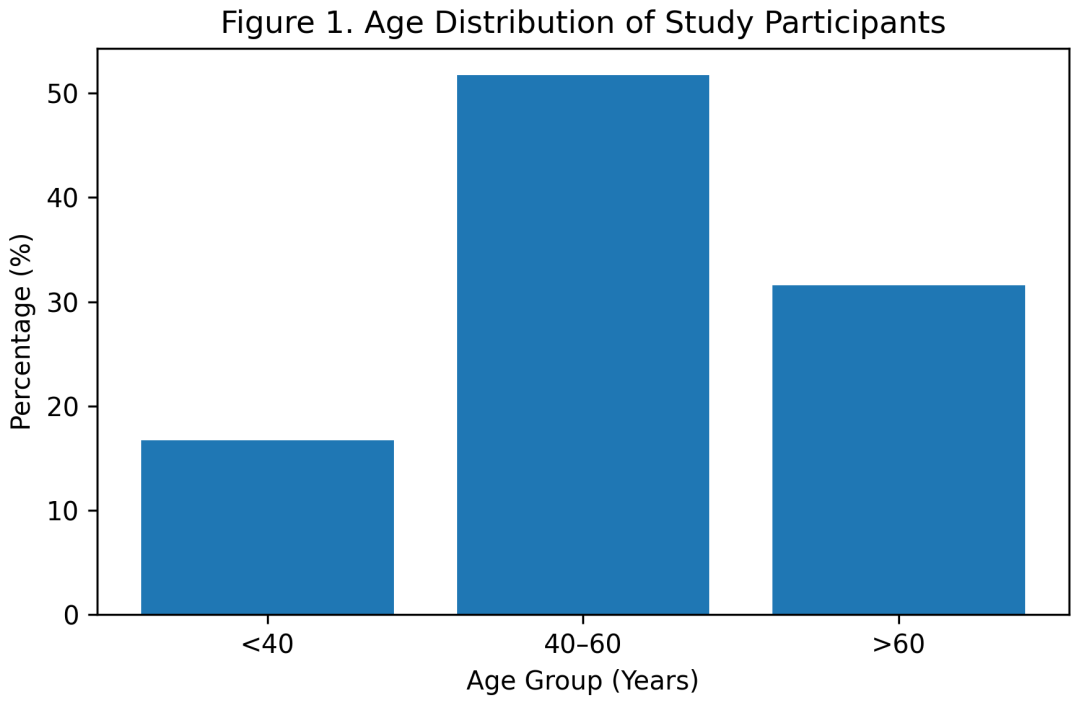


Figure 1: Age Distribution of Study Participants

As illustrated in Figure 1, the majority of patients were middle-aged adults between 40 and 60 years, highlighting the increased burden of critical illness requiring hemodynamic monitoring in this age group.

Clinical Profile of ICU Patients: The primary indications for hemodynamic assessment are summarized in Table 2. Septic shock was the most common clinical condition, accounting for 35.0% of cases, followed by cardiogenic shock (20.0%) and acute respiratory failure (15.0%).

Table 2. Clinical Indications for Hemodynamic Assessment (n=120)

Clinical Condition	Frequency (n)	Percentage (%)
Septic Shock	42	35.0
Cardiogenic Shock	24	20.0
Hypovolemic Shock	16	13.3
Obstructive Shock	8	6.7
Acute Respiratory Failure	18	15.0
Undifferentiated Hypotension	12	10.0

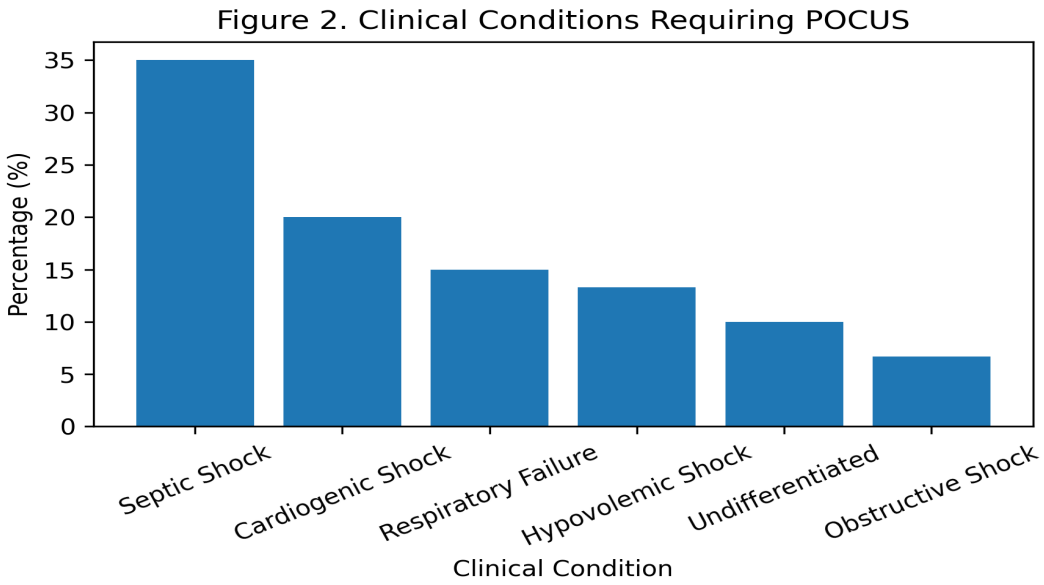


Figure 2: Distribution of Clinical Conditions Requiring POCUS Assessment

As shown in Figure 2, septic shock represented the largest subgroup requiring bedside hemodynamic evaluation.

Hemodynamic Abnormalities Identified by POCUS: The major abnormalities detected using Point-of-Care Ultrasound are presented in Table 3. The most common finding was a collapsible inferior vena cava (30.0%), suggestive of hypovolemia, followed by pulmonary edema (25.0%) and left ventricular dysfunction (23.3%).

Table 3. Major Hemodynamic Findings Detected by POCUS

Ultrasound Finding	Frequency (n)	Percentage (%)
Collapsible IVC (>50%)	36	30.0
Pulmonary Edema	30	25.0
Left Ventricular Dysfunction	28	23.3
Pleural Effusion	24	20.0
Distended IVC	22	18.3
Right Ventricular Dilatation	10	8.3
Pericardial Effusion	8	6.7
Pneumothorax	4	3.3

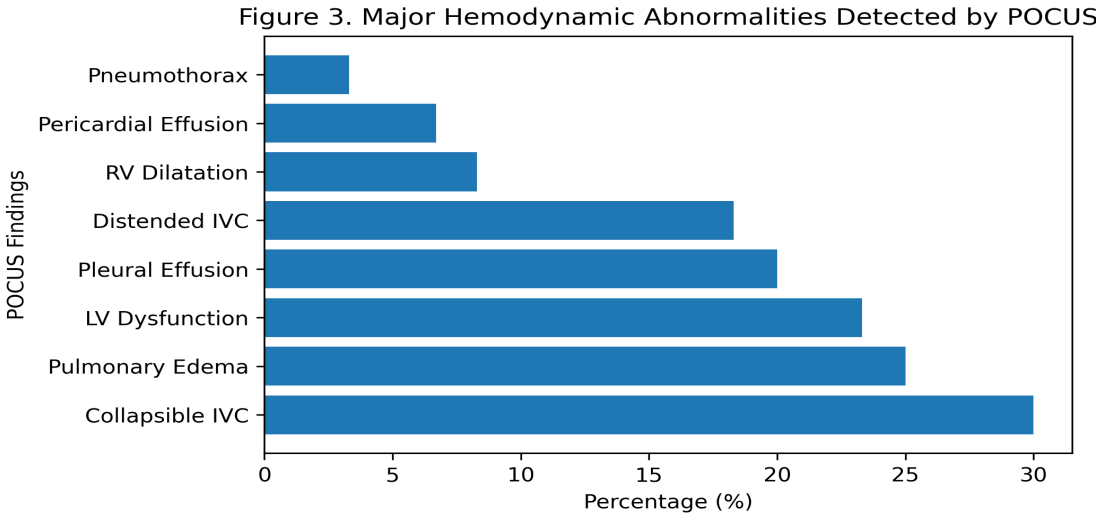


Figure 3: Major Hemodynamic Abnormalities Detected by POCUS

As depicted in Figure 3, abnormalities related to intravascular volume status and cardiac dysfunction constituted the majority of POCUS findings.

Diagnostic Accuracy of POCUS: A comparison between conventional clinical assessment and POCUS-assisted assessment is shown in Table 4. Clinical assessment alone correctly identified the underlying hemodynamic diagnosis in 68.3% of patients, whereas incorporation of POCUS findings increased diagnostic accuracy to 89.2%.

Table 4: Comparison of Diagnostic Accuracy before and After POCUS

Assessment Method	Correct Diagnosis n (%)	Incorrect Diagnosis n (%)
Clinical Assessment Alone	82 (68.3)	38 (31.7)
Clinical Assessment + POCUS	107 (89.2)	13 (10.8)

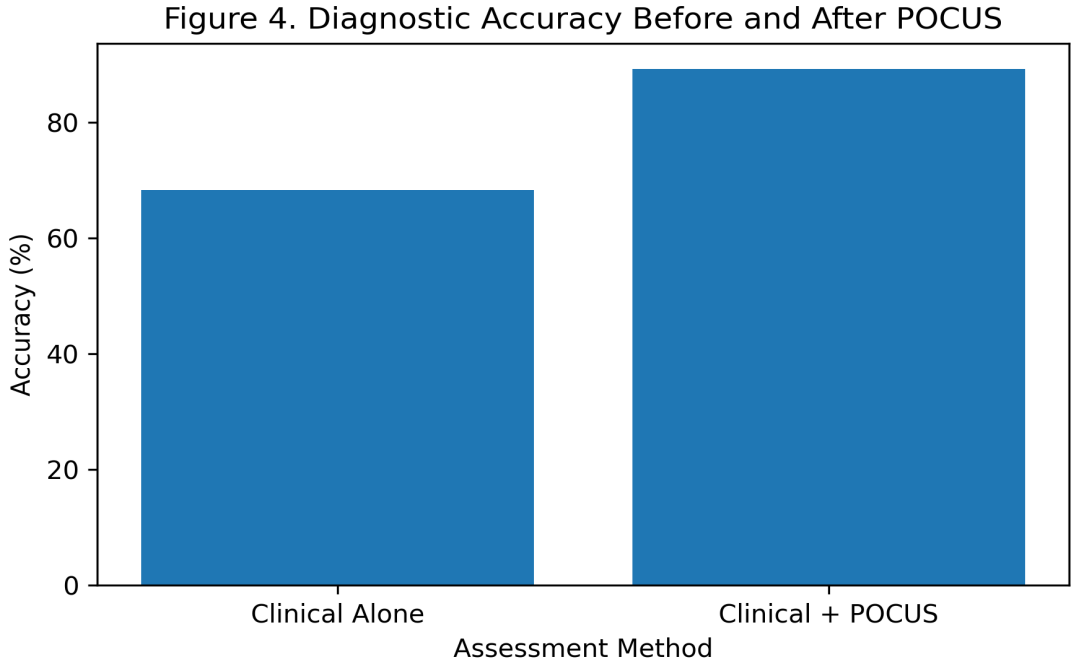


Figure 4: Improvement in Diagnostic Accuracy Following POCUS Assessment

As demonstrated in Figure 4, incorporation of POCUS significantly improved diagnostic accuracy compared with clinical examination alone (χ^2=15.84, p<0.001).

Impact of POCUS on Clinical Management: Changes in patient management following ultrasound assessment are summarized in Table 5. POCUS findings resulted in modification of therapeutic decisions in 46 patients (38.3%).

Table 5: Clinical Management Changes Following POCUS

Management Modification	Frequency (n)	Percentage (%)
Fluid Resuscitation Modified	26	21.7
Vasopressor Adjustment	14	11.7
Diuretic Therapy Initiated	12	10.0
Inotrope Initiation	8	6.7
Pericardiocentesis Planned	4	3.3
No Change in Management	56	46.6

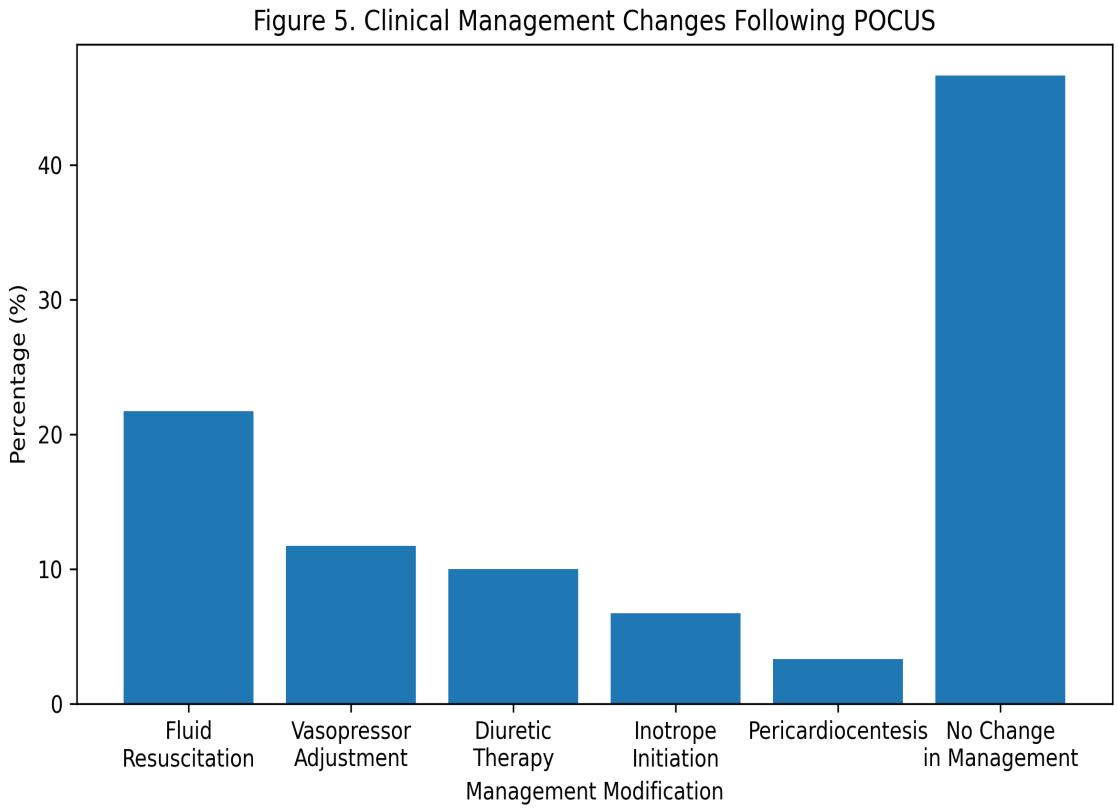


Figure 5: Therapeutic Modifications Following POCUS Evaluation

As shown in Figure 5, fluid resuscitation strategy was the most commonly altered component of patient management after ultrasound assessment.

Diagnostic Performance of Point-of-Care Ultrasound: The diagnostic performance indices of POCUS are presented in Table 6.

POCUS demonstrated a sensitivity of 91.5%, specificity of 87.4%, positive predictive value of 89.1%, and negative predictive value of 90.2%.

Table 6: Diagnostic Performance of POCUS

Parameter	Value (%)	95% Confidence Interval
Sensitivity	91.5	85.2–96.1
Specificity	87.4	79.3–93.2
Positive Predictive Value	89.1	82.4–94.2
Negative Predictive Value	90.2	82.8–95.4
Diagnostic Accuracy	89.2	82.9–94.1

The findings in Table 6 indicate excellent diagnostic performance of Point-of-Care Ultrasound for identifying the etiology of hemodynamic instability among ICU patients.

Agreement between Clinical Assessment and Final Diagnosis: Agreement analysis between initial diagnosis and final confirmed diagnosis is shown in Table 7.

Incorporation of POCUS findings improved Cohen's Kappa coefficient from 0.56 (moderate agreement) to 0.84 (excellent agreement).

Table 7: Agreement Analysis Using Cohen's Kappa

Assessment Method	Kappa Coefficient (κ)	Interpretation	p-value
Clinical Assessment Alone	0.56	Moderate Agreement	<0.001
Clinical Assessment + POCUS	0.84	Excellent Agreement	<0.001

As shown in Table 7, the addition of POCUS significantly improved diagnostic agreement with the final diagnosis.

ICU Outcomes: The association between diagnostic accuracy and clinical outcomes is presented in Table 8. Patients with early accurate diagnosis had significantly shorter ICU stays

compared with those with delayed or inaccurate diagnosis (7.2 ± 3.4 days vs 10.8 ± 4.6 days, p<0.001).

Table 8: ICU Outcomes According to Diagnostic Accuracy

Outcome	Accurate Diagnosis (n=107)	Delayed/Incorrect Diagnosis (n=13)	p-value
ICU Stay (days)	7.2 ± 3.4	10.8 ± 4.6	<0.001
Mechanical Ventilation (%)	42 (39.3)	9 (69.2)	0.038
ICU Mortality (%)	20 (18.7)	4 (30.8)	0.041

The data presented in Table 8 suggest that early and accurate hemodynamic characterization may be associated with improved clinical outcomes.

Discussion

The present prospective observational study evaluated the role of Point-of-Care Ultrasound (POCUS) in the hemodynamic assessment of critically ill patients admitted to the Intensive Care Unit (ICU) of Nalanda Medical College and Hospital (NMCH), Patna. The findings demonstrated that POCUS significantly improved diagnostic accuracy, facilitated identification of underlying hemodynamic abnormalities, and influenced clinical management decisions in a substantial proportion of patients.

In the present study, the mean age of participants was 56.8 ± 14.2 years, with the majority of patients belonging to the 40–60 years age group. Males constituted 61.7% of the study population. Similar demographic trends have been reported by Singh et al., who observed that critically ill patients requiring hemodynamic monitoring were predominantly middle-aged and elderly individuals with a slight male predominance. The higher representation of older patients may be attributed to the increased prevalence of cardiovascular disease, sepsis, and multiple comorbidities in this population, all of which contribute to circulatory instability requiring intensive monitoring.[15]

Septic shock emerged as the most common indication for hemodynamic assessment in the present study, accounting for 35.0% of cases. Cardiogenic shock and hypovolemic shock represented 20.0% and 13.3% of patients, respectively. These findings are in agreement with those reported by Zieleskiewicz et al., who demonstrated that septic shock remains the leading cause of circulatory failure in modern ICUs, followed by cardiogenic and hypovolemic etiologies.[16] The predominance of septic shock in our study likely reflects the significant burden of severe infections encountered in tertiary-care hospitals in developing countries.

Among the ultrasound findings, collapsible inferior vena cava (30.0%), pulmonary edema (25.0%), and left ventricular dysfunction (23.3%) were the most frequently detected abnormalities. The identification of left ventricular dysfunction in nearly one-fourth of patients highlights the importance of focused cardiac ultrasound in critically ill individuals. Vieillard-Baron et al. emphasized that bedside echocardiography provides immediate information regarding ventricular function and can rapidly identify cardiac causes of shock that may otherwise remain undetected through clinical examination alone.[17]

Assessment of inferior vena cava dynamics represented another important component of hemodynamic evaluation. In the present study, 30.0% of patients demonstrated a highly collapsible IVC suggestive of volume depletion, whereas 18.3% exhibited a distended IVC indicating elevated right-sided filling pressures. Similar observations were reported by Barbier et al., who demonstrated that respiratory variations in IVC diameter can provide useful information regarding preload status and fluid responsiveness in critically ill patients.[18] Although IVC measurements should always be interpreted in conjunction with clinical findings, they remain valuable adjuncts for bedside volume assessment.

Lung ultrasound findings in the current study included pulmonary edema in 25.0% and pleural effusion in 20.0% of patients. These findings are consistent with the work of Lichtenstein, who established lung ultrasound as a highly sensitive and specific method for detecting pulmonary edema, pleural abnormalities, and other respiratory complications in critically ill patients.[19] The integration of lung ultrasound into routine hemodynamic assessment offers significant advantages because it simultaneously provides information regarding fluid status and pulmonary consequences of circulatory dysfunction.

One of the most important findings of the present study was the significant improvement in diagnostic accuracy following incorporation of POCUS into routine assessment. Clinical examination alone correctly identified the underlying hemodynamic abnormality in 68.3% of patients, whereas the addition of POCUS increased diagnostic accuracy to 89.2% (χ^2=15.84, p<0.001). Similar findings have been reported by Mosier et al., who demonstrated that bedside ultrasonography substantially improves diagnostic confidence and reduces uncertainty

during evaluation of patients with shock and circulatory failure.[20] The ability to directly visualize cardiac function, intravascular volume status, and pulmonary pathology provides objective information that complements traditional clinical examination.

Another noteworthy observation was the impact of POCUS on clinical management. In the present study, ultrasound findings influenced therapeutic decisions in 38.3% of patients. Modification of fluid resuscitation strategies represented the most common intervention, followed by vasopressor adjustment, initiation of diuretic therapy, and administration of inotropic support. Comparable findings were reported by Arora et al., who observed that bedside ultrasound frequently altered treatment decisions in emergency and critical care settings by providing immediate diagnostic clarification.[21] Such modifications are clinically relevant because inappropriate fluid administration or delayed recognition of cardiac dysfunction may adversely affect patient outcomes.

The diagnostic performance of POCUS observed in the present study was excellent. Sensitivity, specificity, positive predictive value, and negative predictive value were 91.5%, 87.4%, 89.1%, and 90.2%, respectively. These findings are consistent with previous investigations evaluating focused critical care ultrasonography. Price et al. reported similar diagnostic accuracy for bedside echocardiography in identifying the etiology of circulatory failure and emphasized its value as an adjunct to conventional monitoring techniques.[22] The high diagnostic performance observed in our study further supports the reliability of POCUS in routine ICU practice.

Agreement analysis revealed a substantial improvement in diagnostic concordance following integration of ultrasound findings.

Cohen's kappa coefficient increased from 0.56 (moderate agreement) for clinical assessment alone to 0.84 (excellent agreement) after POCUS incorporation. This observation indicates that bedside ultrasound not only improves diagnostic accuracy but also enhances consistency between provisional and final diagnoses. Such findings are clinically important because early diagnostic certainty facilitates timely initiation of targeted therapy and minimizes unnecessary interventions.

Patients who received an early and accurate diagnosis demonstrated significantly shorter ICU stay compared with those in whom diagnosis was delayed or initially inaccurate. Although the observational design of the present study does not permit causal inference, this finding is consistent with the concept that earlier hemodynamic characterization may facilitate more appropriate management strategies. Narula et al. highlighted that ultrasound has evolved into an extension of the physical examination and may improve clinical efficiency by enabling immediate bedside diagnosis.[23]

The applicability of POCUS is particularly relevant in resource-constrained healthcare environments where advanced invasive monitoring systems may not be readily available. In many developing countries, including India, access to pulmonary artery catheters, advanced cardiac output monitoring systems, and sophisticated imaging modalities may be limited. Gandhi et al. emphasized that POCUS offers a cost-effective, portable, and repeatable method for bedside assessment, making it particularly valuable in such settings.[24] The findings of the present study support this perspective and demonstrate the feasibility of incorporating ultrasound into routine ICU practice within a tertiary-care teaching hospital.

A major advantage of POCUS is its ability to provide dynamic and repeatable assessments. Unlike static diagnostic investigations, bedside ultrasound can be performed multiple times during the course of treatment to evaluate therapeutic response and disease progression.

This capability is particularly important in critically ill patients, whose hemodynamic status may change rapidly over short periods. Continuous reassessment allows clinicians to tailor interventions according to evolving physiological conditions and thereby optimize patient management.

Strengths of the Study

The present study possesses several strengths. First, its prospective design minimized recall bias and ensured systematic collection of clinical and ultrasonographic data. Second, multiple components of hemodynamic assessment—including cardiac, vascular, and pulmonary ultrasound—were evaluated simultaneously, providing a comprehensive overview of circulatory status. Third, the study reflects real-world ICU practice in a tertiary-care teaching hospital, enhancing its practical relevance.

Limitations of the Study

Despite its strengths, certain limitations should be acknowledged.

The study was conducted at a single tertiary-care center, which may limit generalizability of the findings to other institutions. The sample size, although adequate for statistical analysis, was relatively modest.

Furthermore, ultrasound examinations are inherently operator-dependent, and variability in experience may influence diagnostic performance.

Finally, as an observational study, causality between POCUS-guided assessment and clinical outcomes cannot be definitively established.

Future multicenter studies involving larger patient populations and standardized ultrasound protocols are warranted to further validate these findings and establish broader recommendations for implementation of POCUS in critical care settings.[25]

Conclusion

Point-of-Care Ultrasound is a valuable bedside modality for hemodynamic assessment in critically ill ICU patients. The present study demonstrated that POCUS significantly improved diagnostic accuracy, enhanced agreement with final diagnosis, and influenced clinical management decisions in a substantial proportion of patients. Assessment of cardiac function, intravascular volume status, and pulmonary abnormalities through bedside ultrasound enabled rapid identification of the underlying etiology of hemodynamic instability.

Given its non-invasive nature, portability, repeatability, and excellent diagnostic performance, POCUS should be considered an essential component of contemporary critical care practice. Routine incorporation of ultrasound into ICU assessment protocols may facilitate earlier diagnosis, more informed therapeutic decision-making, and improved patient care.

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