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Original article

30-DAY OUTCOMES OF LUNG ULTRASOUND-GUIDED DECONGESTION IN ACUTE HEART FAILURE

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Abstract

Introduction: To evaluate whether in-hospital lung ultrasound-guided monitoring improves decongestion and 30-day outcomes in patients hospitalized with acute heart failure.
Background: Acute heart failure is associated with high early morbidity, mortality, and rehospitalization. Lung ultrasound enables bedside assessment of pulmonary congestion and may support dynamic in-hospital monitoring and treatment.

Materials and methods: Sixty patients with acute or acutely decompensated chronic heart failure were allocated to standard care (n=28) or standard care plus serial lung ultrasound-guided monitoring (n=32) using an 8-zone protocol. Clinical, echocardiographic, laboratory, and decongestion parameters were assessed, with 30-day follow-up.

Results: Baseline clinical and hemodynamic characteristics were broadly similar. Lung ultrasound-guided management was associated with greater urine output on day 2 (2968.9 ± 1030.9 *vs*. 2121.6 ± 840.3 mL; p=0.004) and a trend toward lower discharge urea (10.5 ± 4.8 *vs*. 13.8 ± 7.6 mmol/L; p=0.052). Thirty-day MACE occurred in 3 patients (9.4%) in the lung ultrasound group and 5 (17.9%) in standard care, without statistical significance.

Conclusion: In-hospital lung ultrasound-guided monitoring was associated with improved decongestion and a favorable, non-significant trend in 30-day outcomes.

Keywords: heart failure; lung ultrasound; pulmonary congestion; decongestion; hospitalization

Introduction

Acute heart failure (AHF) remains a major cause of hospitalization, morbidity, mortality, and early readmission, particularly among older adults. Despite advances in pharmacological and device-based treatment, short-term outcomes after an AHF admission remain suboptimal. One important reason is the difficulty of achieving adequate decongestion while avoiding renal dysfunction and other treatment-related complications[1-3].

Pulmonary congestion is a central feature of AHF and is strongly related to adverse outcomes. Conventional assessment based on symptoms, physical examination, chest radiography, and natriuretic peptides may be insufficiently sensitive for detecting residual or changing congestion[4,5]. Lung ultrasound (LUS) offers a rapid, non-invasive bedside method

for detecting and quantifying extravascular lung water through B-lines and can be repeated serially during treatment[6-8].

Residual pulmonary congestion at discharge, including congestion that is not clinically apparent, has been associated with early readmission and mortality[9,10]. Previous studies have also suggested that integrating LUS into clinical decision-making can influence diuretic treatment and improve decongestion, with a potential reduction in subsequent heart-failure events[10,11]. However, evidence regarding routine in-hospital LUS-guided management and very early post-discharge outcomes remains limited.

The aim of this study was to evaluate in-hospital decongestion and 30-day clinical outcomes in patients hospitalized with AHF who underwent serial LUS-guided monitoring, compared with patients managed using standard clinical assessment alone.

Materials and methods

Study design and population

This was a prospective, single-center study including 60 patients hospitalized at the University Clinic for Cardiology because of acute or acutely decompensated chronic heart failure and requiring in-hospital decongestive treatment. Eligible patients had to undergo the initial study assessment, including LUS when assigned to the LUS group, before initiation or escalation of decongestive therapy. Patients were allocated to a standard-care group (n=28) or to a standard-care plus serial LUS-guided monitoring group (n=32).

Written informed consent was obtained from all patients prior to their inclusion. The study was approved by the Institutional Ethics Committee of the Faculty of Medicine, Ss. Cyril and Methodius University in Skopje (No.03-2793/8 from 06.06 2024).

On admission, all patients underwent medical history assessment, physical examination with particular attention to pulmonary and systemic congestion, electrocardiography, pulse oximetry, routine and clinically indicated laboratory testing, and transthoracic echocardiography. Blood pressure and body weight were recorded upon admission, and body weight was subsequently followed during hospitalization.

Standard care and lung ultrasound-guided strategy

Patients in the standard-care group were managed according to contemporary clinical practice using symptoms and signs, laboratory findings, echocardiography, and natriuretic peptide measurements. In the LUS group, serial LUS examinations were added at prespecified time points during hospitalization and were used together with the standard assessment to guide the intensity of diuretic therapy and to evaluate decongestion and readiness for discharge.

Lung ultrasound protocol

Lung ultrasound was performed at the bedside using a portable ultrasound system and a convex transducer with a lung preset. The transducer was positioned perpendicular to the ribs to visualize the pleural line and B-line artifacts during spontaneous breathing. An 8-zone protocol was used, evaluating four anterior and lateral zones on each hemithorax. Pulmonary congestion was defined as at least three B-lines in at least one zone bilaterally. The number and distribution of B-lines were used to estimate the degree of pulmonary congestion and to support decisions regarding decongestive therapy.

Follow-up and outcomes

All patients were followed for 30 days after discharge. Follow-up focused on major adverse cardiovascular events (MACE), including rehospitalization for AHF, stroke, and death, as defined in the study protocol. In-hospital treatment response was assessed using diuretic dose, urine output, change in body weight, renal and electrolyte parameters, natriuretic peptide levels, and the day of conversion from intravenous to oral diuretic therapy.

Statistical analysis

Statistical analyses were performed using IBM SPSS Statistics, version 25.0 for Windows. Continuous variables were summarized as mean ± standard deviation and categorical variables as counts and percentages. Between-group comparisons were performed using Student's t-test for continuous variables and Pearson chi-square test or Fisher exact test for categorical variables, as appropriate. Odds ratios (ORs) with 95% confidence intervals (CIs) were calculated for selected categorical outcomes. A backward stepwise (conditional) binary logistic regression model was used to evaluate variables associated with LUS-guided management. Time-to-event data for 30-day MACE were displayed using Kaplan-Meier analysis and compared with the log-rank test. Statistical significance was defined as $p<0.05$.

Results

Study population and baseline characteristics

The study included 60 patients, of whom 32 (53.3%) were managed with serial LUS-guided monitoring and 28 (46.7%) received standard care. The mean age was 68.9±11.2 years and 40 patients (66.7%) were men. Baseline clinical characteristics were generally comparable. Diabetes mellitus and previous coronary artery bypass grafting were more frequent in the standard-care group, although these differences did not reach statistical significance. Previous pharmacological treatment was also broadly similar between groups.

Table 1. Baseline clinical characteristics of the study population

Characteristic	All (n=60)	LUS (n=32)	Standard care (n=28)	p value
Sex, male/female	40(66.7%)/20(33.3%)	20(62.5%)/12(37.5%)	20(71.4%)/8(28.6%)	ns
Age, years	68.9±11.2	68.0±10.5	70.0±12.1	ns
Body mass index, kg/m²	26.1±3.6	25.5±3.2	26.8±3.9	ns
Smoking: never/current/former	35/13/12	21/6/5	14/7/7	ns
Any previous disease	54(90.0%)	28(87.5%)	26(92.9%)	ns
Hypertension	46(76.7%)	25(78.1%)	21(75.0%)	ns
Diabetes mellitus	31(51.7%)	13(40.6%)	18(64.3%)	p=0.070
Hyperlipidemia	29(48.3%)	15(46.9%)	14(50.0%)	ns
Coronary artery disease	29(48.3%)	15(46.9%)	14(50.0%)	ns
Previous PCI	19(31.7%)	12(37.5%)	7(25.0%)	ns
Previous CABG	15(25.0%)	5(15.6%)	10(35.7%)	p=0.080
Valvular disease	11(18.3%)	5(15.6%)	6(21.4%)	ns
Atrial fibrillation	21(35.0%)	12(37.5%)	9(32.1%)	ns
Heart failure with reduced EF	40(66.7%)	23(71.9%)	17(60.7%)	ns
Heart failure with preserved EF	4(6.7%)	3(9.4%)	1(3.6%)	ns
Previous HF hospitalization	17(28.3%)	10(31.3%)	7(25.0%)	ns
Previous cardiovascular therapy	49(81.7%)	26(81.3%)	23(82.1%)	ns
ACE inhibitor	24(40.0%)	10(31.3%)	14(50.0%)	ns
ARB	11(18.3%)	8(25.0%)	3(10.7%)	ns
Beta-blocker	41(68.3%)	22(68.8%)	19(67.9%)	ns
MRA	32(53.3%)	18(56.3%)	14(50.0%)	ns
Loop diuretic	32(53.3%)	14(43.8%)	18(64.3%)	ns
Oral anticoagulant	20(33.3%)	11(34.4%)	9(32.1%)	ns
Statin	37(61.7%)	19(59.4%)	18 (64.3%)	ns
Antiplatelet therapy	21(35.0%)	8(25.0%)	13(46.4%)	p=0.086
SGLT2 inhibitor	17(28.3%)	9(28.1%)	8(28.6%)	ns

Abbreviations: ACE-angiotensin-converting enzyme, ARB-angiotensin receptor blocker, CABG-coronary artery bypass grafting, EF-ejection fraction, HF-heart failure, LUS-lung ultrasound, MRA-mineralocorticoid receptor antagonist, PCI-percutaneous coronary intervention, SGLT2-sodium-glucose cotransporter 2, ns-not significant

All patients presented with dyspnea. Patients in the standard-care group more frequently had clinical evidence of systemic congestion, particularly ascites, whereas pulmonary findings were broadly similar between groups. Ascites was present in 3 of 32 patients (9.4%) in the LUS group and 11 of 28(39.3%) in the standard-care group.

Table 2. Symptoms and signs at hospital admission

Characteristic	All (n=60)	LUS (n=32)	Standard care (n=28)	p value
Dyspnea	60(100%)	32(100%)	28(100%)	ns
Cough	26(43.3%)	13(40.6%)	13(46.4%)	ns
Peripheral edema (symptom)	31(51.7%)	13(40.6%)	18(64.3%)	p=0.070
Ascites (symptom)	14(23.3%)	3(9.4%)	11(39.3%)	p=0.011
Elevated jugular venous pressure	22(36.7%)	9(28.1%)	13(46.4%)	ns
Pulmonary crackles	19(31.7%)	10(31.3%)	9(32.1%)	ns
Diminished breath sounds	12(20.0%)	8(25.0%)	4(14.3%)	ns
Peripheral edema (sign)	46(76.7%)	23(71.9%)	23(82.1%)	ns
Ascites (sign)	13(21.7%)	2(6.3%)	11(39.3%)	p=0.006
Hepatomegaly	12(20.0%)	5(15.6%)	7(25.0%)	ns

Hemodynamic, echocardiographic, and laboratory findings

Admission hemodynamic variables did not differ significantly between groups. Mean admission body weight was numerically higher in the standard-care group (86.4±19.2 vs. 80.2 ±13.8 kg; p=0.083). Oxygen saturation was low in both groups, and 56 of 60 patients required supplemental oxygen during hospitalization.

Table 3. Admission hemodynamic characteristics

Characteristic	All	LUS	Standard care	p value
Admission body weight, kg	83.1±16.6	80.2±13.8	86.4±19.2	0.083
Hospital stay, days	6.8±3.6	7.1±3.9	6.4±3.1	ns
Heart rate on admission, beats/min	106.3±22.4	108.3±19.4	103.9±25.8	ns
Systolic blood pressure, mmHg	152.0±39.5	153.7±39.0	150.1±40.7	ns
Diastolic blood pressure, mmHg	92.9±17.5	95.2±18.8	90.3±15.9	ns
SpO_2, %	83.1±14.2	82.3±13.4	83.9±15.3	ns

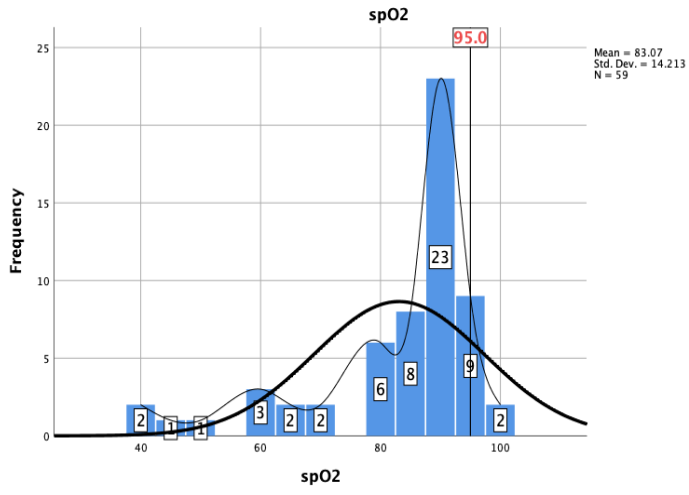

Fig. 1. Distribution of patients according to admission oxygen saturation (SpO_2 available in 59 patients).

Table 4. Requirement for supplemental oxygen

Group	No oxygen	Oxygen support	Total	Fisher exact p
Standard care	2(7.1%)	26(92.9%)	28	0.641
LUS	2(6.3%)	30(93.8%)	32	
Total	4(6.7%)	56(93.3%)	60	

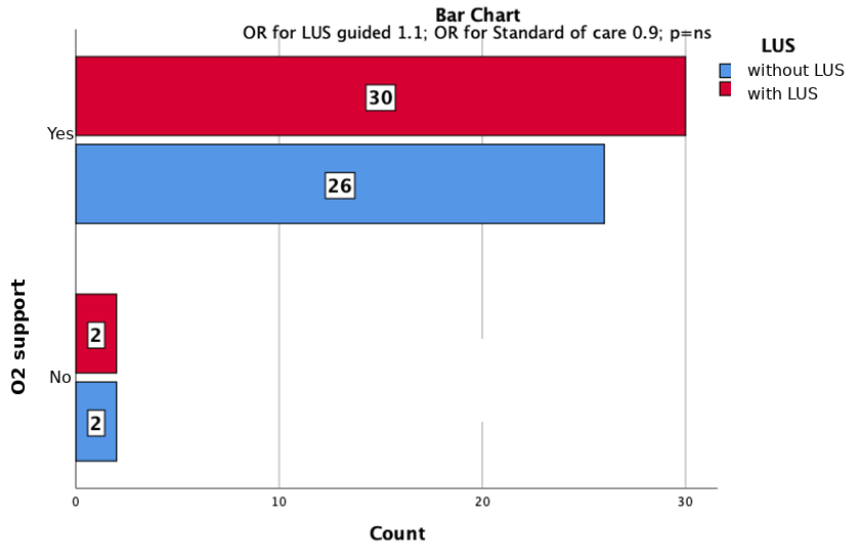

Fig. 2. Distribution of patients according to the need for supplemental oxygen

Left- and right-ventricular functional indices were similar between groups. Mean left ventricular ejection fraction was 36.5 ± 12.8% in the overall population, with no significant between-group difference. Similarly, mitral regurgitation grade, estimated systolic pulmonary artery pressure, tricuspid annular plane systolic excursion, and right-ventricular tissue Doppler systolic velocity did not differ significantly.

Table 5. Echocardiographic functional characteristics

Characteristic	All	LUS	Standard care	p value
Left ventricular ejection fraction, %	36.5±12.8	34.9±13.2	38.4±13.5	ns
Mitral regurgitation grade	1.4±0.8	1.4±0.8	1.4±0.8	ns
sPAP, mmHg	44.4±9.9	42.8±8.6	47.0±11.7	ns
TAPSE, mm	17.12±4.15	17.4±4.8	17.2±3.2	ns
RV sTDI, cm/s	9.38±2.87	9.4±3.1	9.3±2.7	ns

Abbreviations: RV-right ventricular, sPAP-systolic pulmonary artery pressure, sTDI-systolic tissue Doppler imaging velocity, TAPSE-tricuspid annular plane systolic excursion

On admission, the standard-care group had worse renal indices, with higher creatinine (141.9±74.4 *vs*. 106.7±36.8 µmol/L; p=0.021) and uric acid (499.8±217.9 *vs*. 385.9±141.6 µmol/L; p=0.027). Urea and total protein also showed borderline between-group differences. Other hematological, biochemical, thyroid, and natriuretic peptide measurements were not significantly different.

Lung ultrasound findings and in-hospital decongestion

Among patients assigned to the LUS-guided group, the mean total B-line count across the 8-zone protocol was 42.18±11.10, with a median of 41 and a range of 26 to 67. Most patients therefore had a high burden of pulmonary congestion at baseline.

Table 6. Admission biochemical and hematological characteristics

Characteristic	All	LUS	Standard care	p value
Hemoglobin, g/L	127.5±19.8	128.3±16.0	126.6±23.6	ns
Hematocrit, %	40.6±5.5	40.8±4.3	40.4±6.7	ns
MCV, fL	89.2±12.3	89.9±15.9	88.5±6.3	ns
WBC, ×10⁹/L	11.1±3.8	10.6±4.2	11.7±3.2	ns
Platelets, ×10⁹/L	262.7±83.5	251.3±78.7	276.1±88.3	ns
Serum iron	7.6±3.8	8.4±3.9	7.5±3.7	ns
Sodium, mmol/L	137.3±4.7	136.9±5.0	137.7±4.5	ns
Potassium, mmol/L	4.5±0.7	4.4±0.6	4.6±0.9	ns
Glucose, mmol/L	10.2±5.9	10.5±6.3	9.9±5.6	ns
Creatinine, µmol/L	123.3±59.7	106.7±36.8	141.9±74.4	0.021
eGFR, mL/min/1.73 m²	55.6±22.9	60.3±21.1	50.4±24.2	ns
Urea, mmol/L	10.0±6.0	8.7±4.3	11.5±7.3	0.071
Uric acid, µmol/L	439.6±188.8	385.9±141.6	499.8±217.9	0.027
hs-cTn	93.8±252.7	118.1±195.4	67.8±99.4	ns
NT-proBNP, pg/mL	10265.8±8583.6	11444.1±9357.0	9000.0±7642.0	ns
AST	50.4±87.2	56.6±103.6	44.0±66.2	ns
ALT	40.7±49.1	32.5±6.8	53.7±106.6	ns
ALP	95.8±40.9	92.0±42.6	100.6±39.4	ns
GGT	81.2±101.7	77.7±112.8	85.4±88.6	ns
Total proteins, g/L	67.5±6.9	69.1±1.9	65.5±8.1	0.062
Albumin, g/L	38.7±6.1	39.6±3.6	37.7±5.7	ns
Globulin, g/L	28.6±4.9	29.2±4.4	27.8±5.4	ns
TSH	2.77±3.81	2.3±2.2	3.3±5.1	ns
Free T4	16.7±4.0	16.8±4.6	16.5±3.3	ns

Table 7. Baseline total B-line count in the lung ultrasound group

Statistic	Value
Mean	42.18
95% CI for mean	38.18-46.18
Median	41.00
Mode	38
Standard deviation	11.10
Minimum	26.00
Maximum	67.00
Range	41.00
Skewness	0.471
Kurtosis	-0.490

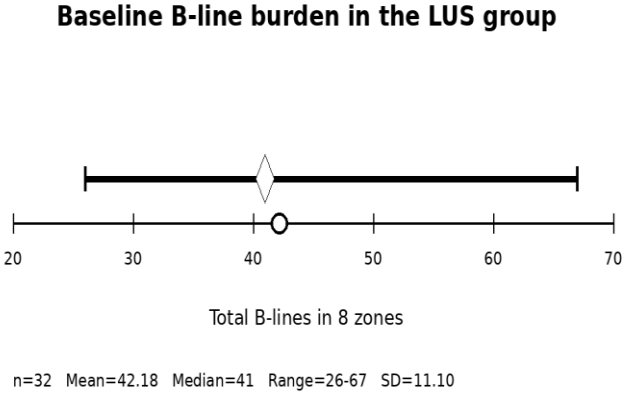

Fig. 3. Baseline B-line burden in the lung ultrasound group, showing the mean, median, and observed range

LUS-guided management was associated with a more pronounced diuretic response during hospitalization. Urine output on day 2 was significantly higher in the LUS group than in the standard-care group (2968.9±1030.9 *vs*. 2121.6±840.3 mL; p=0.004). Discharge urea was lower in the LUS group (10.5±4.8 *vs*. 13.8±7.6 mmol/L), with borderline statistical significance (p=0.052). There were no significant between-group differences in length of hospital stay, initial loop-diuretic dose, day of conversion to oral diuretics, discharge creatinine, sodium, potassium, or NT-proBNP.

Table 8. Effects of lung ultrasound-guided *versus* standard care on the in-hospital course

Characteristic	Group	Mean±SD	p value
Hospital stay, days	LUS	7.0±3.9	ns
	Standard care	6.4±3.1	
Initial loop-diuretic dose, mg	LUS	70.0±37.3	ns
	Standard care	85.9±50.4	
Conversion to oral diuretic, day	LUS	4.7±0.5	ns
	Standard care	4.9±0.5	
NT-proBNP at discharge	LUS	2570.3±2140.5	ns
	Standard care	4424.1±7308.8	
Creatinine at discharge, μmol/L	LUS	109.5±37.2	ns
	Standard care	130.4±54.5	
Urea at discharge, mmol/L	LUS	10.5±4.8	0.052
	Standard care	13.8±7.6	
Sodium at discharge, mmol/L	LUS	138.5±4.4	ns
	Standard care	138.6±4.3	
Potassium at discharge, mmol/L	LUS	4.2±0.5	ns
	Standard care	4.3±0.5	
Admission body weight, kg	LUS	80.2±13.8	ns
	Standard care	86.4±19.2	
Discharge body weight, kg	LUS	74.8±13.1	ns
	Standard care	81.5±17.6	
Urine output first 6 h, mL	LUS	1398.4±642.9	ns
	Standard care	1274.1±678.9	
Urine output first 24 h, mL	LUS	2900.0±1244.9	ns
	Standard care	2698.7±1111.5	
Urine output day 2, mL	LUS	2968.9±1030.9	0.004
	Standard care	2121.6±840.3	
Urine output day 3, mL	LUS	2557.3±884.5	ns
	Standard care	2905.6±2107.5	
Urine output day 4, mL	LUS	2631.6±1304.7	ns
	Standard care	2523.7±820.5	

In the backward stepwise binary logistic regression model, the final model was significant (chi-square=9.151, df=2; p=0.010) and correctly classified 66% of patients. Discharge body weight (OR 0.950, 95% CI 0.906-0.996; p=0.033) and discharge urea (OR 0.887, 95% CI 0.794-0.992; p=0.036) remained independently associated with LUS group assignment. Because the dependent variable was treatment-group assignment rather than a clinical outcome, these findings are interpreted as associations with the LUS-guided treatment strategy rather than as predictors of prognosis.

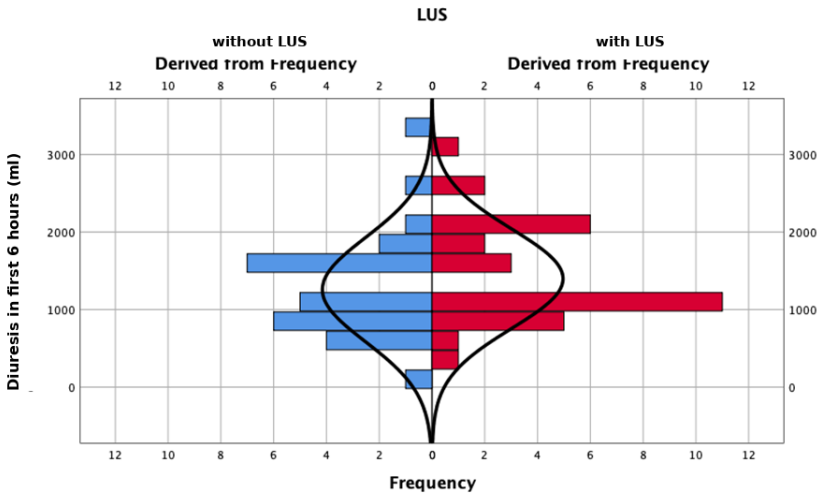

Fig. 4. Population-pyramid display of the distribution of diuretic response in the lung ultrasound and standard-care groups

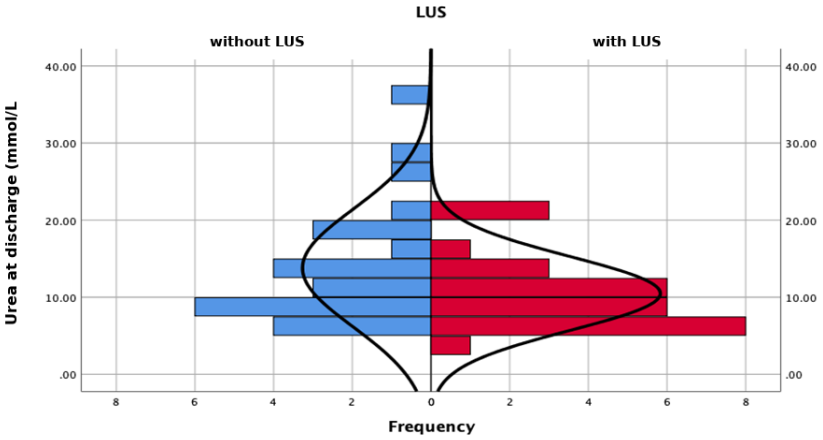

Fig. 5. Population-pyramid display of discharge serum urea values in the lung ultrasound and standard-care groups

Table 9. Backward stepwise binary logistic regression of variables associated with lung ultrasound-guided management

Variable	B	SE	Wald	p value	OR	95% CI
Hospital stay	-0.090	0.159	0.322	0.570	0.914	0.668-1.248
Urine output first 6 h	0.000	0.001	0.006	0.939	1.000	0.998-1.002
Urine output first 24 h	0.000	0.001	0.027	0.869	1.000	0.999-1.001
Admission body weight	0.830	0.978	0.719	0.396	2.293	0.337-15.605
Discharge body weight	-0.900	0.989	0.828	0.363	0.406	0.058-2.827
Net body-weight loss	-0.593	0.976	0.370	0.543	0.552	0.082-3.743
Sodium at discharge	-0.095	0.100	0.910	0.340	0.909	0.748-1.106
Potassium at discharge	-0.184	0.875	0.044	0.833	0.832	0.150-4.621
Creatinine at discharge	0.008	0.012	0.403	0.525	1.008	0.984-1.032
Urea at discharge	-0.133	0.093	2.064	0.151	0.875	0.730-1.050
Initial diuretic dose	0.002	0.011	0.033	0.855	1.002	0.980-1.024
Final model: discharge body weight	-0.051	0.024	4.551	0.033	0.950	0.906-0.996
Final model: discharge urea	-0.119	0.057	4.387	0.036	0.887	0.794-0.992

Thirty-day outcomes

During 30-day follow-up, 8 of 60 patients (13.3%) experienced MACE: 3 of 32(9.4%) in the LUS group and 5 of 28(17.9%) in the standard-care group. Seven events were

rehospitalizations for AHF and one was a stroke. The between-group difference in overall MACE was not statistically significant. Three patients died within 30 days: 1 in the LUS group and 2 in the standard-care group.

Table 10. Thirty-day major adverse cardiovascular events

Outcome	All (n=60)	LUS (n=32)	Standard care (n=28)	p value
MACE	8(13.3%)	3(9.4%)	5(17.9%)	ns
In-hospital mortality	2(3.3%)	0(0%)	2(7.1%)	—
30-day mortality	3(5.0%)	1(3.1%)	2(7.1%)	ns

Kaplan-Meier analysis was performed for cumulative 30-day MACE. Mean time to event was 17.7±4.0 days overall, 13.7±6.7 days in the LUS group, and 20.2±5.3 days in the standard-care group. The log-rank test did not show a significant difference between groups (chi-square=0.969; p=0.325). Given the small number of events, the survival analysis should be considered descriptive and hypothesis-generating.

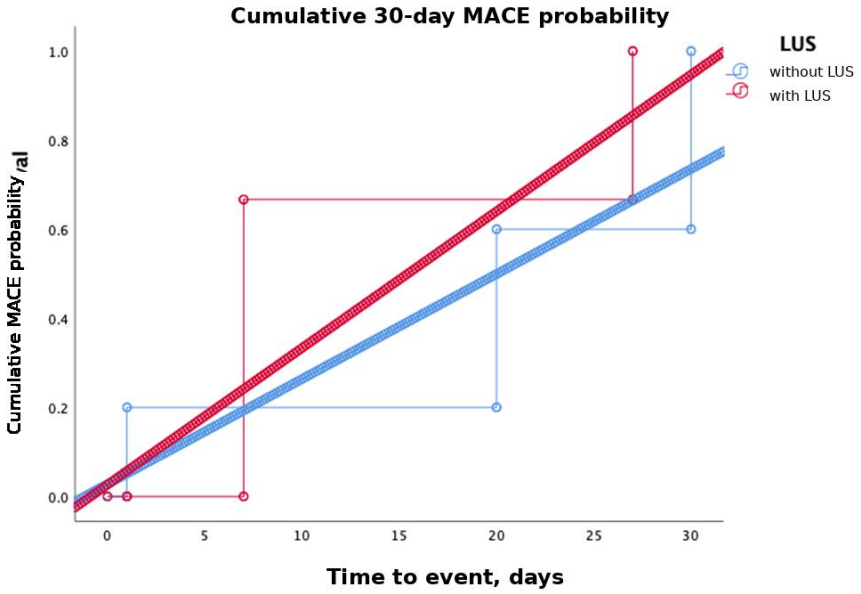

Fig. 6. Kaplan-Meier curve for 30-day major adverse cardiovascular events in the lung ultrasound and standard-care groups

Discussion

In this prospective single-center study of patients hospitalized with AHF, the addition of serial LUS to standard in-hospital assessment was associated with evidence of more effective decongestion. The clearest between-group difference was greater urine output on the second day of treatment, while discharge urea showed a favorable borderline trend. Thirty-day MACE occurred less frequently in the LUS group, but the study was not large enough to demonstrate a statistically significant difference in short-term clinical events.

The clinical rationale for serial LUS in AHF is its ability to provide a rapid and repeatable assessment of pulmonary congestion. B-lines reflect increased extravascular lung water and can change dynamically during decongestive treatment[6-8]. This may be particularly useful when symptoms and physical signs are discordant with the degree of residual congestion. Previous studies have shown that persistent pulmonary congestion at or near discharge is associated with a higher risk of rehospitalization and death[9,10].

Our findings are directionally consistent with prior studies examining LUS-guided management. The LUS-HF trial by Rivas-Lasarte *et al.* showed that LUS-guided treatment in ambulatory heart-failure patients could reduce subsequent heart-failure events, while other studies have shown that serial changes in B-lines parallel changes in clinical congestion and carry prognostic information[4,8,10,11]. In the present study, the treatment effect was most evident during the in-hospital phase, where day-2 diuresis was higher in the LUS-guided group.

The standard-care group entered the study with higher creatinine and uric acid values, indicating a less favorable baseline renal profile. This baseline difference should be considered when interpreting the discharge biochemical findings. Nevertheless, discharge urea was numerically lower in the LUS group and remained associated with LUS group assignment in the stepwise model. These findings suggest that repeated assessment of congestion may help clinicians titrate decongestive therapy more precisely, although a causal renal-protective effect cannot be established from this study.

During 30-day follow-up, MACE was numerically less frequent in the LUS-guided group. However, the number of events was small and the Kaplan-Meier curves did not differ significantly. The observed trend is therefore hypothesis-generating and should be confirmed in larger adequately powered studies before conclusions can be drawn regarding effects on early readmission or mortality.

Several limitations should be acknowledged. This was a single-center study with a small sample size and few 30-day events. Baseline renal function and markers of systemic congestion were not fully balanced between groups, which may have influenced treatment response and biochemical changes. The regression model used LUS group assignment as its dependent variable and should therefore be interpreted as an exploratory association analysis rather than an outcome-prediction model. Finally, the short follow-up period limits conclusions regarding longer-term clinical benefit.

Conclusion

Serial in-hospital LUS-guided monitoring in patients with AHF was associated with a greater diuretic response and evidence of improved decongestion. Thirty-day MACE was numerically lower in the LUS-guided group, but the difference was not statistically significant. These findings support the feasibility and potential clinical value of incorporating bedside LUS into individualized decongestive management, while larger multicenter studies are needed to determine whether this strategy improves post-discharge outcomes.

Conflict of interest statement. None declared.

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