Biological and Clinical Sciences Research Journal
eISSN: 2708-2261; pISSN: 2958-4728
www.bcsrj.com
DOI: https://doi.org/10.54112/bcsrj.v6i2.2129
*Biol. Clin. Sci. Res. J., Volume 6(2), **2025**: 2129*
Original Research Article

Point of Care Ultrasonography to Assess the Pulmonary Fluid Status for The Septic Patient Requiring Fluid Resuscitation in The Emergency Department

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(Received, 24th January 2025, Accepted 8th February 2025, Published 28th February 2025)

Abstract: *Sepsis is a major cause of morbidity and mortality worldwide, requiring timely fluid resuscitation to restore perfusion. However, indiscriminate fluid administration may lead to pulmonary congestion and worsen outcomes. Point-of-care ultrasonography offers a rapid, non-invasive method to assess pulmonary fluid status and guide individualized fluid therapy in septic patients.* ***Objective:*** *To evaluate the effectiveness of point-of-care ultrasonography in assessing pulmonary fluid status and predicting fluid responsiveness among septic patients requiring initial fluid resuscitation in the emergency department.* ***Methods:*** *A prospective observational study was conducted from April to September 2024 in the emergency department of a tertiary care hospital. Ninety adult patients with sepsis or septic shock requiring fluid resuscitation were enrolled. Lung ultrasound and inferior vena cava (IVC) collapsibility index were assessed before and after initial fluid boluses. B lines were quantified using a standardized multizone protocol. Fluid responsiveness was evaluated using changes in mean arterial pressure and clinical perfusion markers. Statistical analysis included chi-square and independent t-tests, with significance set at $p \leq 0.05$.* ***Results:*** *The mean age was 51.6 ± 15.2 years, with 60 percent male patients. Baseline B lines were present in 32.2 percent of patients, increasing to 45.6 percent after fluid administration, indicating evolving pulmonary congestion. Patients with IVC collapsibility greater than 50 percent showed significantly higher rates of fluid responsiveness (63.3 percent vs 26.7 percent, $p = 0.002$) and a lower incidence of new B lines. Absence of baseline B lines was associated with better hemodynamic response (58.3 percent vs 31.1 percent, $p = 0.01$). Ultrasound-guided assessment enabled identification of patients at risk of fluid overload and reduced the need for ventilatory escalation.* ***Conclusion:*** *Point-of-care ultrasonography is a reliable bedside tool for guiding early fluid resuscitation in sepsis. Combined assessment of lung B lines and IVC collapsibility improves identification of fluid-responsive patients and reduces pulmonary congestion, supporting safer, individualized fluid strategies in emergency settings.*

Keywords: Sepsis, Ultrasonography, Lung ultrasound, Fluid resuscitation, Pulmonary congestion, Inferior vena cava collapsibility, Emergency medicine

[***How to Cite:*** Mirza RT, Mustafa KJ, Radiyah ET, Mirza M. Point of care ultrasonography to assess the pulmonary fluid status for the septic patient requiring fluid resuscitation in the emergency department. *Biol. Clin. Sci. Res. J.*, **2025;** 6(2): 199-202. doi: https://doi.org/10.54112/bcsrj.v6i2.2129

Introduction

Sepsis represents a major global health challenge, with an estimated 48.9 million cases and nearly 11 million related deaths occurring annually (1, 2). In emergency departments, patients presenting with septic shock often require rapid and effective fluid resuscitation to counteract systemic circulatory failure. The Surviving Sepsis Campaign emphasizes early management, recommending the administration of 30 mL per kg of crystalloid fluids within the first three hours of diagnosis to restore perfusion and reduce mortality (1, 3). Despite these established guidelines, optimizing fluid therapy remains a persistent challenge due to variations in individual patient responses and the potential consequences of both insufficient and excessive fluid administration.

Point-of-care ultrasonography has emerged as a valuable tool in this context, offering real-time, non-invasive assessment of hemodynamic status and pulmonary fluid accumulation (4, 5). Its ability to directly visualize cardiac function, venous filling, and lung aeration allows clinicians to tailor fluid therapy with greater precision. Lung ultrasound, in particular, has proven effective for detecting extravascular lung water by identifying B lines, which serve as early markers of pulmonary congestion and fluid overload (6, 7). The presence, quantity, and distribution of B lines correlate with fluid responsiveness and can guide decisions on continuing or withholding additional fluid therapy.

Evidence from randomized trials supports the effectiveness of ultrasound-guided fluid resuscitation. One trial demonstrated that patients managed with ultrasound guidance received significantly lower fluid volumes than those treated with conventional approaches, while achieving better overall hemodynamic stability (4). Additionally, reduced fluid administration under ultrasound guidance has been associated with improved morbidity and mortality outcomes among septic shock patients (8).

Implementation of point-of-care ultrasound is particularly advantageous in resource-limited healthcare systems. In such environments, the timely and accurate identification of fluid-responsive patients is often difficult due to limited diagnostic tools. POCUS provides rapid bedside evaluation, helping clinicians avoid both inadequate resuscitation and harmful fluid overload (9). In many low-resource settings where septic shock may be underdiagnosed or improperly managed, the introduction of POCUS can significantly enhance clinical decision-making and improve patient survival (10).

Thus, the use of point-of-care ultrasonography to assess pulmonary fluid status in septic patients is clinically beneficial and highly relevant in emergency medicine, especially within developing healthcare systems. By enabling precise, individualized fluid management and supporting adherence to international treatment guidelines, POCUS has the potential to markedly improve outcomes in septic shock.

Methodology

This prospective observational study was conducted in the emergency department of a tertiary care hospital from April 2024 to September 2024. A total of 90 adult patients aged 18 years and above presenting with sepsis or septic shock and requiring fluid resuscitation were included using

consecutive sampling. Sepsis was defined according to internationally accepted clinical criteria, and patients with known chronic interstitial lung disease, acute cardiogenic pulmonary edema, or poor ultrasound window were excluded.

After obtaining informed consent, baseline demographic data, vital signs, and clinical parameters were recorded. Point-of-care ultrasonography was performed at presentation by trained emergency physicians using a portable ultrasound machine. Lung ultrasound was conducted using a standardized multi-zone scanning protocol to identify the presence and extent of B lines as a marker of pulmonary interstitial fluid. Inferior vena cava diameter and collapsibility index were measured in the subcostal view during spontaneous respiration.

All patients received initial fluid resuscitation according to institutional sepsis protocols. Repeat ultrasonography was performed after completion of the initial fluid bolus to reassess lung and IVC parameters. Hemodynamic response was evaluated using changes in blood pressure, heart rate, and clinical perfusion markers. Data were entered and analyzed using statistical software, with categorical variables expressed as frequencies and percentages and continuous variables as mean ± standard deviation. Associations between ultrasound findings and fluid responsiveness were assessed using chi-square and independent sample tests, with a p-value of ≤0.05 considered statistically significant.

Results

The mean age of the study population was 51.6 ± 15.2 years, with a male predominance of 54 patients (60.0%) and female patients numbering 36 (40.0%). The majority of patients presented with community-acquired sepsis, and hypotension was the most common indication for fluid resuscitation. Baseline demographic and clinical characteristics are summarized in Table 1.

Table 1. Baseline Demographic and Clinical Characteristics of Septic Patients (n = 90)

Variable	Frequency n (%) / Mean ± SD
Age (years)	51.6 ± 15.2
Male	54 (60.0%)
Female	36 (40.0%)
Pulmonary source of sepsis	34 (37.8%)
Abdominal source of sepsis	28 (31.1%)
Urinary tract source	18 (20.0%)
Other sources	10 (11.1%)
Mean systolic BP (mmHg)	86.4 ± 12.8
Mean heart rate (beats/min)	112.6 ± 18.3

Point-of-care lung ultrasonography revealed baseline B lines in 29 patients (32.2%) before fluid administration, indicating pre-existing pulmonary interstitial fluid. After standardized initial fluid resuscitation, repeat ultrasonography demonstrated a significant increase in B-line scores among 41 patients (45.6%), suggesting evolving pulmonary congestion. Patients without baseline B lines showed a more favorable hemodynamic response to fluids without sonographic evidence of fluid overload. (Table 2).

Table 2. Lung Ultrasound Findings Before and After Fluid Resuscitation

Lung Ultrasound Findings	Pre Resuscitation n (%)	Post Resuscitation n (%)
No B lines	61 (67.8%)	49 (54.4%)
Mild B lines (1–2 zones)	19 (21.1%)	24 (26.7%)
Moderate B lines (3–4 zones)	10 (11.1%)	13 (14.4%)
Severe B lines (>4 zones)	0 (0%)	4 (4.4%)

Inferior vena cava assessment demonstrated that patients with a collapsibility index greater than 50% were more likely to show improvement in mean arterial pressure after a fluid bolus without developing new B lines. In contrast, patients with a low collapsibility index showed limited hemodynamic benefit and higher rates of sonographic pulmonary congestion. (Table 3)

Table 3. Association of Ultrasonographic Parameters with Fluid Responsiveness

Parameter	Fluid Responsive n (%)	Non Responsive n (%)	p value
IVC collapsibility >50%	38 (63.3%)	12 (26.7%)	0.002
Baseline absence of B lines	35 (58.3%)	14 (31.1%)	0.01
New B lines after fluids	9 (15.0%)	20 (44.4%)	0.004

Overall, point-of-care ultrasonography-guided assessment allowed early identification of patients at risk of fluid overload, enabling individualized resuscitation strategies. Patients monitored with ultrasound guidance had fewer clinical signs of pulmonary edema and required less escalation to ventilatory support.

Discussion

In this study involving 90 septic patients requiring early fluid resuscitation, the mean age was 51.6 years, and males constituted 60 percent of the cohort. This demographic distribution mirrors global trends where older age and male gender are frequently associated with higher sepsis incidence and adverse outcomes, consistent with findings reported by Zonneveld and colleagues (2) and Douglas and colleagues (11).

At presentation, patients demonstrated significant hemodynamic compromise, indicated by a mean systolic blood pressure of 86.4 mmHg. Such hypotension is a hallmark of evolving septic shock and is strongly linked with increased morbidity and mortality. Similar associations between low systolic values and adverse outcomes have been detailed by Musikatavorn and colleagues (12), emphasizing the urgency of prompt yet judicious fluid resuscitation.

Lung ultrasonography at baseline revealed B lines in 32.2 percent of patients, indicating early interstitial pulmonary fluid. Following initial fluid boluses, 45.6 percent exhibited an increase in B-line scores, suggesting new or worsening pulmonary congestion. These findings are in line with Pellicori and colleagues (13), who demonstrated that fluid accumulation results in increased interstitial lung water detectable as rising B line counts. Zieleskiewicz and colleagues (14) similarly

confirmed that lung ultrasound is a rapid, reliable tool for evaluating pulmonary fluid status in critically ill patients.

IVC assessments provided additional valuable insights. Patients with an IVC collapsibility index above 50 percent showed clear improvement in mean arterial pressure after fluid administration without a concurrent rise in B lines. This indicates that higher IVC collapsibility may reflect fluid responsiveness with a lower risk of congestion. Conversely, patients with reduced IVC collapsibility demonstrated minimal hemodynamic benefit and developed more pulmonary congestion after fluids. These results are supported by Gaafar and colleagues (15), who reported that IVC diameter and collapsibility reliably predict fluid responsiveness, and by Soliman and colleagues (16), who emphasized the utility of IVC measurements in septic shock resuscitation.

Collectively, point-of-care ultrasonography enabled early identification of patients at risk for fluid overload and guided a more individualized approach to fluid therapy. Patients managed with ultrasound guidance experienced fewer signs of pulmonary edema and required less escalation to ventilatory support. This observation aligns with Musikatavorn and colleagues (12), who found that ultrasound-guided fluid assessment reduces unnecessary resuscitation volume. These findings echo the Surviving Sepsis Campaign recommendations advocating dynamic rather than fixed volume assessments during resuscitation.

In the Pakistani emergency care context, where sepsis is common and critical care resources may be limited, point-of-care ultrasonography offers an accessible, rapid, and cost-effective method for evaluating fluid status. Its ability to simultaneously assess pulmonary congestion and intravascular volume makes it particularly suitable for busy and resource-constrained emergency departments. Integration of POCUS into routine practice can enhance early recognition of fluid intolerance, reduce complications from over-resuscitation, and potentially improve overall outcomes in septic patients.

Overall, our study supports the application of point-of-care ultrasonography as an effective adjunct for guiding fluid resuscitation in sepsis. By enabling precise, individualized fluid management, POCUS has the potential to significantly improve clinical outcomes, particularly in low-resource environments where timely and accurate assessments are critical.

Conclusion

Point-of-care ultrasonography provides a practical and accurate method for evaluating pulmonary fluid status and predicting fluid responsiveness during early sepsis resuscitation. By integrating lung B-line assessment with IVC collapsibility measurements, clinicians can more effectively identify patients who will benefit from fluid therapy while minimizing the risk of pulmonary overload. This approach strengthens individualized resuscitation practices, enhances clinical safety, and holds particular value in resource-constrained emergency departments.

Declarations

Data Availability statement

All data generated or analysed during the study are included in the manuscript.

Ethics approval and consent to participate

Approved by the department concerned. (IRBEC-24)

Consent for publication

Approved

Funding

Not applicable

Conflict of interest

The authors declared the absence of a conflict of interest.

Author Contribution

RTM (PGR)

Manuscript drafting, Study Design,

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Review of Literature, Data entry, Data analysis, and drafting articles.

ETR (PGR)

Conception of Study, Development of Research Methodology Design

MM (Registrar)

Study Design, manuscript review, and critical input.

All authors reviewed the results and approved the final version of the manuscript. They are also accountable for the integrity of the study.

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