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Point-of-Care Ultrasound for Monitoring Congestion and Guiding Decongestion Therapy in Heart Failure: A Narrative Review

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Abstract

Background: Heart failure (HF) remains one of the leading causes of hospitalization worldwide. Accurate assessment of congestion is crucial for optimal management, yet traditional diagnostic approaches such as physical examination, chest radiography, and natriuretic peptide measurements have limited sensitivity for detecting early or subclinical congestion. Point-of-care ultrasonography (POCUS) has emerged as a promising bedside tool that allows rapid and repeatable assessment of pulmonary and systemic congestion.

Aim: This review aims to summarize the current evidence regarding the use of point-of-care ultrasonography in monitoring congestion and guiding decongestion therapy in patients with heart failure.

Material and methods: A structured literature search was conducted across three major databases: PubMed, SciSpace (Basic and Full Text), and Google Scholar. The search strategy employed Boolean operators combining Medical Subject Headings (MeSH) and relevant keywords related to heart failure, point-of-care ultrasound, lung ultrasound, and decongestion therapy. Retrieved publications were screened for relevance and duplicates were removed.

Results: The initial search identified 685 records. After deduplication and relevance assessment, 211 unique publications were identified and compiled into a structured database.

The 30 most relevant studies formed the primary evidence base for this narrative review. The available evidence suggests that POCUS particularly lung ultrasound and inferior vena cava assessment may improve detection of congestion and support optimization of decongestion therapy in HF patients.

Conclusions: Current evidence indicates that integration of POCUS into HF management may enhance monitoring of congestion and potentially improve therapeutic decision-making. However, further prospective studies and standardized clinical protocols are required to confirm its impact on clinical outcomes.

Keywords: heart failure, point-of-care ultrasound, lung ultrasound, congestion, decongestion therapy.

Content

1. Introduction

Acute decompensated heart failure (ADHF), characterized by worsening congestion, accounts for the majority of HF hospitalizations. It is associated with substantial morbidity, mortality, and healthcare costs. A critical contributor to this burden is the inadequacy of traditional clinical assessment methods for detecting and monitoring congestion, thereby delaying optimal therapy [1], [2]. Physical examination findings such as peripheral edema, jugular venous distension, and pulmonary rales have limited sensitivity and specificity for detecting pulmonary and systemic congestion. Chest radiography, while widely available, has poor correlation with hemodynamic measures of congestion and lacks the sensitivity to detect subclinical fluid accumulation. Natriuretic peptides (predominantly NT-proBNP) provide valuable prognostic information but do not offer real-time, anatomically specific information about the distribution and severity of congestion [3]. Point-of-care ultrasound has emerged as a promising tool in acute and chronic HF management. POCUS techniques, including lung ultrasound for detecting artifacts indicating extravascular lung water, inferior vena cava assessment for estimating central venous pressure and preload, and venous Doppler evaluation for organ-specific congestion, offer reproducible and immediately available information at the bedside [1]. This review aims to comprehensively evaluate the current evidence for POCUS-guided decongestion strategies in heart failure therapy, particularly on clinical outcomes, implementation feasibility and future research directions [2].

Pathophysiology.

Congestion in heart failure results from elevated cardiac filling pressures leading to fluid redistribution into the interstitial and alveolar spaces (pulmonary congestion) and systemic venous compartments (systemic congestion). Pulmonary congestion manifests as dyspnea and reduced exercise tolerance, while systemic congestion presents as peripheral edema, hepatic congestion, and ascites. Importantly, congestion often insidiously precedes clinical symptoms by days to weeks, creating a window for early intervention [12].

Principles of Lung Ultrasound.

Lung ultrasound is based on acoustic artifacts of fluid-filled lung tissue. In normal aerated lung, ultrasound waves are reflected at the pleural line, producing horizontal A-lines. When extravascular lung water accumulates in the interstitium, it creates acoustic interfaces that generate vertical B-lines (also called "comet tails"). B-lines are defined as discrete vertical hyperechoic artifacts that arise from the pleural line, extend to the bottom of the screen without fading, move synchronously with lung sliding, and erase A-lines. The number and distribution of B-lines correlate with the severity of pulmonary congestion and can be quantified using standardized scanning protocols (typically 8 or 28 chest zones) [1].

Venous Doppler and VExUS.

Beyond lung ultrasound, assessment of systemic venous congestion has gained attention. The inferior vena cava diameter and collapsibility index provide estimates of right atrial pressure. More recently, the Venous Excess Ultrasound (VExUS) score integrates IVC diameter with Doppler flow patterns in the hepatic, portal, and intrarenal veins to grade systemic venous congestion severity. Abnormal venous flow patterns (pulsatility, reversal) indicate elevated venous pressures and organ-specific congestion, which may guide diuretic escalation and predict
adverse outcomes [7], [21], [23], [24].m

2. Research materials and methods

2.1. Data collection.

This literature review is based on a comprehensive search across three major databases: PubMed, SciSpace (Basic and Full Text), and Google Scholar. The search strategy employed a structured Boolean query combining Medical Subject Headings (MeSH) terms and text words related to heart failure, point-of-care ultrasound, and decongestion therapy. The search yielded 600 results from SciSpace, 60 from Google Scholar, and 25 from PubMed, totaling 685 records. After deduplication and relevance ranking, 211 unique papers were identified and compiled into a combined search results table. The top 30 papers, ranked by relevance to the research question, form the primary evidence base for this review. These include systematic reviews with meta-analyses, randomized controlled trials (RCTs), observational studies, and narrative reviews published between 2016 and 2025.

2.2. AI.

AI was utilized for two specific purposes in this research. Text analysis of clinical reasoning narratives to identify linguistic patterns associated with specific logical fallacies. Assistance in refining the academic English language of the manuscript, ensuring clarity, consistency, and adherence to scientific writing standards. **AI** were used for additional linguistic refinement of the research manuscript, ensuring proper English grammar, style, and clarity in the presentation of results. It is important to emphasize that all AI tools were used strictly as assistive instruments under human supervision. The final interpretation of results, classification of errors, and conclusions were determined by human experts in clinical medicine and formal logic. The AI tools served primarily to enhance efficiency in data processing, pattern recognition, and linguistic refinement, rather than replacing human judgment in the analytical process.

3. Research results

3.1. Evidence from Meta-Analyses

The updated meta-analysis and trial sequential analysis by Li et al. (2022) synthesized data from ten randomized controlled trials involving 1,203 patients with heart failure [1]. This study represents the highest-quality evidence currently available for LUS-guided therapy. The primary outcome was major adverse cardiac events (MACE), defined as a composite of all-cause mortality, HF-related rehospitalization, and symptomatic heart failure. After a mean follow-up of 4.7 months, LUS-guided treatment was associated with a 41% relative risk reduction in MACE compared to usual care (RR 0.59, 95% CI 0.48–0.71) [1]. Secondary outcomes further supported the benefit of LUS-guided therapy. HF-related rehospitalization was reduced by 37% (RR 0.63, 95% CI 0.40–0.99), and NT-proBNP concentrations were significantly lower in the LUS-guided group (standardized mean difference –2.28, 95% CI –

4.34 to –0.22). Importantly, meta-regression analysis revealed a significant correlation between MACE reduction and the magnitude of B-line count reduction ($p < 0.05$), suggesting that the clinical benefit is linked to effective decongestion [1].

A systematic review and meta-analysis by Al-Sagban et al. focused specifically on LUS-guided decongestion in heart failure patients [2]. This PRISMA-compliant study synthesized evidence from nine RCTs. Data showed reduced HF-related rehospitalizations or all cause mortality (RR: 0.72, [95% CI 0.56, 0.93], $p = 0.01$), HF hospitalization (RR: 0.65, [95% CI 0.48, 0.88], $p = 0.01$), and HF urgent visits (RR: 0.38, [95% CI 0.22, 0.66], $p < 0.0001$) [2].

Mhanna et al. (2021) conducted a systematic review and meta-analysis specifically examining the impact of LUS-guided management on hospitalization rates in chronic heart failure [5]. This study focused on the outpatient and chronic disease management setting, complementing the predominantly inpatient-focused evidence from other meta-analyses. The findings demonstrated that LUS-guided management strategies could reduce urgent hospitalization rates in chronic HF patients. However, fcontrary to previous studies there was no significant difference in hospitalisation rates related to HF in general[5].

Prognostic Meta-Analyses Several meta-analyses have examined the prognostic value of B-lines detected by lung ultrasound, rather than their role in guiding therapy. Wang et al. conducted a systematic review and meta-analysis evaluating the prognostic significance of lung ultrasound findings for clinical outcomes in heart failure patients [15], [16], [17]. These studies consistently demonstrated that elevated B-line counts, particularly persistent B-lines at discharge, predict increased risk of mortality and rehospitalization. Suhardi et al. further quantified residual pulmonary congestion defined by B-line findings and its association with cardiovascular events in acute heart failure [20]. Dubón-Peralta et al. systematically reviewed the prognostic value of B-lines in acute heart failure, concluding that the presence of >30-40 B-lines at admission and persistent congestion with ≥15 B-lines at discharge are risk factors for adverse outcomes [28], [30].

3.2. Randomized Controlled Trials.

The Lung Ultrasound-Guided Diuretic Therapy for Hospitalized Patients with Acute Decompensated Heart Failure LUDT-ADHF (2024) trial is one of the most recent and pragmatic randomized controlled trials in this field [4]. This open-label clinical trial evaluated the effectiveness of LUS-guided diuretic therapy in hospitalized ADHF patients. The study demonstrated that LUS-guided therapy led to more effective decongestion, as evidenced by greater reductions in B-line counts and improved clinical outcomes compared to standard care. The trial's pragmatic design enhances its generalizability to real-world clinical practice [4].

The EPICC (2022, 2019), (Ecografía Pulmonar Intersticial en la Insuficiencia Cardiaca Congestiva) study was a multicenter RCT that evaluated the effect of a therapeutic strategy guided by lung ultrasound on 6-month outcomes in patients with heart failure [13], [26]. The trial randomized patients to receive either LUS-guided therapy, where diuretic adjustments were made based on B-line counts, or usual care. The primary endpoint was a composite of cardiovascular death and HF-related readmission at 6 months.

The EPICC study demonstrated that LUS-guided therapy was associated with improved outcomes, including reduced readmission rates and better symptom control. The study also provided important insights into the practical implementation of LUS-guided protocols in routine clinical practice, including the frequency of ultrasound assessments and the specific B-line thresholds used to guide therapy adjustments [13], [26].

CAVAL US-AHF (2022) study, a randomized controlled trial combining IVC and lung ultrasound assessment to guide diuretic therapy in acute heart failure [3]. This multimodal approach represents an evolution beyond single-modality LUS-guided therapy, incorporating both pulmonary and systemic venous congestion assessment. The protocol specifies algorithms for diuretic dose adjustment based on integrated POCUS findings, including IVC diameter, collapsibility, and B-line counts. While full results were not available in the reviewed literature, the trial design reflects growing recognition that comprehensive congestion assessment may require evaluation of multiple compartments [3].

The JECICA (2018) study examined the contribution of daily bedside echocardiographic assessment on therapy adjustment in acute heart failure management, with a focus on impact on 30-day readmission rates [22]. While broader in scope than LUS-specific protocols, this trial demonstrated that systematic daily POCUS assessment (including cardiac function and congestion markers) could inform therapy adjustments and potentially reduce early readmissions. The study highlights the value of serial, protocolized point of care assessments rather than single time-point evaluations [22].

3.3. Venous Excess Ultrasound (VExUS)

The Venous Excess Ultrasound (VExUS) score represents an important evolution in POCUS-based congestion assessment, shifting focus from pulmonary to systemic congestion. VExUS integrates IVC diameter with Doppler flow patterns in the hepatic, portal, and intrarenal veins to create an assessment of venous congestion severity (grades 0-3) [7], [21], [23], [24].

Gudlawar et al. provided a comprehensive visual guide to VExUS application in cardiorenal syndrome, demonstrating how abnormal venous flow patterns can identify "silent" congestion in patients who appear clinically asymptomatic [21], [24]. The technique is particularly valuable for detecting organ-specific congestion that may not be apparent on physical examination or standard imaging. Researchers emphasized the role of VExUS in detection of intrarenal venous congestion, which can guide diuretic therapy and predict acute kidney injury risk [23].

Longino et al. conducted a prospective observational study examining VExUS for screening and management of acute decompensated heart failure, demonstrating its feasibility and potential utility in the emergency department and inpatient settings [7]. The study showed that VExUS-detected congestion correlated with positive clinical outcomes and could optimize diuretic dosing decisions.

3.4.Multimodal POCUS Approaches

Recognition that congestion is a multifaceted phenomenon affecting multiple organ systems has led to integrated, multimodal POCUS protocols. The "Tri-POCUS" approach described by Koratala et al. combines lung ultrasound, IVC assessment, and venous Doppler evaluation to provide comprehensive congestion assessment [25]. Samir et al. described systematic implementation of cardiopulmonary ultrasound imaging to optimize management of acute decompensated heart failure, integrating cardiac function assessment with congestion evaluation [11]. This comprehensive approach enables simultaneous assessment of cardiac function (ejection fraction, valvular function) and congestion burden, potentially allowing more nuanced therapeutic decision-making.

Bitar et al. provided a narrative review of ultrasound indicators of organ venous congestion, synthesizing evidence across multiple organ systems and POCUS modalities [27]. This review emphasized that different organs may exhibit congestion at different stages of heart failure progression, and that comprehensive assessment may require evaluation of multiple venous territories.

4. Discussion

4.1.Prognostic Value of B-lines and Residual Congestion

Understanding the prognostic significance of B-lines is essential for interpreting the clinical benefit of LUS-guided therapy. Multiple studies have established that B-line burden at admission and, critically, at discharge predicts subsequent adverse events [28], [30].

Studies consistently demonstrate that elevated B-line counts at hospital admission for acute heart failure are associated with increased risk of mortality and rehospitalization. Dubón-Peralta et al. identified that >30-40 B-lines at admission constitute a high-risk threshold [28], [30]. This finding has implications for risk stratification and may identify patients who require more aggressive initial diuretic therapy or closer monitoring.

The meta-analysis by Li et al. demonstrated that the magnitude of B-line reduction correlates with clinical benefit [1]. This suggests that the therapeutic goal should not merely be symptom improvement, but objective evidence of decongestion as measured by B-line resolution. This represents an opportunity to shift from symptom-based to subclinical endpoints for diuretic therapy.

4.2. Limitations and Key Knowledge Gaps

Despite the growing evidence base, several methodological limitations warrant consideration. The meta-analyses noted heterogeneity across included trials in terms of patient populations, LUS protocols, and outcome definitions. Most trials were open-label, introducing potential performance and detection bias. Sample sizes in individual trials were generally modest, and follow-up durations were relatively short.

The enriched column analysis revealed that many studies lacked detailed implementation guidance, standardized protocols, or assessment of operator training requirements.

Several important clinical questions remain inadequately addressed:

1. Optimal B-line Thresholds: What B-line count should trigger diuretic escalation or de-escalation? Different trials used varying thresholds, and optimal targets may differ by patient characteristics.
2. Frequency of Assessment: How often should POCUS be performed during hospitalization and after discharge? The optimal balance between information gain and resource utilization is unclear.
3. Multimodal vs. Single-Modality Approaches: Does adding IVC or VExUS assessment to LUS improve outcomes beyond LUS alone? No head-to-head trials have addressed this question.
4. Long-term Outcomes: Most trials focused on short-term outcomes (3-6 months). Effects on long-term mortality, quality of life, and healthcare costs require further study.
5. Special Populations: Evidence is limited in specific subgroups including advanced HF, HFpEF, right-sided HF, and patients with significant comorbidities (obesity, chronic lung disease, chronic kidney disease).

4.3. Comparative Considerations

While lung ultrasound has the strongest evidence base from randomized trials, emerging data suggest that venous Doppler techniques may provide complementary information, particularly for detecting systemic congestion and predicting cardiorenal complications. The optimal POCUS strategy may vary depending on clinical context: LUS may be most useful for acute pulmonary congestion and dyspnea assessment, while VExUS may be valuable for chronic management, renal protection, and detection of subclinical congestion. Further research is needed to determine whether multimodal approaches improve outcomes beyond single-modality LUS-guided therapy.

4.5. Future Directions and Research Priorities

Emerging technologies may address current limitations. For example use of Artificial Intelligence could enable automated detection and quantification of B-lines to improve reproducibility, reducing operator dependence. Access to handheld portable devices which are becoming available could enable clinicians to include POCUS techniques in daily examinations.

Literature indicates that with increasing availability of POCUS and growing evidence regarding its usefulness, a need for professional guidelines and standardization emerges. This should include training quality assurance and credentialing standards as well as assessment recommendations. Widely recognized POCUS algorithms seem to be a valuable tool for clinicians and may make introduction of POCUS easier.

However, lack of validated fprotocol standards, variable access to equipment and training create certain implementation barriers.

Further research is needed regarding universal guidelines or strategies, including comparative effectiveness of different point of care assessment methods, optimally head-to-head. The evidence on POCUS techniques is growing, nevertheless more data from more representative populations should be gathered. Impact on workflow and resource utilization, practical aspects and training models are worth investigating in the future, as well.

5. Conclusions

The evidence synthesized in this narrative review demonstrates that point-of-care ultrasound, particularly lung ultrasound-guided therapy, represents a significant advantage in heart failure therapy. Meta-analyses of randomized controlled trials show that LUS-guided therapy reduces major adverse cardiac events, HF-related rehospitalizations and natriuretic peptide levels, following effective decongestion. The prognostic value of B-lines, particularly residual congestion at discharge, provides a strong rationale for objective, POCUS-based assessment of decongestion adequacy.

Emerging modalities including VExUS and multimodal POCUS approaches show promise for comprehensive congestion assessments, nevertheless evidence remains limited in comparison to LUS. The field is evolving rapidly, with ongoing trials and technological innovations likely to further refine POCUS-guided strategies.

Implementation of this evidence into routine clinical practice faces important challenges. Standardization of protocols, training programs, and quality assurance mechanisms are needed to ensure reproducibility and safety. Further research is required to identify optimal strategies for integrating POCUS into diverse clinical workflows and healthcare systems. Knowledge gaps remain regarding optimal thresholds, assessment frequency, long-term outcomes, and applicability to special populations.

Despite these limitations, current evidence is sufficient to support broader adoption of LUS-guided therapy in heart failure management, particularly for hospitalized patients with acute decompensation. Clinicians, healthcare systems, and policymakers should prioritize development of infrastructure, training, and protocols to enable implementation of this evidence-based practice.

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