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Comparative Analysis Of Point-Of-Care Ultrasound And, Conventional Clinical Assessment For Volume Status Evaluation In Newly Admitted Hospital Patients

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ABSTRACT

Background: Accurate volume status assessment remains a fundamental challenge in managing newly admitted hospital patients. Traditional clinical assessment methods demonstrate significant inter-observer variability and limited diagnostic accuracy. Point-of-care ultrasound (POCUS), particularly inferior vena cava (IVC) assessment, has emerged as a promising non-invasive bedside tool, yet its comparative effectiveness against conventional methods in Saudi Arabian healthcare requires investigation.

Objectives: This study compares the diagnostic accuracy, clinical utility, and feasibility of POCUS-guided IVC assessment versus conventional clinical evaluation for determining volume status in newly admitted hospital patients. Secondary objectives include evaluating POCUS impact on clinical decision-making, fluid management strategies, and patient outcomes within Saudi Arabian tertiary care settings.

Methods: This prospective observational comparative study will enroll 200 adult patients admitted to emergency departments and intensive care units at tertiary hospitals in Riyadh. Patients undergo simultaneous assessment using POCUS (IVC diameter and collapsibility/distensibility indices) and conventional methods (physical examination, vital signs, clinical gestalt). The reference standard comprises hemodynamic response to fluid challenge. Primary outcomes include sensitivity, specificity, and area under receiver operating characteristic curve for predicting fluid responsiveness. Secondary outcomes encompass inter-rater reliability, assessment completion time, and clinical decision concordance.

Results: Based on existing literature, POCUS-guided IVC assessment should demonstrate superior diagnostic accuracy compared to conventional methods, with expected sensitivity of 75-88% and specificity of 73-86% for predicting fluid responsiveness. The caval index cutoff of 40-50% should show optimal performance. POCUS is expected to reduce inter-observer variability and provide more objective, reproducible measurements compared to clinical gestalt, potentially improving fluid management decisions.

Conclusions: Integration of POCUS-guided volume assessment represents significant advancement in bedside hemodynamic evaluation. This study will provide crucial evidence for Saudi Arabian healthcare institutions regarding POCUS protocol implementation, potentially establishing new care standards combining objective ultrasound measurements with traditional clinical acumen to optimize patient management and resource utilization.

Keywords: Point-of-care ultrasound; Inferior vena cava; Volume status assessment; Fluid responsiveness; Clinical assessment; Hemodynamic monitoring; Emergency medicine.

1. INTRODUCTION

1.1 Background and Clinical Significance

Accurate intravascular volume status assessment constitutes one of the most critical yet challenging aspects of acute care medicine. In emergency departments and intensive care units across Saudi Arabia, clinicians encounter numerous patients requiring rapid volume status evaluation to guide therapeutic interventions. Consequences of inaccurate assessment range from inadequate tissue perfusion and organ dysfunction in under-resuscitated patients to pulmonary edema, prolonged mechanical ventilation, and increased mortality in those receiving excessive fluid administration. Traditional volume assessment has relied predominantly on clinical examination, vital signs monitoring, and physician gestalt—methods demonstrating significant limitations in diagnostic accuracy and reproducibility.

This challenge is particularly pronounced in Saudi Arabian healthcare, where tertiary centers manage high volumes of acutely ill patients with diverse conditions including sepsis, trauma, cardiac emergencies, and heat-related illnesses. The Kingdom's Vision 2030 healthcare transformation initiatives emphasize adopting evidence-based practices and advanced diagnostic technologies to improve patient outcomes and efficiency. Within this framework, point-of-care ultrasound has emerged as transformative technology placing powerful diagnostic capabilities directly at the bedside, enabling real-time clinical decision-making without delays and resource requirements of traditional imaging modalities.

Volume status assessment centers on relationships between intravascular volume, cardiac preload, and cardiac output. In hypovolemic states, reduced venous return leads to decreased cardiac filling pressures and diminished stroke volume, potentially compromising tissue perfusion. Conversely, volume overload increases hydrostatic pressures, promoting fluid extravasation and potentially causing pulmonary congestion. Fluid responsiveness—the cardiovascular system's ability to increase cardiac output following fluid administration—has become central to modern hemodynamic management. However, accurately predicting fluid responsiveness at the bedside remains challenging, as static volume measures often fail to reflect dynamic cardiovascular physiology.

1.2 Current Challenges in Volume Assessment

Conventional clinical assessment encompasses physical examination findings and vital signs parameters. Clinicians traditionally assess skin turgor, capillary refill time, mucous membrane moisture, jugular venous pressure, peripheral edema, lung auscultation, and vital signs including heart rate, blood pressure, and urine output. While providing valuable information, multiple studies demonstrate limited sensitivity and specificity for accurately determining volume status and predicting fluid responsiveness. Physical examination findings are particularly unreliable in patients with chronic conditions, elderly individuals, and those with altered tissue characteristics.

Clinical gestalt's subjective nature introduces significant inter-observer variability, with different clinicians potentially reaching divergent conclusions examining the same patient. This variability is compounded by clinician experience level, time constraints, and cognitive biases. Studies comparing physician volume status assessment to objective measurements reveal concordance rates as low as 50-70%, highlighting inadequacy of relying solely on clinical impression for critical therapeutic decisions. Furthermore, vital signs are influenced by numerous factors beyond volume status, including pain, anxiety, medications, and underlying cardiovascular disease, limiting their utility as isolated volume indicators.

Central venous pressure monitoring, once considered the gold standard, has fallen from favor as evidence demonstrates poor correlation with actual intravascular volume and inability to predict fluid responsiveness. CVP measurement's invasive nature, requiring central venous catheter placement, introduces procedural risks including pneumothorax, arterial puncture, and catheter-related infections. These risks are particularly concerning in resource-limited settings and with less experienced operators. More sophisticated hemodynamic monitoring technologies provide detailed physiological data but require invasive procedures, specialized equipment, and expertise that may not be readily available, particularly in emergency departments during initial assessment.

1.3 Rationale for Point-of-Care Ultrasound

Point-of-care ultrasound represents a paradigm shift in bedside diagnostic capabilities, transforming ultrasound from a radiology department procedure to an extension of physical examination performed by treating clinicians. POCUS integration into emergency and critical care has accelerated dramatically over two decades, driven by technological advances producing portable, high-quality ultrasound devices at increasingly accessible prices. Modern POCUS devices range from pocket-sized units to full-featured portable systems, enabling ultrasound assessment in virtually any clinical environment.

POCUS application for volume assessment centers on inferior vena cava evaluation, a large central vein serving as a reservoir for venous return to the right atrium. IVC diameter and respiratory variation reflect right atrial pressure and intravascular volume status, providing non-invasive insight into central hemodynamics. In spontaneously breathing patients, the IVC normally collapses during inspiration as negative intrathoracic pressure increases venous return. Collapse degree, quantified as collapsibility index, correlates with intravascular volume status—greater collapse suggests lower volume and potential fluid responsiveness, while minimal collapse indicates adequate or excessive volume. In mechanically ventilated patients, physiology reverses, with positive pressure ventilation causing IVC distension during inspiration, measured as distensibility index.

POCUS-guided volume assessment offers compelling theoretical advantages. The technique is non-invasive, eliminating procedural risks associated with central line placement. It provides real-time, dynamic information that can be serially repeated without additional risk or cost. Ultrasound imaging's visual nature offers objective, documentable findings reviewable by multiple clinicians, potentially reducing inter-observer variability compared to subjective physical examination. POCUS assessment can be performed rapidly at the bedside, typically requiring 2-5 minutes, enabling timely clinical decision-making without transport delays or invasive monitoring placement.

Furthermore, POCUS enables integration of multiple assessment modalities in comprehensive bedside evaluation. Beyond IVC assessment, clinicians can simultaneously evaluate cardiac function, assess for pulmonary edema using lung ultrasound, and examine for free fluid. This multimodal approach provides more complete hemodynamic pictures than any single parameter.

POCUS educational benefits are also significant, as visual feedback enhances learning and allows immediate correlation between ultrasound findings and clinical presentation, potentially improving diagnostic reasoning skills.

1.4 Study Rationale and Objectives

Despite growing enthusiasm for POCUS in volume assessment, important questions remain regarding comparative effectiveness against conventional clinical methods in real-world practice. While numerous studies have evaluated IVC ultrasound in isolation, fewer have directly compared POCUS-guided assessment to clinical evaluation methods clinicians currently employ. Understanding relative performance is essential for evidence-based POCUS integration into clinical workflows and determining whether POCUS should supplement or potentially replace certain traditional assessment aspects.

The Saudi Arabian healthcare context presents unique POCUS implementation considerations. The Kingdom's healthcare system combines state-of-the-art tertiary facilities with diverse patient populations and varying clinician training levels. Cultural factors, including patient preferences for non-invasive procedures and family involvement importance in medical decision-making, may influence new diagnostic technology acceptability and implementation. Additionally, POCUS adoption economic considerations, including equipment costs, training requirements, and potential healthcare efficiency impacts, require careful evaluation within Saudi healthcare financing frameworks.

This study aims to provide comprehensive, high-quality evidence comparing POCUS-guided IVC assessment to conventional clinical evaluation for volume status determination in newly admitted hospital patients. By conducting research within Saudi Arabian tertiary centers, we will generate locally relevant data informing clinical practice guidelines and healthcare policy decisions. Findings will contribute to growing international evidence while addressing specific Middle Eastern healthcare system questions. Ultimately, this research seeks to optimize patient care by identifying the most accurate, efficient, and feasible bedside volume assessment approaches, potentially establishing new care standards leveraging complementary strengths of technological innovation and clinical expertise.

2. LITERATURE REVIEW

2.1 Physiological Basis of IVC Assessment

The inferior vena cava serves as the primary conduit for venous return from the lower body to the right atrium, making it ideal for non-invasive central venous pressure and volume status assessment. IVC diameter and respiratory variation are influenced by multiple physiological factors, including intravascular volume, right atrial pressure, intrathoracic pressure changes during respiration, and right ventricular function. Understanding these physiological relationships is fundamental to interpreting IVC ultrasound findings and applying them appropriately in clinical decision-making.

In spontaneously breathing patients, inspiration generates negative intrathoracic pressure increasing the pressure gradient between peripheral veins and right atrium, augmenting venous return. This increased venous return causes IVC collapse as blood is drawn into the thorax. Collapse magnitude reflects venous system compliance and intravascular volume adequacy. In hypovolemic states, the IVC demonstrates marked inspiratory collapse, often exceeding 50% diameter reduction, as limited intravascular volume is readily mobilized by negative intrathoracic pressure. Conversely, in euvolemic or hypervolemic states, the IVC maintains larger diameter with minimal respiratory variation, as the well-filled venous system is less responsive to respiratory pressure changes.

Collapsibility index is calculated as the difference between maximum IVC diameter during expiration and minimum diameter during inspiration, divided by maximum diameter, expressed as percentage. Multiple studies have investigated optimal cutoff values, with most evidence suggesting values greater than 40-50% indicate potential fluid responsiveness in spontaneously breathing patients. However, the relationship between collapsibility index and fluid responsiveness is not absolute, as numerous factors can influence IVC dynamics independent of volume status, including right ventricular dysfunction, tricuspid regurgitation, pulmonary hypertension, and increased intra-abdominal pressure.

In mechanically ventilated patients, physiology reverses due to positive pressure ventilation. During inspiratory phase, positive intrathoracic pressure impedes venous return, causing IVC distension as blood accumulates. Distensibility index, calculated as the difference between maximum IVC diameter during inspiration and minimum diameter during expiration divided by minimum diameter, serves as the analogous parameter. Distensibility index values greater than 18-20% have been associated with fluid responsiveness in mechanically ventilated patients, though evidence is more variable than for spontaneously breathing patients.

2.2 Evidence for POCUS in Volume Assessment

Literature supporting POCUS-guided IVC assessment for volume status evaluation has expanded substantially over the past decade, encompassing diverse patient populations and clinical settings. A landmark prospective study by Sawe et al. enrolled 364 emergency department patients requiring fluid resuscitation and compared IVC collapsibility index measurements to physician gestalt for predicting blood pressure response to fluid administration [1]. The study found that collapsibility index cutoff of 50% demonstrated sensitivity of 88% and specificity of 73% for predicting 10 mmHg mean arterial pressure increase per liter of fluid, with area under receiver operating characteristic curve of 0.85. Notably, physician gestalt showed comparable overall performance with AUC of 0.83, but with different sensitivity-specificity characteristics (68% sensitivity, 86% specificity), suggesting POCUS and clinical assessment may provide complementary information [1].

A systematic review and meta-analysis by Kim et al. evaluated diagnostic accuracy of ultrasonographic respiratory variation in IVC and other central veins for predicting fluid responsiveness across 30 studies comprising 1,719 critically ill patients [19]. The meta-analysis revealed substantial heterogeneity in study methodologies, patient populations, and cutoff values, reflecting the field's evolving nature and challenges in standardizing POCUS protocols. Despite heterogeneity, overall findings supported IVC assessment utility, particularly in spontaneously breathing patients, though authors emphasized need for careful clinical context consideration and integration with other assessment parameters.

Recent randomized controlled trial evidence has begun addressing whether POCUS-guided fluid management improves clinical outcomes beyond diagnostic accuracy alone. Musikatavorn et al. conducted a randomized controlled trial of 202 patients with sepsis-induced hypoperfusion and septic shock, comparing ultrasound-guided fluid resuscitation to usual care [12]. The ultrasound-guided group received fluid management based on IVC collapsibility index and other ultrasound parameters, while controls received standard care based on clinical assessment and vital signs. The study demonstrated ultrasound-guided management was feasible and safe, though differences in major clinical outcomes were not statistically significant, possibly due to sample size limitations and overall high care quality in both groups.

POCUS application in specific patient populations has revealed important nuances. In pediatric patients, Yildizdas et al. reviewed evidence for IVC assessment in critically ill children, noting that while physiological principles remain similar to adults, age-specific reference values and technical considerations are necessary [4]. Smaller pediatric IVC size and challenges obtaining adequate imaging windows in uncooperative children present practical obstacles. Similarly, in elderly patients and those with chronic conditions such as heart failure or chronic kidney disease, IVC findings interpretation requires careful consideration of baseline cardiovascular function and chronic volume status alterations.

2.3 Comparison with Conventional Assessment Methods

Direct comparisons between POCUS and conventional clinical assessment have yielded valuable insights into relative strengths and limitations of each approach. The Sawe et al. study is particularly instructive, as it prospectively compared IVC ultrasound to physician gestalt in the same patient cohort [1]. The finding that both methods demonstrated similar overall diagnostic accuracy (AUC 0.85 vs 0.83) but with different sensitivity-specificity profiles suggests they may capture different volume status aspects. POCUS showed higher sensitivity, potentially making it more useful for ruling out fluid responsiveness, while physician gestalt demonstrated higher specificity, which may be valuable for confirming fluid administration need in resource-limited settings where conservative fluid strategies are preferred.

A prospective observational study by Valk et al. evaluated 45 emergency department patients with shock signs, comparing IVC collapsibility index to clinical assessment and hemodynamic response to fluid challenge [5]. The study found that while IVC assessment provided objective measurements, clinical factors including shock etiology (sepsis vs. dehydration vs. hemorrhage) significantly influenced IVC parameter predictive value. This highlights an important limitation of relying on any single parameter in isolation—clinical context and underlying pathophysiology must inform interpretation of both POCUS findings and conventional assessment parameters.

Inter-observer variability represents a critical consideration in comparing assessment methods. While physical examination findings are notoriously subjective and variable between observers, POCUS is not immune to operator-dependent variability. Factors including probe positioning, measurement location along IVC, timing relative to respiratory cycle, and image quality all influence IVC measurement reliability. Studies evaluating inter-rater reliability of IVC measurements show variable results, with some demonstrating excellent agreement between trained operators while others reveal significant variability, particularly among less experienced users. This underscores the importance of standardized training protocols and quality assurance measures when implementing POCUS programs.

2.4 Diagnostic Accuracy Studies

IVC assessment diagnostic accuracy for predicting fluid responsiveness has been extensively studied, though with considerable variability in reported performance characteristics. A recent systematic review and meta-analysis by Ping et al. specifically examined IVC indices accuracy in predicting fluid responsiveness in patients with shock [23]. The meta-analysis included multiple studies and found pooled sensitivity and specificity values varied based on patient population (spontaneously breathing vs. mechanically ventilated), cutoff values employed, and reference standards used to define fluid responsiveness. Result heterogeneity emphasizes that IVC assessment should not be viewed as a binary test with fixed performance characteristics, but rather as a tool whose utility depends on appropriate patient selection and clinical judgment integration.

Several studies have compared IVC assessment to other hemodynamic monitoring modalities. Surendran et al. conducted a prospective observational study correlating IVC collapsibility index with central venous pressure in postoperative ICU patients [25]. While correlation was observed, the relationship was not sufficiently strong to allow IVC measurements to reliably replace CVP monitoring in all clinical scenarios. This finding aligns with broader understanding that CVP itself is an imperfect fluid responsiveness predictor, and that dynamic measures of cardiovascular response to volume loading are superior to static pressure measurements.

IVC assessment integration with other ultrasound parameters has shown promise for improving diagnostic accuracy. Innocenti et al. evaluated an integrated ultrasonographic approach combining IVC collapsibility index, passive leg raise testing with aortic flow velocity time integral measurement, and lung ultrasound for interstitial syndrome in 113 patients with acute circulatory failure [29]. This multimodal approach enabled more nuanced fluid management decisions, with fluid-responsive patients receiving appropriate volume resuscitation while non-responsive patients were spared unnecessary fluid administration. The study demonstrated non-fluid-responsive patients received significantly less fluid over 12 hours compared to responsive patients (1,119 mL vs. 2,010 mL), suggesting comprehensive ultrasound assessment can guide more individualized and appropriate fluid therapy.

2.5 Implementation Challenges and Gaps in Evidence

Despite promising evidence for POCUS in volume assessment, several challenges must be addressed for successful clinical implementation. Training requirements represent significant consideration, as competent IVC assessment requires both technical skills in image acquisition and cognitive skills in image interpretation and clinical integration. Various professional organizations have proposed competency standards and training curricula, typically requiring supervised performance of 25-50 IVC examinations to achieve basic competency. However, optimal training approach, competency verification assessment methods, and strategies for maintaining skills over time remain areas of ongoing investigation.

Technical factors can significantly impact IVC assessment feasibility and accuracy. Obesity, bowel gas, and patient positioning challenges may limit image quality in some patients. Studies report successful IVC visualization rates of 85-95% in most populations, but certain patient groups, including morbidly obese individuals and those unable to lie supine, present particular challenges. Additionally, IVC filters, thrombosis, or anatomical variants presence can complicate interpretation. Standardized protocols addressing probe selection, imaging windows, measurement location, and respiratory phase timing are essential for reproducible results.

Despite substantial literature on POCUS for volume assessment, several important gaps remain. Most studies have been conducted in Western healthcare settings, with limited data from Middle Eastern populations and healthcare systems. Cultural, genetic, and environmental factors that may influence cardiovascular physiology and ultrasound findings in Saudi Arabian populations have not been systematically studied. Additionally, POCUS implementation cost-effectiveness, including equipment costs, training expenses, and potential impacts on healthcare utilization and outcomes, requires rigorous economic evaluation within Saudi healthcare context. This study aims to address these gaps by providing comprehensive comparative data from Saudi Arabian tertiary care centers.

3. METHODOLOGY

3.1 Study Design and Setting

This prospective observational comparative study will be conducted at three tertiary care hospitals in Riyadh, Saudi Arabia: King Fahad Medical City, King Abdulaziz Medical City, and King Saud University Medical City. These institutions were selected to represent diverse patient populations and clinical practice patterns within the Saudi healthcare system. The study will enroll patients presenting to emergency departments and admitted to intensive care units over a 12-month period from March 2026 to February 2027. The study protocol has been approved by Institutional Review

Boards of all participating institutions and will be conducted in accordance with the Declaration of Helsinki and Good Clinical Practice guidelines.

The study design employs a within-subject comparison approach, where each enrolled patient undergoes both POCUS-guided assessment and conventional clinical evaluation, performed by different clinicians blinded to each other's findings. This design minimizes confounding by ensuring both assessment methods are applied to the same patient population under identical clinical circumstances, allowing direct comparison of diagnostic performance. A reference standard assessment will be performed to establish true volume status and fluid responsiveness of each patient, enabling calculation of sensitivity, specificity, and other diagnostic accuracy metrics for both POCUS and conventional assessment methods.

3.2 Patient Population and Selection Criteria

The study will enroll adult patients (age ≥18 years) newly admitted to participating emergency departments or intensive care units requiring volume status assessment as part of clinical care. Inclusion criteria capture a representative sample of patients for whom volume assessment is clinically relevant: (1) patients presenting with signs or symptoms suggesting potential volume depletion or overload, including hypotension (systolic blood pressure <90 mmHg or mean arterial pressure <65 mmHg), tachycardia (heart rate >100 beats per minute), oliguria (urine output <0.5 mL/kg/hour), altered mental status, or clinical suspicion of sepsis, dehydration, or heart failure; (2) patients in whom the treating physician has determined volume status assessment is necessary to guide management decisions; and (3) patients or legal representatives providing informed consent for study participation.

Exclusion criteria eliminate patients in whom IVC assessment may be unreliable or study procedures may pose unacceptable risks: (1) patients with known IVC abnormalities including thrombosis, filters, or congenital anomalies; (2) patients with significant intra-abdominal pathology that may compress or distort IVC, including massive ascites, large abdominal masses, or recent abdominal surgery; (3) patients with severe right heart failure or significant tricuspid regurgitation; (4) patients requiring immediate life-saving interventions precluding study assessments; (5) pregnant patients; (6) patients with end-stage renal disease on dialysis; and (7) patients declining consent or unable to provide consent without available legal representative.

Based on power calculations assuming 15% difference in diagnostic accuracy (AUC) between POCUS and conventional assessment, with alpha of 0.05 and power of 80%, a sample size of 180 patients is required. Accounting for anticipated 10% rate of incomplete assessments or loss to follow-up, we will enroll 200 patients to ensure adequate statistical power for primary analysis.

3.3 POCUS Assessment Protocol

POCUS assessments will be performed by emergency medicine and critical care physicians who have completed standardized training in IVC ultrasound. The training program consists of didactic instruction covering IVC anatomy, physiology, and measurement techniques, followed by hands-on training with supervised performance of at least 30 IVC examinations prior to study participation. Competency will be verified through review of recorded images by expert sonographers, with inter-rater reliability assessment to ensure consistency across operators.

IVC imaging will be performed using portable ultrasound devices (SonoSite X-Porte or equivalent) with low-frequency curvilinear transducer (2-5 MHz). Patients will be positioned supine with head of bed elevated to 30 degrees when clinically feasible. The IVC will be visualized using subcostal long-axis view, with transducer placed in subxiphoid region and angled cephalad to obtain longitudinal view of IVC as it enters right atrium. Hepatic veins will be identified to confirm proper vessel identification and establish measurement location approximately 2-3 cm caudal to hepatic vein-IVC junction.

IVC diameter measurements will be obtained in M-mode, capturing at least three complete respiratory cycles. Maximum IVC diameter during expiration and minimum diameter during inspiration will be measured in anteroposterior dimension, perpendicular to vessel long axis. For spontaneously breathing patients, collapsibility index will be calculated as: (IVC diameter expiration - IVC diameter inspiration) / IVC diameter expiration × 100%. For mechanically ventilated patients, distensibility index will be calculated as: (IVC diameter inspiration - IVC diameter expiration) / IVC diameter expiration × 100%. All measurements will be performed in triplicate and averaged to improve reliability.

Additional POCUS parameters will be recorded to provide comprehensive hemodynamic assessment, including qualitative assessment of left ventricular systolic function, presence of pericardial effusion, and lung ultrasound findings (presence or absence of B-lines suggesting pulmonary edema). These additional findings will be analyzed as secondary outcomes to evaluate incremental value of multimodal ultrasound assessment. All ultrasound examinations will be recorded and stored for quality assurance review and inter-rater reliability analysis.

3.4 Conventional Clinical Assessment Protocol

Conventional clinical assessments will be performed by experienced clinicians (attending physicians or senior residents with at least three years of clinical experience) blinded to POCUS findings. Assessment will follow a standardized protocol capturing key elements of traditional volume status evaluation. Clinicians will perform focused physical examination including assessment of skin turgor, capillary refill time, mucous membrane moisture, jugular venous pressure estimation, presence and extent of peripheral edema, lung auscultation for crackles or decreased breath sounds, and cardiac auscultation for gallop rhythms or murmurs.

Vital signs will be recorded including heart rate, blood pressure (systolic, diastolic, and mean arterial pressure), respiratory rate, oxygen saturation, and temperature. When available, additional data including urine output over preceding hours, central venous pressure (if central line is in place for clinical indications), and laboratory values (lactate, creatinine, blood urea nitrogen, hematocrit) will be documented. Clinicians will then provide overall clinical gestalt assessment of patient's volume status, categorized as: (1) hypovolemic and likely fluid responsive, (2) euvolemic, or (3) hypervolemic or unlikely to be fluid responsive. They will also indicate confidence level in this assessment on 5-point Likert scale (1 = very uncertain to 5 = very certain).

To ensure standardization, all clinicians performing conventional assessments will complete brief training session reviewing assessment protocol and completing practice assessments on sample cases. A standardized data collection form will be used to ensure consistent documentation of all required elements. Time required to complete conventional assessment will be recorded to enable comparison of efficiency between assessment methods.

3.5 Reference Standard Assessment

Establishing an appropriate reference standard for volume status and fluid responsiveness presents methodological challenges, as no single gold standard exists. This study will employ a composite reference standard based on hemodynamic response to standardized fluid challenge, which represents the most clinically relevant and widely accepted approach in literature. Patients determined by treating physicians to require fluid administration will receive 500 mL bolus of crystalloid solution (normal saline or lactated Ringer's solution) over 15-30 minutes, unless contraindicated by clinical concerns for volume overload.

Hemodynamic parameters will be measured immediately before and 15 minutes after completion of fluid bolus, including heart rate, blood pressure, and when available, cardiac output or stroke volume measurements via non-invasive cardiac output monitoring or echocardiography. Fluid responsiveness will be defined as increase in mean arterial pressure of ≥10 mmHg or increase in cardiac output/stroke volume of ≥10-15% following fluid challenge. For patients in whom fluid administration is contraindicated due to clinical evidence of volume overload, reference standard will be based on response to diuretic therapy (improvement in clinical signs of congestion) or comprehensive clinical assessment by two independent senior clinicians.

For patients who do not receive fluid challenge or diuretic therapy during initial assessment period, reference standard will be established through retrospective adjudication by expert panel of three senior clinicians who will review all available clinical data, including patient's clinical course, response to interventions, and final diagnosis. The panel will reach consensus on patient's volume status and fluid responsiveness category through structured discussion.

3.6 Data Collection and Statistical Analysis

Data will be collected using standardized case report forms and entered into secure, password-protected electronic database (REDCap). All study personnel will complete training in data collection procedures and human subjects research ethics. Patient identifiers will be separated from clinical data, with each patient assigned unique study identification number. Baseline demographic and clinical data will be collected including age, sex, body mass index, primary diagnosis, comorbidities, current medications, and presenting vital signs. Process measures including time from emergency department arrival to assessment completion, time required for each assessment method, and any technical difficulties encountered will be documented.

The primary analysis will compare diagnostic accuracy of POCUS-guided IVC assessment versus conventional clinical assessment for predicting fluid responsiveness, using reference standard assessment as criterion. Sensitivity, specificity, positive predictive value, negative predictive value, and likelihood ratios will be calculated for both assessment methods. Receiver operating characteristic curves will be constructed, and area under curve will be compared between methods using DeLong test for paired data. Optimal cutoff values for IVC collapsibility and distensibility indices will be determined using Youden's index, which maximizes sum of sensitivity and specificity.

Secondary analyses will evaluate inter-rater reliability of IVC measurements using intraclass correlation coefficients, compare time required for each assessment method using paired t-tests, and assess concordance between POCUS and conventional assessment using Cohen's kappa statistic. Subgroup analyses will be performed based on patient characteristics (spontaneously breathing vs. mechanically ventilated, primary diagnosis category, presence of chronic comorbidities) to identify populations in which one assessment method may demonstrate superior performance. Multivariable logistic regression will be used to evaluate whether POCUS provides incremental diagnostic value beyond conventional clinical assessment.

4. EXPECTED RESULTS AND DISCUSSION

4.1 Anticipated Diagnostic Accuracy Findings

Based on existing literature and methodological rigor of our study design, we anticipate POCUS-guided IVC assessment will demonstrate superior diagnostic accuracy compared to conventional clinical assessment alone for predicting fluid responsiveness in newly admitted hospital patients. Specifically, we expect IVC collapsibility index measurements in spontaneously breathing patients to achieve sensitivity of 75-88% and specificity of 73-86% for predicting fluid responsiveness, with area under receiver operating characteristic curve of 0.80-0.88. These projections are based on performance characteristics reported in the landmark study by Sawe et al., which found sensitivity of 88% and specificity of 73% for collapsibility index cutoff of 50% [1].

For mechanically ventilated patients, we anticipate IVC distensibility index will demonstrate somewhat lower but still clinically useful diagnostic accuracy, with expected sensitivity of 65-75% and specificity of 70-80%. Lower performance in ventilated patients reflects greater complexity of hemodynamic assessment in this population, where positive pressure ventilation, sedation, and often more severe underlying illness introduce additional variables influencing IVC dynamics. Optimal cutoff value for distensibility index is expected to fall in range of 15-20%, consistent with prior literature, though we will determine optimal cutoff for our specific population using Youden's index.

In contrast, we anticipate conventional clinical assessment will demonstrate more variable performance, with sensitivity of 60-75% and specificity of 70-85%, yielding AUC of 0.70-0.80. The relatively high specificity of clinical gestalt, as observed in Sawe et al. study where physician assessment achieved 86% specificity [1], suggests experienced clinicians are reasonably good at identifying patients who are clearly volume replete and unlikely to benefit from additional fluid. However, lower sensitivity indicates clinical assessment may miss substantial proportion of patients who would actually respond to fluid administration, potentially leading to under-resuscitation in some cases.

Importantly, we expect to observe that POCUS and conventional assessment provide complementary information, with different sensitivity-specificity profiles that may be optimally combined in clinical practice. Higher sensitivity of POCUS suggests it may be particularly valuable for ruling out fluid responsiveness when collapsibility index is low, while higher specificity of clinical gestalt may be useful for confirming need for fluid administration when clinical signs clearly indicate hypovolemia. This complementary relationship will be formally evaluated through our multivariable analysis assessing incremental value of adding POCUS to conventional assessment.

4.2 Clinical Implications and Decision-Making

Integration of POCUS into clinical decision-making for volume management has potential to significantly impact patient care through multiple mechanisms. First, by providing more accurate identification of fluid-responsive patients, POCUS may enable more targeted fluid administration, ensuring patients who will benefit from volume resuscitation receive appropriate therapy while avoiding unnecessary fluid administration in those unlikely to respond. This precision in fluid management is particularly important given growing evidence that both under-resuscitation and over-resuscitation are associated with adverse outcomes.

We anticipate POCUS will reduce inter-clinician variability in volume assessment, as objective, quantifiable nature of IVC measurements provides common reference point less subject to individual interpretation than physical examination findings. This standardization may be particularly valuable in teaching hospitals where clinicians with varying experience levels are involved in patient care. Junior clinicians may gain confidence in their assessment when POCUS findings corroborate clinical impression, while discordance between POCUS and clinical assessment may prompt more senior consultation or additional evaluation.

Real-time, bedside nature of POCUS enables dynamic reassessment of volume status as clinical conditions evolve and interventions are administered. Unlike laboratory tests requiring time for processing or imaging studies requiring patient transport, POCUS can be repeated serially at bedside to assess response to fluid administration, diuretic therapy, or other interventions. This capability for longitudinal monitoring may improve timeliness of clinical decision-making and enable more responsive adjustment of management strategies based on patient's evolving hemodynamic status.

However, we also anticipate potential challenges in translating POCUS findings into clinical decisions. The probabilistic nature of diagnostic tests means neither POCUS nor conventional assessment will be perfectly accurate in all cases. Clinicians must be trained to interpret POCUS findings in context of overall clinical picture, recognizing that single parameter should not override comprehensive clinical judgment. Development of clinical decision support tools or algorithms that integrate POCUS findings with conventional assessment parameters and other clinical data may help optimize translation of diagnostic information into appropriate therapeutic decisions.

4.3 Advantages and Limitations

Point-of-care ultrasound offers several distinct advantages over conventional clinical assessment methods extending beyond diagnostic accuracy alone. The non-invasive nature eliminates procedural risks associated with invasive monitoring techniques such as central venous catheterization, including pneumothorax, arterial puncture, catheter-related infections, and thrombosis. In Saudi Arabian healthcare context, where patient preferences often favor non-invasive approaches and family involvement in medical decision-making is culturally important, the non-invasive nature of POCUS may enhance patient and family acceptance of volume assessment procedures.

Visual, documentable nature of ultrasound imaging provides objective evidence reviewable by multiple clinicians, shared with consulting specialists, and used for teaching purposes. Unlike physical examination findings existing only in examiner's assessment and documentation, ultrasound images can be stored, retrieved, and re-evaluated, enabling quality assurance, second opinions, and retrospective analysis. This documentation capability may also have medicolegal benefits, providing objective evidence of clinical assessment and decision-making process.

Despite advantages, POCUS-guided volume assessment has important limitations that must be acknowledged and addressed in clinical implementation. Technical factors can limit feasibility and reliability of IVC assessment in certain patient populations. Obesity, bowel gas, recent abdominal surgery, and patient positioning constraints may prevent adequate IVC visualization in 5-10% of patients. Additionally, certain clinical conditions including IVC thrombosis, filters, or anatomical variants may complicate interpretation. Our study will systematically document these technical challenges to provide realistic estimates of POCUS feasibility in real-world practice.

Operator-dependent nature of ultrasound introduces potential variability in image acquisition and measurement. While our study employs standardized training and quality assurance procedures, generalizability of findings to settings with less rigorous training programs or quality oversight is uncertain. Learning curve for competent IVC assessment, while shorter than for comprehensive echocardiography, still requires dedicated training time and supervised practice. Healthcare systems implementing POCUS programs must invest in appropriate training infrastructure, competency assessment, and ongoing quality assurance to ensure reliable results.

IVC findings interpretation requires consideration of numerous physiological and pathological factors that can influence IVC dynamics independent of volume status. Right ventricular dysfunction, tricuspid regurgitation, pulmonary hypertension, increased intra-abdominal pressure, and certain respiratory patterns can all alter IVC diameter and respiratory variation in ways that may not accurately reflect volume status or predict fluid responsiveness. Clinicians must be educated about these confounding factors and trained to recognize clinical scenarios where IVC assessment may be unreliable.

4.4 Relevance to Saudi Healthcare Context

Saudi Arabian healthcare system presents unique considerations for POCUS implementation influencing both feasibility and potential impact of this technology. The Kingdom's Vision 2030 healthcare transformation initiatives emphasize modernization, quality improvement, and adoption of innovative technologies, creating supportive policy environment for POCUS integration. Major tertiary care centers in Saudi Arabia have invested substantially in advanced medical technologies and have infrastructure to support comprehensive POCUS programs, including equipment acquisition, training programs, and quality assurance systems.

Patient population in Saudi Arabia includes both Saudi nationals and large expatriate workforce from diverse geographic and ethnic backgrounds, creating heterogeneous population that may influence generalizability of diagnostic cutoff values derived from Western populations. While fundamental physiology of IVC dynamics is universal, factors such as body habitus, baseline cardiovascular health, and disease prevalence may differ. Our study, by generating data from Saudi Arabian patients, will provide locally relevant evidence that can inform clinical practice guidelines and training programs tailored to regional context.

Cultural factors in Saudi Arabia may influence POCUS acceptability and implementation. Preference for non-invasive procedures aligns well with non-invasive nature of ultrasound assessment. Importance of family involvement in medical decision-making creates opportunities to use ultrasound images as visual aids in explaining patient's condition and treatment rationale to family members, potentially enhancing understanding and shared decision-making. However, gender considerations in patient care, including preferences for same-gender healthcare providers, must be accommodated in POCUS training and clinical implementation.

Distribution of healthcare resources in Saudi Arabia, with concentration of advanced capabilities in major urban centers and more limited resources in rural areas, creates both opportunities and challenges for POCUS implementation. In tertiary care centers with robust emergency medicine and critical care programs, comprehensive POCUS programs including IVC assessment can be readily implemented. However, extending these capabilities to smaller hospitals and rural facilities requires consideration of training accessibility, equipment availability, and telemedicine support for quality assurance and consultation.

4.5 Future Directions

This study will provide important foundational evidence for POCUS-guided volume assessment in Saudi Arabian patients, but several areas require further investigation. Long-term outcome studies evaluating whether POCUS-guided fluid management improves patient-centered outcomes such as mortality, organ dysfunction, hospital length of stay, and quality of life are needed. While diagnostic accuracy is important, ultimate value of any diagnostic test lies in its ability to improve clinical outcomes through better-informed treatment decisions. Randomized controlled trials comparing POCUS-guided protocols to conventional management strategies, with adequate sample sizes to detect clinically meaningful differences in major outcomes, represent critical next step.

Optimal integration of POCUS with other assessment modalities and clinical decision support tools requires further study. Machine learning algorithms that integrate POCUS findings with clinical data, laboratory values, and other diagnostic information may enhance predictive accuracy beyond what any single parameter can achieve. Development and validation of such integrated decision support systems could help clinicians synthesize complex, multidimensional data into actionable treatment recommendations. Additionally, role of artificial intelligence in automated image acquisition, measurement, and interpretation may reduce operator dependence and improve POCUS accessibility to less experienced users.

Economic impact of POCUS implementation, including comprehensive cost-effectiveness analyses accounting for equipment costs, training expenses, time savings, and impacts on resource utilization and outcomes, is needed to inform healthcare policy decisions. In Saudi Arabian context, where healthcare financing involves both government funding and private insurance, understanding economic value proposition of POCUS is essential for justifying investment and ensuring sustainable implementation. Studies evaluating budget impact of POCUS programs at institutional and health system levels would provide valuable information for decision-makers.

5. CONCLUSION

Accurate volume status assessment remains fundamental challenge in acute care medicine, with significant implications for patient outcomes and resource utilization. Traditional clinical assessment methods, while valuable, demonstrate important limitations in diagnostic accuracy and reproducibility. Point-of-care ultrasound, particularly IVC assessment, has emerged as promising non-invasive bedside tool providing objective, quantifiable measurements of volume status and fluid responsiveness. This study will provide comprehensive comparative evidence evaluating POCUS-guided assessment versus conventional clinical methods in newly admitted hospital patients within Saudi Arabian healthcare context.

Based on existing literature and rigorous methodology of our study design, we anticipate POCUS will demonstrate superior diagnostic accuracy compared to conventional assessment alone, with expected sensitivity of 75-88% and specificity of 73-86% for predicting fluid responsiveness. However, we also expect POCUS and conventional assessment provide complementary information, with optimal patient care likely achieved through integration of both approaches rather than replacement of clinical judgment with technology. Non-invasive nature, real-time availability, and documentable findings of POCUS offer distinct advantages extending beyond diagnostic accuracy to include enhanced patient safety, improved clinician confidence, and educational benefits.

Successful POCUS implementation for volume assessment requires careful attention to training, quality assurance, and clinical integration. Standardized protocols, competency-based training programs, and ongoing quality monitoring are essential to ensure reliable, reproducible results. Clinicians must be educated about physiological basis of IVC assessment, factors that can influence IVC dynamics, and appropriate integration of POCUS findings with comprehensive clinical evaluation. Development of institutional guidelines and decision support tools specifying how POCUS should be incorporated into clinical workflows will facilitate consistent, evidence-based practice.

For Saudi Arabian healthcare institutions, POCUS integration represents opportunity to enhance quality and efficiency of acute care delivery in alignment with Vision 2030 healthcare transformation goals. Technology is well-suited to Saudi healthcare context, with emphasis on non-invasive approaches, visual communication facilitating family involvement in decision-making, and potential to reduce healthcare disparities through deployment in resource-limited settings. Evidence generated by this study will inform clinical practice guidelines, training program development, and healthcare policy decisions regarding POCUS implementation.

Ultimately, volume assessment goal is not simply to measure IVC diameter or estimate central venous pressure, but to guide therapeutic decisions optimizing patient outcomes. Point-of-care ultrasound provides clinicians with powerful diagnostic capabilities that, when properly trained and appropriately integrated with clinical judgment, can enhance precision and timeliness of fluid management decisions. As evidence base continues to evolve and technology continues to advance, POCUS is poised to become essential component of bedside hemodynamic assessment, complementing rather than replacing clinical expertise and judgment that remain central to excellent patient care. This study will contribute important evidence to support evidence-based integration of POCUS into clinical practice, potentially establishing new care standards leveraging complementary strengths of technological innovation and clinical acumen to optimize outcomes for critically ill patients.

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