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Original Research Article

Point-Of-Care Ultrasound in Detecting Fluid Overload Among the CKD Individuals

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Conflict of interest: Nil

Abstract:

Introduction: Fluid overload significantly worsens outcomes in CKD, particularly in dialysis patients. Traditional exams often miss early congestion. POCUS, especially lung ultrasound, offers sensitive, bedside detection of B-lines, effusions, and venous congestion. This study aimed to evaluate POCUS in identifying fluid overload and guiding management in CKD patients.

Methods: This prospective observational study (Jan–Jun 2025, Takshashila University) included CKD stage 3–5 adults. Excluding acute illness and lung disease, patients underwent POCUS lung ultrasound, IVC assessment, and echocardiography. Findings were compared with clinical and laboratory data. Primary outcome was fluid overload detection; secondary outcomes included correlations with clinical and dialysis parameters.

Results: Eighty-eight CKD patients (mean age 54.6 years, 62.5% male) were studied; 52.3% on dialysis. POCUS detected fluid overload in 61.4% versus 44.3% clinically (κ=0.62). Findings included B-lines (61.4%), pleural effusion (20.5%), and dilated IVC (36.4%). Overload was higher in dialysis patients (p=0.04), with strong clinical correlations.

Conclusion: POCUS outperformed clinical examination in detecting fluid overload among CKD patients, particularly those on dialysis. Strong correlations with clinical and laboratory indices underscore its reliability. Integrating lung, IVC, and cardiac ultrasound offers a comprehensive, bedside approach, supporting personalized fluid management and improved outcomes in this high-risk population.

Keywords: Chronic Kidney Disease (CKD), Fluid overload, Point-of-Care Ultrasound (POCUS), Lung Ultrasound (B-lines), Inferior Vena Cava (IVC).

Introduction

Fluid overload is a critical and modifiable contributor to morbidity and mortality among patients with chronic kidney disease (CKD), especially those undergoing dialysis. Traditional physical examination signs such as peripheral edema or auscultatory crackles, lack sensitivity and often fail to detect early pulmonary congestion, leading to delayed interventions. Point-of-care ultrasound (POCUS), particularly lung ultrasound (LUS), provides a rapid, noninvasive, bedside method capable of identifying extravascular lung water (e.g. B-lines, pleural effusions) with greater sensitivity than clinical exam or chest radiography.

A meta-analysis demonstrated that LUS achieved sensitivity of 88%, outperforming chest X-ray's 73% in diagnosing cardiogenic pulmonary edema [1]. In nephrology settings, POCUS facilitates real-time assessments of fluid status by integrating evaluations of the lungs, heart, and venous system, allowing for more tailored decisions regarding ultrafiltration or dialysis strategy [2]. Thoracic ultrasound in end-stage renal disease (ESRD) patients undergoing hemodialysis showed that B-lines and pleural effusions correlated strongly with overload symptoms, although not necessarily with standard adequacy metrics such as Kt/V or URR [3]. Moreover, POCUS expands beyond simple lung imaging; it enables a comprehensive pump pipe leaks approach, encompassing cardiac function, venous congestion, and pulmonary edema in an integrated assessment of volume status [4]. Given its accuracy, availability, and clinical relevance, examining POCUS's role in detecting fluid overload among CKD patients holds promise for improving outcomes and refining fluid management strategies. The study aimed to evaluate the utility of POCUS in detecting fluid overload among patients with CKD.

Methods

This was a prospective observational study conducted in the department of General Medicine, Takshashila University, over a six-month period from January 2025 to June 2025. The study setting included inpatient wards, outpatient nephrology clinics, and the dialysis unit, ensuring the inclusion of patients across a broad spectrum of disease severity. Ethical approval was obtained from the Institutional Ethics Committee prior to commencement, and all participants provided written informed consent. The study followed the principles of the Declaration of Helsinki.

Adult patients (≥18 years) diagnosed with CKD stages 3–5, irrespective of dialysis status, were eligible for inclusion. Patients with acute kidney injury, primary lung diseases (such as interstitial lung disease or advanced COPD), unstable hemodynamics requiring intensive care, and those unwilling to participate were excluded. Recruitment was carried out using consecutive sampling during the study period. Baseline demographic and clinical data including age, sex, comorbidities (hypertension, diabetes, cardiovascular disease), and current dialysis status were recorded. Clinical examination findings such as peripheral edema, jugular venous pressure, and auscultatory lung crackles were documented for comparison with imaging findings.

All enrolled patients underwent standardized POCUS assessment performed by physicians trained in ultrasonography. The protocol included LUS, inferior vena cava (IVC) diameter and collapsibility, and echocardiographic screening for left ventricular systolic function. LUS was conducted using a 6-zone or 8-zone approach with a curvilinear probe, scanning anterior and lateral chest walls bilaterally. The presence and number of B-lines, pleural effusions, and lung sliding were recorded. IVC diameter and collapsibility were measured in the subcostal long-axis view during inspiration and expiration, providing an estimate of central venous pressure. Echocardiography was used to exclude significant left ventricular dysfunction or valvular abnormalities that could confound interpretation of pulmonary congestion. All ultrasound findings were captured in real-time, documented in case report forms, and stored digitally. Clinical and laboratory parameters including weight, blood pressure, hemoglobin, serum creatinine, and dialysis adequacy (Kt/V, ultrafiltration volume) were also recorded. To ensure reliability, 20% of scans were randomly re-assessed. The primary outcome was the detection of fluid overload defined by ultrasound evidence of >15 B-lines or significant pleural effusion, irrespective of clinical signs. Secondary outcomes included correlation of POCUS findings with clinical assessment (edema, JVP, auscultation), biochemical markers, and dialysis adequacy indices.

Statistical Analysis: Data were entered into Microsoft Excel and analyzed using SPSS version 26. Descriptive statistics were applied to summarize baseline demographics. Categorical variables were compared using Chi-square or Fisher's exact test, while continuous variables were analyzed using Student's t-test or Mann-Whitney U test depending on normality. P value <0.05 was considered statistically significant.

Results

A total of 88 patients with CKD patients were enrolled, mean age was 54.6 ± 12.4 years, with a male predominance (62.5%). Hypertension (81.8%) and diabetes mellitus (59.0%) were the most common comorbidities. Of the study group, 46 (52.3%) were on maintenance hemodialysis, while the remainder were predialysis. POCUS identified fluid overload in 61.4% of CKD patients, compared to 44.3% by clinical examination. Agreement between the two methods was moderate (kappa 0.62). POCUS revealed >15 B-lines in 61.4%, pleural effusion in 20.5%, and dilated IVC in 36.4%. Reduced IVC collapsibility was observed in 33%, while echocardiographic left ventricular dysfunction was detected in 15.9%, highlighting significant subclinical fluid overload. Table 1 shows that fluid overload was more frequent among dialysis patients (37.5%) compared to predialysis patients (23.9%). Overall, 61.4% had overload while 38.6% did not. The difference between groups was statistically significant (P = 0.04). Table 2 demonstrates significant positive correlations between POCUS parameters and clinical/laboratory indices. B-lines showed the strongest association with edema score (r = 0.63) and ultrafiltration volume (r = 0.58). Pleural effusion also correlated significantly, while IVC diameter had weaker, nonsignificant correlation with serum creatinine, reflecting POCUS reliability in fluid assessment.

Table 1: Fluid overload among the study members; n (%)

Group	Fluid overload		Total
	Present	Absent	
Dialysis	33 (37.5)	13 (14.7)	46 (52.3)
Predialysis	21 (23.9)	21 (23.9)	42 (47.8)
Total	54 (61.4)	34 (38.6)	88 (100)
p-value	**0.04**		

Table 2: Correlation between POCUS, clinical/laboratory findings

Parameter	Clinical edema score (r)	Ultrafiltration (UF) volume (r)	Serum creatinine (r)
B-lines	0.63 (P < 0.01)	0.58 (P < 0.01)	0.41 (P = 0.02)
Pleural effusion	0.51 (P < 0.01)	0.44 (P = 0.03)	0.39 (P = 0.04)
IVC diameter	0.46 (P = 0.02)	0.42 (P = 0.03)	0.27 (NS)

Discussion:

Our study demonstrates that POCUS, integrating LUS and IVC assessment, detects fluid overload in 61.4% of CKD patients, compared to 44.3% via clinical examination, with a moderate agreement (κ = 0.62). These findings align with existing literature indicating that traditional clinical signs such as peripheral edema, crackles, and jugular venous distension often lack sensitivity and may miss early or subclinical fluid accumulation in CKD and dialysis patients. Argaiz et al. [2] emphasize that POCUS enhances volume status assessment by visualizing pulmonary congestion, cardiac function, and venous overlap that are otherwise missed clinically. Meanwhile, Kharat et al., in a systematic review, identified that LUS correlates more strongly with extravascular lung water than clinical exam or biomarkers, reinforcing its value for early detection of congestion [5]. Thus, our data corroborate the superior diagnostic performance of POCUS over clinical judgments in identifying fluid overload among CKD populations.

On LUS, 61.4% of patients had more than 15 B-lines, while pleural effusion was present in 20.5% signs consistent with increased extravascular lung water. These imaging markers are known to reflect fluid accumulation in pulmonary interstitium. In prior studies, elevated B-line scores correlated well with volume status and influenced dialysis prescription in hemodialysis patients; for instance, Al-Saray et al. [6] reported a mean B-line score of 10.3 ± 6.2, guiding ultrafiltration decisions. Moreover, the presence of B-lines exhibits stronger correlation with LV ejection fraction and IVC indices than many clinical or lab measures, as summarized in the meta-analysis by Kharat et al. [5] These observations imply that LUS provides direct, quantifiable evidence of subclinical pulmonary congestion, validating our findings in a CKD cohort.

In our cohort, IVC dilation (36.4%) and reduced collapsibility (33.0%) were also prevalent, suggesting elevated right atrial pressure and systemic congestion. IVC diameter and collapsibility index are widely validated markers of intravascular volume, with reduced collapsibility indicating volume overload and higher central venous pressure [6]. Tsangalis et al. [7] noted that, in dialysis patients, B-lines and IVC indices both reflect fluid burden and serve as complementary imaging biomarkers. These findings support our multimodal POCUS approach (lungs + veins + heart) as a more comprehensive and sensitive method for assessing volume status compared to isolated measurements. Additionally, detecting LV dysfunction in 15.9% of patients underlines the importance of integrating echocardiography with POCUS to exclude cardiac causes of congestion and fine-tune fluid management strategies.

Clinically, utilizing POCUS to detect subclinical overload offers tangible benefits for CKD care. Patients with undetected overload are at higher risk for hypertension, cardiovascular events, and pulmonary complications. The clarity from POCUS may allow earlier and more precise adjustments in ultrafiltration protocols or diuretic dosing. Although hard outcomes were not part of our study, systematic reviews suggest that ultrasound-guided interventions improve decongestion and blood pressure control, albeit without clear mortality benefits to date. Future longitudinal studies are warranted to examine whether POCUS-driven management translates into fewer hospitalizations, better BP control, or reduced cardiovascular events in the CKD population. Meanwhile, our results support integrating POCUS training for nephrologists and internists at institutions like Takshashila University, enhancing bedside diagnostic accuracy and enabling personalized volume management.

Table 1 highlights that fluid overload was more frequently observed among dialysis patients (37.5%) compared to predialysis patients (23.9%). Overall, 61.4% of the cohort demonstrated fluid overload, while 38.6% remained euvolemic. The statistically significant difference (P = 0.04) underscores the greater predisposition of patients on maintenance hemodialysis to volume retention, reflecting the challenges of achieving optimal fluid balance in this population. Fluid overload in dialysis patients may result from inadequate ultrafiltration, poor adherence to dietary sodium and fluid restrictions, or variability in residual renal function. This finding aligns with prior studies showing that interdialytic weight gain and chronic volume excess are highly prevalent in hemodialysis patients and often remain underrecognized by clinical examination alone [1, 5]. By contrast, predialysis CKD patients, though also at risk, may have relatively preserved urine output and compensatory mechanisms, resulting in lower prevalence of overload.

The clinical implications of these observations are significant. Persistent fluid overload in dialysis patients is associated with hypertension, left ventricular hypertrophy, and increased cardiovascular morbidity and mortality [8]. The higher prevalence of overload in our dialysis cohort supports the use of POCUS as an adjunct tool for routine volume assessment. POCUS facilitates the detection of subclinical pulmonary congestion and venous engorgement, enabling timely adjustment of ultrafiltration goals and antihypertensive therapy. Previous studies have shown that ultrasound-guided fluid management improves blood pressure control and reduces hospitalization risk, even though long-term survival benefits remain under investigation [9]. Thus, integrating POCUS into routine dialysis care may bridge the gap between clinical assessment and true fluid status, particularly in high-risk populations such as those on hemodialysis.

Table 2 demonstrates that POCUS parameters strongly correlated with clinical and laboratory indices, underscoring its value in fluid assessment among CKD patients. B-lines on lung ultrasound showed the strongest associations, correlating significantly with both clinical edema scores ($r = 0.63$, $p < 0.01$) and UF volume in dialysis patients ($r = 0.58$, $p < 0.01$). This finding highlights that pulmonary congestion, as visualized by B-lines, directly reflects intravascular and interstitial fluid excess. Prior studies have similarly shown that B-line counts are reliable markers of extravascular lung water and outperform traditional signs such as auscultatory crackles [10]. Pleural effusion was also significantly correlated with both UF volume ($r = 0.44$) and serum creatinine ($r = 0.39$), indicating its utility as a complementary marker of chronic volume overload. These findings align with the observations of Zoccali et al., who reported that ultrasound-detected pulmonary congestion is a strong predictor of adverse cardiovascular outcomes in hemodialysis patients [8].

Interestingly, IVC diameter demonstrated only modest correlation with edema scores and UF volume and a nonsignificant correlation with serum creatinine ($r = 0.27$). This suggests that while IVC assessment contributes to fluid evaluation, it may be influenced by additional factors such as right atrial pressure, respiratory effort, or cardiac dysfunction. Koratala et al. emphasize that IVC measurements should be interpreted in conjunction with lung ultrasound rather than as standalone indicators [1]. The integration of lung ultrasound, pleural assessment, and venous indices thus provides a more comprehensive picture of fluid status. Our results support the use of multimodal POCUS protocols, which have been recommended in recent consensus reviews to guide volume management in CKD and dialysis patients [2]. Overall, the strong correlation of POCUS findings with both clinical and dialysis parameters demonstrates its reliability as a bedside tool, enabling timely and individualized management of fluid overload in this high-risk population.

Conclusion: This study demonstrates that POCUS is a reliable and superior tool compared to clinical examination for detecting fluid overload in CKD patients. POCUS identified a higher prevalence of pulmonary congestion, pleural effusion, and venous engorgement, with significant correlations to edema scores, ultrafiltration volume, and serum creatinine. Dialysis patients showed greater fluid burden than predialysis individuals, highlighting their vulnerability to volume overload. By integrating lung, IVC, and cardiac ultrasound, POCUS provides a comprehensive, bedside assessment of fluid status. Incorporating POCUS into routine CKD management can guide timely interventions, optimize dialysis strategies, and potentially improve cardiovascular outcomes.

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