Prognostic values of B-lines combined with clinical congestion assessment at discharge in heart failure patients

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Abstract

Aims We aim to investigate the additive effect of B-lines on lung ultrasound (LUS) for predicting outcome in patients with heart failure (HF) when combined with conventional assessment of clinical congestion.

Methods and results This study prospectively enrolled 117 hospitalized HF patients (61 ± 16 years, 70.1% males) who underwent congestion assessment by the ‘wet/dry’ status, clinical congestion score (CCS), and B-lines on LUS. The primary endpoint was all-cause mortality or hospitalization for HF during the 180-day follow-up after discharge. The ‘Wet’, CCS ≥ 3, and B-lines >5, indicators of congestion positive (+), were observed in 83.8%, 76.1%, and 70.1% of the patients on admission, respectively; and the numbers significantly decreased to 41.9%, 41.9%, and 35.9% at discharge, respectively. The agreement between the ‘wet/dry’ status and B-lines (58.1%) or between CCS and B-lines (56.4%) was moderate at discharge, in terms of both positive and both negative. By incorporating the B-lines with assessment of clinical congestion, the patients at discharge were divided into three phenotypes as clinical congestion (+), clinical congestion (−)/B-lines (+), and clinical congestion (−)/B-lines (−). The Kaplan–Meier analysis showed a better survival in the both (−)/B-lines (+) group (‘wet/dry’ with B-lines: Chi-square 10.591, P = 0.005; CCS with B-lines: χ² 6.239, P = 0.031). When the ‘wet’ patients (n = 49) being taken as the reference, the ‘dry’ patients with B-lines (+) (n = 21) had an identical risk of the composite endpoint (hazard ratio [HR] adjusted for clinical covariates 1.021, 95% confidence interval [CI] 0.480–2.134, P = 0.974), while the ‘dry’ patients with B-lines (−) (n = 47) had a lower risk (HR 0.264, 95% CI 0.113–0.617, P = 0.002). When the CCS (+) patients (n = 49) being regarded as the reference, similar results were obtained in the patients with CCS (−) but B-lines (+) (n = 22) (HR 1.348, 95% CI 0.627–2.896, P = 0.444) as well as in those with both CCS (−) and B-lines (−) (n = 46) (HR 0.447, 95% CI 0.202–0.992, P = 0.048).

Conclusions The combination of B-lines on LUS and conventional assessment helped to identify new phenotypes of congestion that aid in the risk stratification of discharged HF patients. Further investigation is warranted to determine whether this strategy could be adopted as a guide for decongestion therapy.

Keywords Heart failure; Congestion; Lung ultrasound; B-lines

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Introduction

Congestion is considered not only the most common cause of hospitalization in patients with heart failure (HF), but also an established prognosticator of rehospitalization and mortality. Thus, decongestion is one of the major goals of management during hospitalization.1,2 However, approximately one-third of patients at discharge had residual congestion. They were at a higher risk of rehospitalization or mortality than those who were fully decongested.3–5 However, the ‘optimal’ vol-
Lung ultrasound scan and analysis

On the same day, LUS was performed by an experienced investigator (Z. X. K.), who was blinded to the results of clinical congestion assessment and other clinical data. Patients were asked to lie in a recumbent position during the LUS examination performed using a pocket US device (VScan, General Electric, USA) with a phased array transducer in sagittal orientation at an imaging depth of 18 cm. A 28-zone protocol was used for image acquisition as previously recommended. The highest number of B-lines visualized during the entire clip was quantified for each zone, and the sum of the 28 zones was used for analysis; B-lines positive (+) was defined as the presence of >5 comets.

Outcomes

The primary endpoint was a composite of all-cause mortality or hospitalization for heart failure (HHF). The events were adjudicated by two physicians (K. Y. and Z. Q.), which were assessed through follow-up phone calls, contact with primary care physicians, or review of electronic medical system (EMS) records.

Statistical analysis

Statistical analyses were performed using Statistical Product and Service Solutions (version 21.0). Normally distributed continuous variables are presented as means ± standard deviations and non-normally distributed variables as medians (interquartile ranges). Categorical variables are described as frequencies with percentages. Differences in continuous variables were tested by Student’s t-test, paired t-test or Mann–Whitney U test when appropriate. Difference in categorical variables were tested by χ² test. Kaplan–Meier curves with log-rank tests were used to compare the survival between different congestion profiles. Cox proportional hazard model was generated to assess the association between congestion profiles and the primary outcome. Adjusted model was used, applying the adjustment covariates of age, gender, systolic blood pressure at discharge, atrial fibrillation (AF), ≥30% decrease in N-terminal pro-brain natriuretic peptide (NT-proBNP) during hospitalization, use of angiotensin converting enzyme inhibitor, or angiotensin receptor blocker, or angiotensin receptor-neprilysin inhibitor (ACEI/ARB/ARNI) and beta-blocker. A P-values < 0.05 (two-tailed) were considered statistically significant.
Results

Patient characteristics

According to the study criteria, 138 patients were enrolled on admission. However, 12 patients were excluded before discharge because of heart transplantation (n = 1), cardiac surgery (n = 3), transfer to intensive care (n = 5), and home palliative care (n = 3). Nine patients were lost to follow-up, as their information could not be obtained via EMS or phone call. As a result, 117 patients (aged 61 ± 16 years, 70.1% males) who had complete data at admission, discharge, and 180-day follow-up were included in the final analysis. Among them, 78 (66.7%) patients had a history of previous admission for HF. Non-ischaemic HF was observed in 85 (72.6%) patients, while comorbidity with valvular heart diseases was seen in 20 (17.1%) patients, hypertension in 38 (32.5%), diabetes in 30 (25.6%), and pulmonary infection in 56 (47.9%). The left ventricular ejection fraction (LVEF) was 37 ± 14%, and 92 (78.6%) patients had HF with reduced ejection fraction (LVEF < 50%). The rate of use for diuretic was 94.0%, for ACEI/ARB/ARNI was 50.4%, for beta-blocker was 60.7% and for mineralocorticoid receptor antagonist (MRA) was 46.2%.

Residual congestion at discharge

The average length of hospital stay was 10 ± 4 days. From admission to discharge, there was a reduction in heart rate (82 ± 16 vs. 74 ± 14 beat per minute; P < 0.001), blood pressure (systolic: 111 ± 21 vs. 107 ± 14 mmHg, P = 0.026; and diastolic: 71 ± 13 vs. 68 ± 9 mmHg, P = 0.040), weight (65.6 ± 14.6 vs. 62.3 ± 13.8 kg), Borg score (3 ± 3 vs. 1 ± 1), and NT-proBNP level (4666 [2246–11 388] vs. 2417 [980–5084] pg/mL) (all P < 0.001). The proportion of patients with congestion signs was decreased (rales: 59.8 vs. 19.7%, P < 0.001; lower extremity oedema: 49.6 vs. 7.7%, P < 0.001; and jugular vein distension: 51.3 vs. 41.0%, P = 0.065). The ‘wet’ (83.8 vs. 41.9%) or CCS (+) (76.1 vs. 41.9%) patients were significantly fewer, as well as the patients with B-lines (+) (70.1 vs. 35.9%) (all P < 0.001).

When comparing between residual congestion at discharge by different methods, there was only moderate agreement between the ‘wet/dry’ status and CCS (67.5%), between the ‘wet/dry’ status and B-lines (58.1%) or between CCS and B-lines (56.4%), in terms of both positive and both negative. Conflicting results were observed in over 40% patients as clinical congestion (+) but B-lines (−), and clinical congestion (−) but B-lines (+) (Figure 1).

Figure 1. Concordance and discordance between ‘wet/dry’ and B-lines (A) and between CCS and B-lines (B). CCS, clinical congestion score.
## Table 1  Comparisons between patients with and without congestion

|                           | Wet/dry status | CCS (N = 49) | B-lines (N = 42) |
|---------------------------|----------------|-------------|-----------------|
|                           | Wet (N = 49)   | Dry (N = 68) | ( + ) N = 42    |
|                           | ( - ) N = 68   | ( - ) N = 75 |
| Age, years                | 62 ± 17        | 60 ± 15     | 56 ± 15         |
| Male, n (%)               | 29 (59.2)      | 53 (77.9)*  | 31 (73.8)       |
| BMI, kg/m²                | 24 ± 4         | 24 ± 4      | 24 ± 5          |
| AF, n (%)                 | 20 (40.8)      | 29 (42.6)   | 16 (38.1)       |
| Non-ischaemic HF, n (%)   | 34 (69.4)      | 50 (73.5)   | 27 (64.3)       |
| NYHA class, n (%)         | 12 (24.5)      | 40 (58.8)   | 18 (42.9)       |
|                           | 37 (75.5)      | 28 (41.2)*  | 34 (45.3)       |
| Heart rate, b.p.m.        | 74 ± 17        | 71 ± 11     | 74 ± 14         |
| SBP, mmHg                 | 106 ± 12       | 108 ± 15    | 106 ± 12        |
| DBP, mmHg                 | 68 ± 9         | 69 ± 10     | 68 ± 9          |
| NT-proBNP, pg/mL          | 3698 (1391, 7663) | 1887 (769, 3738)* | 3662 (1075, 8582) | 2085 (844, 3716)* |
| Scr, μmol/L               | 104 (87, 148)  | 98 (79,142) | 104 (91, 156)  |
| K+, mmol/L                | 4.3 ± 0.4      | 4.3 ± 0.5   | 4.2 ± 0.5       |
| Na+, mmol/L               | 140 ± 3        | 139 ± 4     | 139 ± 4         |
| Cl−, mmol/L               | 99 ± 5         | 99 ± 4      | 99 ± 4          |
| LVEF, %                   | 37 ± 16        | 37 ± 14     | 35 ± 14         |
| ACEI/ARB/ARNI, n (%)      | 22 (44.9)      | 37 (54.5)   | 21 (50.0)       |
| Beta-blocker, n (%)       | 27 (55.1)      | 44 (64.7)   | 21 (50.0)       |

ACEI, angiotensin-converting enzyme inhibitor; AF, atrial fibrillation; ARB, angiotensin receptor blocker; ARNI, angiotensin receptor-neprilysin inhibitor; BMI, body mass index; bpm, beat per minute; CCS, clinical congestion score; Cl−, serum chloride; DBP, diastolic blood pressure; K+, serum potassium; LVEF, left ventricular ejection fraction; Na+, serum sodium; NT-proBNP, N-terminal pro-brain natriuretic peptide; NYHA, New York Heart Association classification; SBP, systolic blood pressure; Scr, serum creatinine; +, positive; −, negative. *P < 0.05, when compared with patients with congestion.
As shown in Table 1, congestive patients at discharge had a higher proportion of females and NYHA III/IV class when assessed by ‘wet/dry’ status and CCS. They had a lower body mass index level and use rate of ACEI/ARB/ARNI when assessed by CCS, while they were younger when assessed by B-lines. A higher NT-proBNP concentration was observed in congestive patients assessed by any one of the three methods. However, there was no difference in the blood pressure, heart rate, serum creatinine, potassium, sodium, chloride, LVEF, and the proportion of AF, non-ischaemic HF and use of beta-blocker between the groups with and without residual congestion.

Outcome at 180 days

During the 180-day follow-up, 14 (12.0%) patients died, all due to cardiovascular causes. There were 37 (31.6%) patients who underwent rehospitalization, and 36 (97.3%) of them were admitted for HF. The primary composite endpoint was observed in 45 patients (38.5%).

Residual congestion and outcome

The primary endpoint was observed in 24 (49.0%) ‘wet’ and 21 (30.9%) ‘dry’ patients ($P = 0.056$), in 23 (46.9%) CCS (+) and 22 (32.4%) CCS (−) patients ($P = 0.126$), as well as in 24 (57.1%) B-lines (+) and 21 (28.0%) B-lines (−) patients ($P = 0.003$). The Kaplan–Meier analysis showed a better event-free survival in the group with ‘dry’ status, CCS (−) or B-lines (−) compared with its counterpart, respectively (Figure 2A–C).

When combined conventional ‘wet/dry’ or CCS assessment with B-lines, a three-group division was established as clinical congestion (+), clinical congestion (−) with B-lines (+), and clinical congestion (−) with B-lines (−). As shown in Figure 3, the group having both ‘dry’ and B-lines (−), or both CCS (−) and B-lines (−) exerted the best survival among the three groups. After adjusting age, gender, systolic blood pressure at discharge, AF, ≥30% decrease in NT-proBNP during hospitalization, use of ACEI/ARB/ARNI and beta blocker, the patients with ‘dry’ and B-lines (−) had a significant lower risk for the composite endpoint (Hazard ratio [HR] = 0.264, 95% confidence interval [CI]: 0.113–0.617, $P = 0.002$) when...
The combination of B-lines and clinical congestion assessment for prognosis prediction

compared with those with ‘wet’ (as the reference). In contrast, the patients with ‘dry’ and B-lines (+) had an identical risk with ‘wet’ (HR = 1.012, 95% CI: 0.480–2.134, P = 0.974). Similarly, when the group with CCS (+) taken as the reference, the group with CCS (–) and B-lines (–) showed a lower risk (HR = 0.447, 95% CI: 0.202–0.992, P = 0.048), but the group with CCS (–) and B-lines (+) was comparable (HR = 1.348, 95% CI: 0.627–2.896, P = 0.444).

Discussion

This prospective study demonstrated the feasibility of quantifying B-lines using a hand-held US device in HHF patients, which was incorporated into the conventional method of congestion evaluation. By adopting a combined assessment strategy, a three-group division of patients into new congestion phenotypes as clinical congestion (+), clinical congestion (–) but B-lines (+), or both clinical congestion (–) and B-lines (–) improved the prediction of the 180-day all-cause mortality or HHF.

B-lines assessed by LUS showed higher sensitivity and specificity in diagnosing pulmonary congestion than did crackles and chest radiography. Additionally, this significantly correlated with the wet/dry ratio of lung tissue (r = 0.91; P < 0.001) measured by gravimetric analysis, which is the gold standard in assessing extravascular lung water. In fact, B-lines are regarded as the most reproducible signs of US that are easy to recognize. After a short period of training, doctors, nurses, or paramedical staff can achieve excellent reproducibility in the assessment of B-lines, irrespective of their experience with US imaging. Usually, LUS is an add-on to transthoracic echocardiography by high-end devices to investigate lung congestion in hospital settings as seen in previous studies, whereas the adoption of hand-held devices to quantify B-lines was only reported in outpatient settings. In this study, its use was extended to in-hospital patients for serial congestion assessment rather than single vision, and more importantly for a predischarge assessment in order to predict mid-term outcomes.

As reported in previous HF registry or trials, wherein 80–97.2% of patients admitted for worsening HF showed ‘wet’ status or CCS ≥ 3 at admission and 10–48% had residual congestion at discharge, patients with congestion were prevalent in this study too. Although congestion is correlated with elevated LV filling pressure, NT-proBNP level, and NYHA class, the absence of clinical signs of congestion does not necessarily indicate a normal LV filling pressure. Stevenson et al. found that 43% of patients without congestion signs had a pulmonary capillary wedge pressure ≥22 mmHg. Unfortunately, the consensus between the different methods of congestion assessment is only moderate. On admission, clinical assessment revealed more number of patients with congestion than did the B-lines on LUS in this study. This corroborated with the findings by Platz et al. that 70.5% of the patients had >3 B-lines but 80–97.6% presented congestion signs. This could be attributed to a more severe peripheral congestion than pulmonary congestion, which may lead to overestimation of volume overload on admission. In contrast, more than half of the patients were found to be congestion negative at discharge on clinical assessment, and approximately one-third of them showed B-lines on LUS as reported in this study as well as previous reports. This could be explained by a later remission of pulmonary congestion than that of peripheral congestion due to a gradually lowered LV filling pressure after therapy.

Clinical congestion is regarded as an independent predictor of poor prognosis. In the post hoc analysis of the EVEREST trial, the modified CCS at discharge was associated with an increased risk of combined all-cause mortality or HHF during a median follow-up period of 9.9 months. However, patients with a CCS of zero still reported high incidence of HHF (26.2%) and all-cause mortality (19.1%). This emphasized the need for better stratification of patients at discharge, especially in those without clinical congestion upon conventional assessment. When used individually, the presence of B-lines at discharge could also predict short-term or mid-term prognosis, but it showed a better effect if combined with other assessment. In the post-hoc analysis of the Lung Ultrasound Guided Treatment in Chronic Heart Failure Patients (LUS-HF) trial, only 19% patients having rales at discharge were clinical pulmonary congestion (+). In the rest of patients without rales, 40% presenting ≥5 B-lines were regarded as subclinical congestion, while the other 60% with <5 B-lines were congestion (–). The adjusted risk of rehospitalization, unexpected visit for worsening HF, or death in the 6-month follow-up was lower in the latter group, but similar between those with clinical and subclinical congestion. It corroborated the findings of the present study which adopted more comprehensive assessment of clinical congestion. The current three-group division established on initial clinical assessment followed by B-lines could be a feasible strategy in daily practice. Further research on whether LUS alone or combined with clinical assessment guided decongestion therapy or discharge could improve outcomes is warranted, despite that the LUS-HF trial demonstrated that LUS guided diuretic therapy in ambulant HF patients lowered the risk of rehospitalization for worsening HF.

Study limitations

First, this was a single-centre study with a relatively small sample size, which might affect the generalizability of the results. Second, heterogeneity of the enrolled patients might exist in terms of LVEF or underlying aetiology, but subgroup
analysis was not performed due to our focus on congestion in this study and the small sample size. Third, the state or change of congestion was not assessed during follow-up, which might provide further information on congestion and HF prognosis.

**Conclusions**

The combination of B-lines on LUS with conventional clinical methods is feasible for congestion assessment in hospitalized HF patients. It can help detect more congestion phenotypes and accordingly further stratify patients with different risks of all-cause mortality or HHF. Further exploration is warranted to determine whether this combined strategy could serve as a guide for decongestion therapy.

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**Conflict of interest**

None declared.

**Supporting information**

Additional supporting information may be found online in the Supporting Information section at the end of the article.

**Table S1.** Grading scale for simplified clinical congestion score.

**References**

1. Boorsma EM, Ter Maaten JM, Damman K, Dinh W, Gustafsson F, Goldsmith S, et al. Congestion in heart failure: A contemporary look at physiology, diagnosis and treatment. *Nat Rev Cardiol*. 2020; 17: 641–655.
2. Girerd N, Seronde MF, Coiro S, Chouhed T, Bilbault P, Braun F, et al. Integrative assessment of congestion in heart failure throughout the patient journey. *JACC Heart Fail*. 2018; 6: 273–285.
3. Chioncel O, Mebazaa A, Maggioni AP, Harjola VP, Rosano G, Laroche C, et al. Acute heart failure congestion and perfusion status - impact of the clinical classification on in-hospital and long-term outcomes; insights from the ESC-EORP-HFA heart failure long-term registry. *Eu J Heart Fail*. 2019; 21: 138–155.
4. Ambrosy AP, Pang PS, Khan S, Konstam MA, Fonarow GC, Traver B, et al. Clinical course and predictive value of congestion during hospitalization in patients admitted for worsening signs and symptoms of heart failure with reduced ejection fraction: Findings from the EVEREST trial. *Eu J Heart Fail*. 2013; 34: 835–843.
5. Rubio-Gracia J, Demissei BG, Ter Maaten JM, Cleland JG, O’Connor CM, Metra M, et al. Prevalence, predictors and clinical outcome of residual congestion in acute decompensated heart failure. *Int J Cardiol*. 2018; 258: 185–191.
6. Rohde LE, Beck-da-Silva L, Goldraich L, Grazziotin TC, Palombini DV, Polanyczky CA, et al. Reliability and prognostic value of traditional signs and symptoms in outpatients with congesitive heart failure. *Can J Cardiol*. 2004; 20: 697–702.
7. Mullens W, Damman K, Harjola VP, Mebazaa A, Brunner-La Rocca HP, Martens P, et al. The use of diuretics in heart failure with congestion - a position statement from the heart failure Association of the European Society of cardiology. *Eu J Heart Fail*. 2019; 21: 137–155.
8. Selvaraj S, Claggett B, Pozzi A, McMurray JLV, Jhund PS, Packer M, et al. Prognostic implications of congestion on physical examination among contemporary patients with heart failure and reduced ejection fraction: PARADIGM-HF. *Circulation*. 2019; 140: 1369–1379.
9. Picano E, Scali MC, Ciampi Q, Lichtenstein D. Lung ultrasound for the cardiologist. *JACC Cardiovasc Imaging*. 2018; 11: 1692–1705.
10. Pivetta E, Goffi A, Lupia E, Tizzani M, Porroni G, Ferreri E, et al. Lung ultrasound-implemented diagnosis of acute decompensated heart failure in the ED: A SIMEU multicenter study. *Chest*. 2015; 148: 202–210.
11. McDonagh TA, Metra M, Adamo M, Gardner RS, Baumbach A, Bohm M, et al. 2021 ESC guidelines for the diagnosis and treatment of acute and chronic heart failure. *Eu J Heart Fail*. 2021; 42: 3599–3726.
12. Rivas-Lasarte M, Alvarez-Garcia J, Fernandez-Martinez J, Maestro A, Lopez-Lopez L, Sole-Gonzalez E, et al. Lung ultrasound-guided treatment in ambulatory patients with heart failure: A randomized controlled clinical trial (LUS-HF study). *Eu J Heart Fail*. 2019; 21: 1605–1613.
13. Bajraktari G, Pugliese NR, D’Agostino A, Rosa GM, Ibrahim P, Percuku L, et al. Echo- and B-type natriuretic peptide-guided follow-up versus symptom-guided follow-up: Comparison of the outcome in ambulatory heart failure patients. *Cardiol Res Pract*. 2018; 2018: 3139861.
14. Bidaut A, Hubert A, Charton M, Paven E, Leclercq G, Galli E, et al. One year prognostic value of B-lines in dyspnoic patients. *ESC Heart Fail*. 2021; 8: 1759–1766.
15. Ponikowski P, Voors AA, Anker SD, Bueno H, Cleland JGF, Coats AJS, et al. 2016 ESC guidelines for the diagnosis and treatment of acute and chronic heart failure: The task force for the diagnosis and treatment of acute and chronic heart failure of the European Society of Cardiology (ESC) developed with the special contribution of the heart failure
The combination of B-lines and clinical congestion assessment for prognosis prediction

ESC Heart Fail 2022; 9: 3044–3051
DOI: 10.1002/ehf2.14041

association (HFA) of the ESC. Eur Heart J. 2016; 37: 2129–2200.

16. Platz E, Jhund PS, Girerd N, Pivetta E, McMurray JJV, Peacock WF, et al. Expert consensus document: Reporting checklist for quantification of pulmonary congestion by lung ultrasound in heart failure. Eur J Heart Fail. 2019; 21: 844–851.

17. Torino C, Gargani L, Sicari R, Letachowicz K, Ekart R, Fliser D, et al. The agreement between auscultation and lung ultrasound in hemodialysis patients: The LUST study. Clin J Am Soc Nephrol. 2016; 11: 2005–2011.

18. Iwakura K, Onishi T. A practical guide to the lung ultrasound for the assessment of congestive heart failure. J Echocardiogr. 2021; 19: 195–204.

19. Jambrik Z, Gargani L, Adamicza A, Kaszaki J, Varga A, Forster T, et al. B-lines quantify the lung water content: A lung ultrasound versus lung gravimetry study in acute lung injury. Ultrasound Med Biol. 2010; 36: 2004–2010.

20. Platz E, Merz AA, Jhund PS, Vazir A, Campbell R, McMurray JJ. Dynamic changes and prognostic value of pulmonary congestion by lung ultrasound in acute and chronic heart failure: A systematic review. Eur J Heart Fail. 2017; 19: 1154–1163.

21. Coiro S, Rossignol P, Ambrosio G, Carluccio E, Alunni G, Murrone A, et al. Prognostic value of residual pulmonary congestion at discharge assessed by lung ultrasound imaging in heart failure. Eur J Heart Fail. 2015; 17: 1172–1181.

22. Coiro S, Porot G, Rossignol P, Ambrosio G, Carluccio E, Trito I, et al. Prognostic value of pulmonary congestion assessed by lung ultrasound imaging during heart failure hospitalisation: A two-Centre cohort study. Sci Rep. 2016; 6: 39426.

23. Palazzuoli A, Ruocco G, Beltrami M, Nuti R, Cleland JG. Combined use of lung ultrasound, B-type natriuretic peptide, and echocardiography for outcome prediction in patients with acute HFpEF and HFrEF. Clin Res Cardiol official journal of the German Cardiac Society. 2018; 107: 586–596.

24. Platz E, Campbell RT, Claggett B, Lewis EF, Groarke JD, Docherty KF, et al. Lung ultrasound in acute heart failure: Prevalence of pulmonary congestion and short- and long-term outcomes. JACC Heart Fail. 2019; 7: 849–858.

25. Platz E, Lewis EF, Uno H, Peck J, Pivetta E, Merz AA, et al. Detection and prognostic value of pulmonary congestion by lung ultrasound in ambulatory heart failure patients. Eur Heart J. 2016; 37: 1244–1251.

26. Lala A, McNulty SE, Mentz RJ, Dunlay SM, Vider JM, AbouEzzeeddine OF, et al. Relief and recurrence of congestion during and after hospitalization for acute heart failure: Insights from diuretic optimization strategy evaluation in acute decompensated heart failure (DOSE-AHF) and Cardiorenal rescue study in acute decompensated heart failure (CARESS-HF). Circ Heart Fail. 2015; 8: 741–748.

27. Stevenson LW, Perloff JK. The limited reliability of physical signs for estimating hemodynamics in chronic heart failure. JAMA. 1989; 261: 884–888.

28. Miglioranza MH, Gargani L, Sant’Anna RT, Rover MM, Martins VM, Mantovani A, et al. Lung ultrasound for the evaluation of pulmonary congestion in outpatients: A comparison with clinical assessment, natriuretic peptides, and echocardiography. JACC Cardiovasc Imaging. 2013; 6: 1141–1151.

29. Cooper LB, Lippmann SJ, DiBello JR, Gorsh B, Curtis LH, Sikirica V, et al. The burden of congestion in patients hospitalized with acute decompensated heart failure. Am J Cardiol. 2019; 124: 545–553.

30. Rivas-Lasarte M, Maestro A, Fernandez-Martinez J, Lopez-Lopez L, Sole-Gonzalez E, Vives-Borras M, et al. Prevalence and prognostic impact of subclinical pulmonary congestion at discharge in patients with acute heart failure. ESC Heart Fail. 2020; 7: 2621–2628.