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Original Article

Lung ultrasound versus lung auscultation to detect pulmonary congestion in patients with advanced heart failure before discharge

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Abstract: Background: Residual lung congestion is common in patients discharged after an acute heart failure (HF) hospitalization and represents a risk for HF rehospitalization. The aim of this study was to compare the diagnostic accuracy of B-lines on lung ultrasound and lung auscultation to detect residual congestion. We hypothesized that lung ultrasound would be more sensitive than physical examination. Methods: In this observational study of consecutive chronic HF patients discharged after an acute HF exacerbation, auscultation performed by two cardiologists and ultrasound examination performed by one experienced sonographer were compared at discharge. Residual congestion was defined by the presence of B-lines in all four zones and/or pleural effusion. Results: The study compared one hundred patients with severe heart failure (mean left ventricular (LV) ejection fraction 26%), mean age 70 years. Among the patients with signs of pulmonary congestion by lung auscultation, 31 zones were positive on lung ultrasound. Using positive ultrasound as reference, the accuracy of lung auscultation was 89.5%, with 52.5% sensitivity and 95.9% specificity. The positive and negative predictive values of lung auscultation were 68.9% and 92.1%, respectively. Conclusion: Lung auscultation has a moderate sensitivity and high specificity for detecting residual lung congestion in patients with chronic HF before discharge compared to lung ultrasound. These findings suggest, that lung ultrasound should be implemented as part of the discharge exam for the detection of residual congestion.

Keywords: Heart failure, physical examination, lung auscultation, lung ultrasound, pulmonary congestion

Introduction

Recognizing and treating lung congestion remains the cornerstone of heart failure (HF) treatment. The incidence of asymptomatic lung congestion in patients with chronic HF is high even after intensive and successful diuretic treatment during the hospital stay [1].

Advanced heart failure (HF) represents the extreme of HF and is characterized by persistent HF symptoms and progressive myocardial dysfunction, despite guideline-recommended treatment [2]. The readmission rate among patients with advanced HF remains very high, particularly in those with residual pulmonary congestion [3-5].

Physical examination with lung auscultation is currently used for the assessment of pulmonary congestion, but is not always accurate and reveals congestion in relatively later and more severe stages.

Recently, the number of B-lines was reported to correlate with left ventricular (LV) filling pressure, making it an important ultrasound marker in the management of patients with HF [6-8]. Importantly, patients with HF and chronic or acute elevation of left atrial pressure will

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often have radiographic and symptomatic signs of pulmonary congestion [9-11].

Laboratory evaluation with NT-pro-BNP, and patient evaluation for signs and symptoms of volume overload taken together with echocardiography are the first-line method for the diagnosis and follow-up of patients with HF [12]. However, NT-pro-BNP level is not necessarily a benchmark used for discharge decision-making in contemporary practice, and patients may often remain asymptomatic despite subclinical hypervolemia.

The possibility of detecting pulmonary congestion through integrated cardiopulmonary ultrasound assessment of extravascular lung fluid and atrial pressure would provide a complete evaluation of patients with HF both at hospital and in outpatient settings. NT-pro-BNP may not be available in all centers or may be judged as too costly.

Chest X-ray and computed tomography may not always be accessible and are associated with radiation, inadequately validated and, thus, not adapted for repeated assessment during HF hospitalization. Lung ultrasound (LUS) assessment of B-lines is a rapid, safe and easy bedside alternative, which can be repeatedly performed with or without a simultaneous cardiovascular ultrasound using the same cardiac transducer.

LUS for the detection of residual congestion in high-risk HF patients considered clinically stable at discharge would allow for identification of patients with residual congestion, who require more intensive diuretic regimen and HF guideline indicated drug or device therapy to prevent future deterioration and re-hospitalizations.

LUS has been proven as a highly valuable diagnostic method for detection of pulmonary congestion in patients with both acute and chronic HF. It has several advantages due to its sensitivity to detect pulmonary deaeration, rapid and noninvasive implementation with integration to a complex cardiopulmonary ultrasound examination. Several randomized clinical trials have shown that implementation of LUS leads to reduction of HF related events in the 6-12 months following hospital discharge [13, 14]. Moreover, in complex clinical scenarios of acute decompensated HF, LUS can serve as a rapid non-invasive tool to inform the differential diagnosis of dyspnea with high sensitivity and specificity to rule out non-cardiac etiologies [15].

Methods

The institutional Ethics Committee approved the study and data collection from the patients. All the patients had advanced HF with reduced ejection fraction on admission and underwent extensive cardiovascular evaluation and received guideline-recommended medical treatment in the hospital. Our therapeutic goal before the discharge consisted of stabilization.

Inclusion and exclusion criteria

Eligibility criteria for inclusion in the study were: (1) advanced heart failure having at least 1 hospitalization during the last 12 months, (2) LV ejection fraction ≤35%, (3) NYHA class III-IV, symptomatic patients on admission despite the maximally tolerated guideline-recommended medical treatment.

All patients were considered compensated or subcompensated and clinically stable before the discharge. The decision to discharge the patient from the hospital was made by treating physician based on clinical stability, absence of pulmonary congestion signs by physical examination and interruption of intravenous loop diuretic use in most of the cases.

Patients with end-stage renal disease were excluded to rule out various ultrasound patterns of B-lines. Patients with known pulmonary fibrosis, pneumonia, other active lung diseases or COVID-19 were excluded from the study considering the possible interference with image acquisition.

Lung auscultation

All patients underwent lung auscultation before discharge from hospital. Lung auscultation was performed by two independent cardiology residents who were unaware of patients' possible congestion at the time of examination. Pulmonary congestion was assessed by presence of crackles on lung auscultation. Auscultation was performed by two independent physicians blinded to the results of the lung ultrasound. Zones were predetermined and separated into two upper and two lower posterior

Table 1. Baseline characteristics of the study patients at discharge

Characteristics	Values
Age	70 ± 8.5
NYHA functional class III (n, %)	54 (54%)
NYHA functional class IV (n, %)	3 (3%)
Male (n, %)	66 (66%)
Female (n, %)	34 (34%)
EF (%)	26.2 ± 6.8
eGFR	37.8 ± 14.8
BMI	28.2 ± 4.4
Atrial fibrillation (n, %)	28 (28%)
HTN (n, %)	50 (50%)
CAD (n, %)	68 (68%)
DCM (n, %)	39 (39%)
Valvular disease (n, %)	5 (5%)
Diabetes mellitus (n, %)	38 (38%)
ICD (n, %)	6 (6%)
E/e'	14.3 ± 7.6
RA Pressure	8.4 ± 5.8
Length of hospital stay (days)	8.8

Data presented as Mean ± SD. NYHA, New York Heart Association; EF, Ejection Fraction; eGFR, estimated glomerular filtration rate; BMI, body mass index; HTN, hypertension; CAD, coronary artery disease; DCM, dilated cardiomyopathy; ICD, implantable cardioverter defibrillator.

and anterior aspects of the chest wall. The presence of inspiratory crackles or decreased lung sounds in ≥1 predetermined zones was deemed a positive observation indicator for pulmonary congestion.

Lung ultrasound

LUS examination was performed at the end of the standard two-dimensional echocardiography with the patient in supine position.

According to a recent consensus guideline, the ultrasound scanning of two sites in each hemithorax was obtained with the same probe used for the echocardiographic study, with the transducer orientation parallel to the ribs placing the probe at the third intercostal space along the anterior axillary and mid-axillary lines with imaging depth of 10-14 cm [16, 17]. For each intercostal space, 3 second clips were recorded, and the number of B-lines was analyzed in real time. The scanning lasted less than 4 minutes. The sum of B-lines recorded at each scanning site yielded a score ranging from 0 to 10, which denoted the extent of extravascular fluid in the lung. Congestion on LUS was defined as ≥3 B-lines in one zone bilaterally. B-lines were defined as discrete, laser-like vertical hyperechoic reverberation artefacts arising from the pleural line, extending to the bottom of the screen without fading, and moving synchronously with lung sliding. B-lines were considered cardiogenic if they were homogeneous without spared areas [18, 19].

All exams were performed by an experienced operator with several years of experience, who was unaware of the auscultation data and didn't participate in the clinical management or the final decision of discharging the patient. The intra-and inter-observer variability for the B-lines score were assessed by two independent observers.

Statistical analysis

Data were analyzed by a commercially available IBM_22.0.0 SPSS statistical package (IBM, Armonk, NY, USA). Categorical variables were assessed in terms of percentages. Continuous variables were reported as mean and standard deviation.

Comparisons between continuous variables were performed with Student *t* test. We used ultrasound assessment as the comparative diagnostic modality to physical examination.

The accuracy of LUS was calculated with 95% confidence interval and agreement was quantified with the Cohen k coefficient, in which k values were interpreted as follows; 0 to 0.2 - no agreement, 0.2 to 0.5 - weak agreement, 0.5 to 0.7 - moderate agreement, 0.7 to 0.99 - strong and excellent agreement between examiners. Sensitivity, specificity, positive and negative predictive values were assessed as well. Significance was defined as $P<0.05$.

Results

A total of 100 patients with decompensated HF or after acute HF recovery were examined before discharge for the assessment of possible residual congestion in the lungs. The mean age was 70 years and the mean LV ejection fraction (EF) 26%. In all patients, the performance of LUS was accessible and feasible. Baseline characteristics of patients are presented in **Table 1**.

Table 2. Performance of physical examination with reference to LUS

	Value	95% Confidence interval
Sensitivity	52.5%	39.1% to 65.7%
Specificity	95.9%	93.2% to 97.7%
Positive Likelihood Ratio	12.8	7.3 to 22.6
Negative Likelihood Ratio	0.5	0.4 to 0.6
Disease prevalence	14.8%	11.4% to 18.6%
Positive Predictive Value	68.9%	55.7% to 79.6%
Negative Predictive Value	92.1%	89.9% to 93.9%
Accuracy	89.5%	86.1% to 92.3%

Congestion was detected in 49% of patients by ultrasound and in 33% of patients by auscultation in all lobes. There was a weak to moderate agreement between physical examination and LUS (k = 0.5; P = 0.61). Lung auscultation accuracy was 89.5%, (95% CI: 86.1% to 92.3%) with 52.5% sensitivity (95% CI: 39.1% to 65.7%) and 95.9% specificity (95% CI: 93.2% to 97.7%). The lung auscultation positive predictive value was 68.9% (95% CI: 55.7% to 79.61%) (**Table 2**).

Discussion

In this study of 100 patients with advanced HF at discharge after an acute HF exacerbation, we found that lung auscultation alone was insufficient to detect residual congestion compared to LUS examination. Thus, we believe that LUS should accompany lung auscultation at discharge to identify residual congestion. Finally, we believe that LUS could have a valuable role in the clinical follow-up among high risk HF patients. In a healthy aerated lung, the only anatomical structure that can be detected is the pleura, which appears as "pleural line with lung sliding'' movement. However, when the air content in the lung is decreased and lung density is increased, vertical reverberation artifacts are detected (B-lines), which originate from pleural line and expand vertically to bottom of ultrasound view on screen [17]. Increasing number of visualized B-lines are associated with decreasing air/water content ratio [20]. It should be mentioned that pulmonary B-lines are not specific for cardiogenic congestion and can be detected in several pulmonary diseases, including ARDS. However, cardiogenic B-lines have typical sonographic characteristics [18], which can differentiate various types of B-lines. For HF with reduced ejection fraction, B-lines are characterized by presence of multiple, diffuse and bilateral visualization [21].

Accurate detection of lung congestion represents important clinical value and remains a challenge in everyday practice despite advances in radiologic opportunities. X-Ray examination and computed tomography have several limitations for dynamic assessment of congestion and safety concerns. In this context, LUS has several advantages offering non-invasive bedside rapid and safe evaluation for detection of pulmonary congestion. LUS is a valuable non-invasive diagnostic method with safe rapid dynamic assessment for patients with advanced HF.

Pre-hospital discharge evaluation of residual congestion seems to identify patients with worse prognosis and higher probability of rehospitalization [22]. A recent meta-analysis showed that a greater number of B-lines at admission, at hospital discharge, and in the outpatient setting was associated with higher rates of rehospitalization for HF decompensation and mortality [23].

Taking these data into consideration, we aimed to assess the opportunity of LUS to better and more accurately determine pulmonary congestion in high-risk patients with advanced HF, having high probability of rehospitalization.

The main finding of our study was that lung auscultation has low to moderate sensitivity (52.5%) and high specificity (95.9%) with moderate agreement (k = 0.54 for right lower anterior zone, 0.55 for left lower anterior zone) for detection of lung congestion in patients with decompensated HF after treatment with diuretics before the discharge.

Our study is the first to assess the accuracy and clinical value of lung auscultation comparing with LUS as a reference in detecting congestion among vulnerable HF patients at discharge. In the pre-specified subgroup analysis, we have demonstrated benefit of LUS over a physical examination for congestion assessment. Identifying patients or subgroups who

may have residual congestion before discharge despite adequate auscultation carries important implications for HF management, including diuretic titration at discharge.

Despite significant progress in HF treatment in recent decades, a high proportion of patients continue to be re-hospitalized with decompensation after the discharge. Meanwhile, clinical signs of congestion may not be present in such patients. Therefore, detailed assessment of lung congestion by LUS may allow physicians to detect congestion both before discharge and at outpatient period for modifying diuretic and other treatment approaches. The recent STRONG-HF study demonstrated that intensive up-titration of neuro-humoral blocking pharmacotherapy in HF patients at baseline in hospital led to successful and sustained decongestion, lower risk of 180-day re-hospitalization [24]. Several studies showed that LUS-guided management strategy reduces hospitalizations, urgent visits, mortality in patients with HF and after acute decompensated HF.

In our opinion, routine assessment of B-lines is important and feasible to evaluate whether a patient in HF is compensated at discharge and along with clinical assessment should be part of an integrated congestion exam. Moreover, the moderate reliability of lung auscultation, as reported in literature, raises concerns on whether the physical examination alone is adequate [25, 26]. Accordingly, patients with HF should be examined by ultrasound to evaluate for subclinical pulmonary congestion as opposed to relying on lung auscultation alone.

Limitations

Several factors may limit the generalization of the study findings. In addition, ultrasound examination of the lungs requires certain skill level with ultrasound and detection of B-lines is operator dependent. While LUS has high diagnostic sensitivity in HF congestion assessment, the detection of B-lines is not always related to cardiogenic etiologies. To avoid causes for non-cardiogenic B-lines we excluded any pathologies which could possibly cause B-lines.

Conclusions

In 100 patients with advanced HF at discharge after a hospitalization for acute HF exacerbation, LUS offered better diagnostic accuracy for detection of pulmonary congestion than lung auscultation. Our findings suggest the importance of routine incorporation of LUS at discharge and follow-up in high risk HF patients.

These findings suggest that when searching for pulmonary congestion at discharge it may be advisable to provide ultrasound evaluation instead of relying on lung auscultation.

Disclosure of conflict of interest

None.

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References

[1] Hage C, LÖfstrÖm U, Donal E, Oger E, KapŁonCieŚlicka A, Daubert JC, Linde C and Lund LH. Do patients with acute heart failure and preserved ejection fraction have heart failure at follow-up: implications of the framingham criteria. J Card Fail 2020; 26: 673-684.

[2] Truby LK and Rogers JG. Advanced heart failure: epidemiology, diagnosis, and therapeutic approaches. JACC Heart Fail 2020; 8: 523-536.

[3] Löfström U, Hage C, Savarese G, Donal E, Daubert JC, Lund LH and Linde C. Prognostic impact of Framingham heart failure criteria in heart failure with preserved ejection fraction. ESC Heart Fail 2019; 6: 830-839.

[4] Ambrosy AP, Pang PS, Khan S, Konstam MA, Fonarow GC, Traver B, Maggioni AP, Cook T, Swedberg K, Burnett JC Jr, Grinfeld L, Udelson JE, Zannad F and Gheorghiade M; EVEREST Trial Investigators. 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. Eur Heart J 2013; 34: 835-43.

[5] Chioncel O, Mebazaa A, Maggioni AP, Harjola VP, Rosano G, Laroche C, Piepoli MF, Crespo-Leiro MG, Lainscak M, Ponikowski P, Filippatos G, Ruschitzka F, Seferovic P, Coats AJS and Lund LH; ESC-EORP-HFA Heart Failure Long-Term Registry Investigators. 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. Eur J Heart Fail 2019; 21: 1338-1352.

[6] Picano E, Pierard L, Peteiro J, Djordjevic-Dikic A, Sade LE, Cortigiani L, Van De Heyning CM, Celutkiene J, Gaibazzi N, Ciampi Q, Senior R, Neskovic AN and Henein M. The clinical use of stress echocardiography in chronic coronary syndromes and beyond coronary artery disease: a clinical consensus statement from the European Association of Cardiovascular Imaging of the ESC. Eur Heart J Cardiovasc Imaging 2024; 25: e65-e90.

[7] Menegazzo WR, Saadi MP, Silvano GP, Gonzalez VL and Silveira AD. Theoretical concepts of lung ultrasound in the diagnosis of congestion. ABC Heart Fail Cardiomyop 2024; 4: e20240022.

[8] Demi L, Wolfram F, Klersy C, De Silvestri A, Ferretti VV, Muller M, Miller D, Feletti F, Wełnicki M, Buda N, Skoczylas A, Pomiecko A, Damjanovic D, Olszewski R, Kirkpatrick AW, Breitkreutz R, Mathis G, Soldati G, Smargiassi A, Inchingolo R and Perrone T. New international guidelines and consensus on the use of lung ultrasound. J Ultrasound Med 2023; 42: 309-344.

[9] Dwyer KH, Merz AA, Lewis EF, Claggett BL, Crousillat DR, Lau ES, Silverman MB, Peck J, Rivero J, Cheng S and Platz E. Pulmonary congestion by lung ultrasound in ambulatory patients with heart failure with reduced or preserved ejection fraction and hypertension. J Card Fail 2018; 24: 219-226.

[10] Cuthbert JJ, Pellicori P, Flockton R, Kallvikbacka-Bennett A, Khan J, Rigby AS, Girerd N, Zannad F, Cleland JGF and Clark AL. The prevalence and clinical associations of ultrasound measures of congestion in patients at risk of developing heart failure. Eur J Heart Fail 2021; 23: 1831-1840.

[11] Agricola E, Bove T, Oppizzi M, Marino G, Zangrillo A, Margonato A and Picano E. "Ultrasound comet-tail images": a marker of pulmonary edema: a comparative study with wedge pressure and extravascular lung water. Chest 2005; 127: 1690-5.

[12] McDonagh TA, Metra M, Adamo M, Gardner RS, Baumbach A, Böhm M, Burri H, Butler J, Čelutkienė J, Chioncel O, Cleland JGF, Coats AJS, Crespo-Leiro MG, Farmakis D, Gilard M, Heymans S, Hoes AW, Jaarsma T, Jankowska EA, Lainscak M, Lam CSP, Lyon AR, McMurray JJV, Mebazaa A, Mindham R, Muneretto C, Francesco Piepoli M, Price S, Rosano GMC, Ruschitzka F and Kathrine Skibelund A; ESC Scientific Document Group. 2021 ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure. Eur Heart J 2021; 42: 3599-3726.

[13] Rivas-Lasarte M, Álvarez-García J, Fernández-Martínez J, Maestro A, López-López L, Solé-González E, Pirla MJ, Mesado N, Mirabet S, Fluvià P, Brossa V, Sionis A, Roig E and Cinca J. Lung ultrasound-guided treatment in ambulatory patients with heart failure: a randomized controlled clinical trial (LUS-HF study). Eur J Heart Fail 2019; 21: 1605-1613.

[14] Araiza-Garaygordobil D, Gopar-Nieto R, Martinez-Amezcua P, Cabello-López A, Alanis-Estrada G, Luna-Herbert A, González-Pacheco H, Paredes-Paucar CP, Sierra-Lara MD, Briseño-De la Cruz JL, Rodriguez-Zanella H, Martinez-Rios MA and Arias-Mendoza A. A randomized controlled trial of lung ultrasound-guided therapy in heart failure (CLUSTER-HF study). Am Heart J 2020; 227: 31-39.

[15] Perrone T, Maggi A, Sgarlata C, Palumbo I, Mossolani E, Ferrari S, Melloul A, Mussinelli R, Boldrini M, Raimondi A, Cabassi A, Salinaro F and Perlini S. Lung ultrasound in internal medicine: a bedside help to increase accuracy in the diagnosis of dyspnea. Eur J Intern Med 2017; 46: 61-65.

[16] Scali MC, Zagatina A, Simova I, Zhuravskaya N, Ciampi Q, Paterni M, Marzilli M, Carpeggiani C and Picano E; Stress Echo 2020 study group of the Italian Society of Cardiovascular Echography (SIEC). B-lines with lung ultrasound: the optimal scan technique at rest and during stress. Ultrasound Med Biol 2017; 43: 2558-2566.

[17] Volpicelli G, Elbarbary M, Blaivas M, Lichtenstein DA, Mathis G, Kirkpatrick AW, Melniker L, Gargani L, Noble VE, Via G, Dean A, Tsung JW, Soldati G, Copetti R, Bouhemad B, Reissig A, Agricola E, Rouby JJ, Arbelot C, Liteplo A, Sargsyan A, Silva F, Hoppmann R, Breitkreutz R, Seibel A, Neri L, Storti E and Petrovic T; International Liaison Committee on Lung Ultrasound (ILC-LUS) for International Consensus Conference on Lung Ultrasound (ICC-LUS). International evidence-based recommendations for point-of-care lung ultrasound. Intensive Care Med 2012; 38: 577-91.

[18] Gargani L. Lung ultrasound: a new tool for the cardiologist. Cardiovasc Ultrasound 2011; 9: 6.

[19] Gargani L, Girerd N, Platz E, Pellicori P, Stankovic I, Palazzuoli A, Pivetta E, Miglioranza MH, Soliman-Aboumarie H, Agricola E, Volpicelli G, Price S, Donal E, Cosyns B and Neskovic AN; This document was reviewed by members of the 2020-2022 EACVI Scientific Documents Committee. Lung ultrasound in acute and chronic heart failure: a clinical consensus statement of the European Association of Car-

diovascular Imaging (EACVI). Eur Heart J Cardiovasc Imaging 2023; 24: 1569-1582.
[20] Soldati G, Sher S and Testa A. Lung and ultrasound: time to "reflect". Eur Rev Med Pharmacol Sci 2011; 15: 223-7.
[21] Neskovic AN, Skinner H, Price S, Via G, De Hert S, Stankovic I, Galderisi M, Donal E, Muraru D, Sloth E, Gargani L, Cardim N, Stefanidis A, Cameli M, Habib G, Cosyns B, Lancellotti P, Edvardsen T and Popescu BA; Reviewers: This document was reviewed by members of the 2016-2018 EACVI Scientific Documents Committee. Focus cardiac ultrasound core curriculum and core syllabus of the European Association of Cardiovascular Imaging. Eur Heart J Cardiovasc Imaging 2018; 19: 475-481.
[22] Rastogi T, Bozec E, Pellicori P, Bayes-Genis A, Coiro S, Domingo M, Gargani L, Palazzuoli A and Girerd N. Prognostic value and therapeutic utility of lung ultrasound in acute and chronic heart failure: a meta-analysis. JACC Cardiovasc Imaging 2022; 15: 950-952.
[23] Rastogi T, Gargani L, Pellicori P, Lamiral Z, Ambrosio G, Bayés-Genis A, Domingo M, Lupon J, Simonovic D, Pugliese NR, Ruocco G, Duarte K, Coiro S, Palazzuoli A and Girerd N. Prognostic implication of lung ultrasound in heart failure: a pooled analysis of international cohorts. Eur Heart J Cardiovasc Imaging 2024; 25: 1216-1225.
[24] Biegus J, Mebazaa A, Davison B, Cotter G, Edwards C, Čelutkienė J, Chioncel O, Cohen-Solal A, Filippatos G, Novosadova M, Sliwa K, Adamo M, Arrigo M, Lam CSP, Ter Maaten JM, Deniau B, Barros M, Čerlinskaitė-Bajorė K, Damasceno A, Diaz R, Gayat E, Kimmoun A, Pang PS, Pagnesi M, Saidu H, Takagi K, Tomasoni D, Voors AA, Metra M and Ponikowski P. Effects of rapid uptitration of neurohormonal blockade on effective, sustainable decongestion and outcomes in STRONG-HF. J Am Coll Cardiol 2024; 84: 323-336.
[25] Pivetta E, Goffi A, Lupia E, Tizzani M, Porrino G, Ferreri E, Volpicelli G, Balzaretti P, Banderali A, Iacobucci A, Locatelli S, Casoli G, Stone MB, Maule MM, Baldi I, Merletti F, Cibinel GA, Baron P, Battista S, Buonafede G, Busso V, Conterno A, Del Rizzo P, Ferrera P, Pecetto PF, Moiraghi C, Morello F, Steri F, Ciccone G, Calasso C, Caserta MA, Civita M, Condo' C, D'Alessandro V, Del Colle S, Ferrero S, Griot G, Laurita E, Lazzero A, Lo Curto F, Michelazzo M, Nicosia V, Palmari N, Ricchiardi A, Rolfo A, Rostagno R, Bar F, Boero E, Frascisco M, Micossi I, Mussa A, Stefanone V, Agricola R, Cordero G, Corradi F, Runzo C, Soragna A, Sciullo D, Vercillo D, Allione A, Artana N, Corsini F, Dutto L, Lauria G, Morgillo T, Tartaglino B, Bergandi D, Cassetta I, Masera C, Garrone M, Ghiselli G, Ausiello L, Barutta L, Bernardi E, Bono A, Forno D, Lamorte A, Lison D, Lorenzati B, Maggio E, Masi I, Maggiorotto M, Novelli G, Panero F, Perotto M, Ravazzoli M, Saglio E, Soardo F, Tizzani A, Tizzani P, Tullio M, Ulla M and Romagnoli E; SIMEU Group for Lung Ultrasound in the Emergency Department in Piedmont. Lung ultrasound-implemented diagnosis of acute decompensated heart failure in the ED: a SIMEU multicenter study. Chest 2015; 148: 202-210.
[26] Pivetta E, Goffi A, Nazerian P, Castagno D, Tozzetti C, Tizzani P, Tizzani M, Porrino G, Ferreri E, Busso V, Morello F, Paglieri C, Masoero M, Cassine E, Bovaro F, Grifoni S, Maule MM and Lupia E; Study Group on Lung Ultrasound from the Molinette and Careggi Hospitals. Lung ultrasound integrated with clinical assessment for the diagnosis of acute decompensated heart failure in the emergency department: a randomized controlled trial. Eur J Heart Fail 2019; 21: 754-766.