Review Article

Ultrasound imaging of congestion in heart failure: a narrative review

Álvaro Gamarra^, Jorge Salamanca, Pablo Díez-Villanueva, Sofia Cuenca, Jorge Vázquez, Río Jorge Aguilar, Guillermo Diego, Ana Pilar Rodríguez, Fernando Alfonso

Cardiology Department, Hospital Universitario de La Princesa, Princesa Institute for Health Research (IIS-IP), Universidad Autónoma de Madrid, CIBERCV, Madrid, Spain

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Correspondence to: Jorge Salamanca, MD. Cardiology Department, Hospital Universitario de La Princesa, Princesa Institute for Health Research (IIS-IP), Universidad Autónoma de Madrid, CIBERCV, Diego de León, 62, 28006 Madrid, Spain. Email: jsalamancaviloria@gmail.com.

Background and Objective: Congestion is a key determinant in the evolution of patients with heart failure (HF), leading to higher rates of emergency visits, hospital admissions and even mortality. Both clinical and subclinical congestion have been associated with a worse prognosis, hence the importance of its correct detection, characterization and treatment. Multiparametric assessment with ultrasound imaging, lung ultrasound (LUS) and venous Doppler analysis, has emerged as a very informative and accessible diagnostic tool in HF patients throughout their evolution. This review aims to provide a practical approach for the implementation of these techniques as well as a comprehensive summary of their prognostic and therapeutic applications in specific clinical settings.

Methods: Relevant literature from 1997 to 2024 on congestion evaluation and management based on ultrasonographic findings was retrieved through PubMed research. Only English publications were included.

Key Content and Findings: Ultrasound imaging for congestion detection and management is increasingly convening attention in HF scientific literature. Observational and randomized studies exhibit consistent and reproducible results where greater degrees of congestion have been strongly associated with worse clinical short- and long-term outcomes both in acute and chronic HF. On the other hand, ultrasound imaging helps adjusting diuretic therapy with more frequent and robust evidence regarding LUS than venous Doppler analysis.

Conclusions: Despite exponential growing evidence supporting the use of ultrasound imaging in HF, LUS and venous Doppler analysis are not yet routine. Forthcoming evidence may help to consolidate these techniques in the management of HF patients.

Keywords: Heart failure (HF); congestion; lung ultrasound (LUS); vascular doppler; narrative review

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^ ORCID: 0000-0001-5745-1986.

Introduction

Heart failure (HF) is a chronic disease that affects millions of people worldwide, with a rising prevalence due to the aging population and improved survival rates from other cardiovascular diseases (1).

HF is characterized by the heart's inability to pump sufficient blood to meet the body's metabolic needs, or by the necessity to operate under elevated filling pressures to do so, leading to fluid accumulation in tissues and organs, known as congestion. Congestion may manifest in different ways, including pulmonary edema, causing symptoms like dyspnea and orthopnea, and as peripheral edema, presenting with limb swelling and ascites. A detailed characterization of congestion should comprise not only its localization (pulmonary/systemic) but also the affected compartment (intravascular/interstitial) in order to implement the ideal treatment for each phenotype (2).

As a matter of fact, congestion is known to predict hospitalizations and mortality in patients with HF (3); thus, accurate assessment of congestion is fundamental to optimize treatment and improve clinical outcomes in HF patients. This refers to evident forms detectable through physical examination, but also to subclinical forms of congestion, which may only be detected through complementary techniques (4,5).

Ultrasound techniques, such as lung ultrasound (LUS) and vascular Doppler, have emerged as valuable, non-invasive tools complementary to echocardiography for both identifying and assessing congestion in HF patients. These techniques not only enhance diagnostic precision for quantifying and phenotyping congestion, but also facilitate goal-directed management and can provide significant prognostic information. The objective of this narrative review is to examine the methodology of each ultrasound technique, as well as the peculiarities of their application at different stages of the clinical evolution of HF patients; from acute decompensation, including evaluation at the time of hospital discharge, to ambulatory management. We present this article in accordance with the Narrative Review reporting checklist (available at https://cdt.amegroups.com/article/view/10.21037/cdt-24-430/rc).

Methods

We conducted a search of the PubMed database for this narrative review, covering the period from 1997 to July 2024. The details of the search strategy are provided in *Table 1* and Table S1 of the supplementary material. This review includes original research, review articles and expert consensus documents published in English.

Discussion

Ultrasound techniques for congestion assessment

Echocardiography

Beyond enabling the evaluation of systolic and diastolic function or the presence of valvular disease, echocardiography can detect signs of increased filling pressures and provide valuable information about the presence of congestion.

The main indicators of hemodynamic congestion assessable through echocardiography include left atrial enlargement, a high ratio between early mitral inflow velocity and mitral annular early diastolic velocity (E/e'), elevated estimated pulmonary artery systolic pressure (>35 mmHg), and a dilated inferior vena cava (IVC) (6,7).

Pulmonary capillary wedge pressure (PCWP) can be estimated using echocardiographic data. The E/e' value is used as a non-invasive estimator of left-sided filling pressures (8). An E/e' greater than 15 suggests elevated filling pressures (9). Studies have shown that this measurement correlates well with PCWP obtained invasively via right heart catheterization, providing a useful and less invasive tool for hemodynamic evaluation in HF patients (10,11).

Chronically elevated left-sided filling pressures eventually lead to increased right atrial pressures and IVC dilation. An IVC smaller than 21 mm that collapses more than 50% during inspiration suggests normal right atrial pressures, typically between 0 and 5 mmHg. Alternatively, IVC diameter over 21 mm with inspiratory collapse less than 50% indicates moderately elevated right atrial pressures, around 15 mmHg (range, 10–20 mmHg) (7). An IVC larger than 25 mm with minimal collapsibility indicates significantly elevated right atrial pressures, even over 15–20 mmHg (12). It should be noted that in patients with a low body surface area, IVC dilation may be considered at smaller diameters, with a cutoff at 17 mm correlating with a central venous pressure (CVP) of 10 mmHg (13).

IVC dilation predicts a high risk of rehospitalization for HF or death in patients with acute or chronic HF across the entire ejection fraction spectrum (14,15).

LUS

LUS emerged as a diagnostic technique in critical care at the beginning of the 21^{st} century. Only in recent years has

Table 1 The search strategy summary

Items	Specification
Date of search	01/05/2024–31/07/2024
Databases and other sources searched	PubMed
Search terms used	See Table S1 for details
Timeframe	1997–2024
Inclusion and exclusion criteria	Inclusion criteria: original articles, reviews, and expert consensus; articles in English. Exclusion criteria: single case reports and articles not in English or not translated into English
Selection process	The selection process was conducted independently by all authors, who reached a consensus in a final meeting

its use extended and become widespread in other clinical settings, gaining significant relevance in HF patients. LUS has proven to be an easy-to-learn, reliable, and reproducible technique (16). Moreover, it has demonstrated higher sensitivity than physical examination and other radiological and laboratory methods for detecting pulmonary congestion, both parenchymal edema and pleural effusion (17-19).

Ultrasound findings suggesting the presence of pulmonary congestion include bilateral B-lines and pleural effusion. B-lines, also known as “comet tails”, are hyperechoic vertical artifacts that originate at the pleural line and extend to the bottom of the screen without attenuation. These lines indicate increased extravascular water in the lungs and suggest the presence of pulmonary edema at the interlobular septal level. B-lines may be present in acute respiratory distress syndrome (ARDS) or pulmonary fibrosis (20), hence this finding must be correlated with the patient’s clinical context and information from other complementary studies. Nevertheless, a bilateral and diffuse B-line pattern is very suggestive of pulmonary congestion while ARDS and pulmonary fibrosis often showcase patchy patterns and pleural abnormalities (21). Pleural effusion manifests on ultrasound as an anechoic or hypoechoic collection in the pleural cavity, often visible in the dependent regions of the chest, where passive or secondary atelectasis may also be observed.

Several documents have been recently published advocating for standardization of the technique to achieve the best results (20,22,23) (*Figure 1*).

- ❖ The use of phased array or convex transducers is recommended, with cardiac or abdominal presets respectively, and an imaging depth of 16–18 cm.
- ❖ The patient can be placed in a sitting or supine position, but it should be noted that patients with acute HF may have a higher B-line count in the latter position.
- ❖ There are several LUS protocols (ranging from 2 to 28 explored zones) for investigating dyspnea and detecting congestion. The more rapid anterior 2-zone scan may be useful in critically ill patients, while the more detailed 28-zone protocol may be more informative in stable patients. The 8-zone examination appears to be the most efficient for diagnosis and prognostic stratification, balancing simplicity and accuracy (20,24).
- ❖ Posterior basal regions of the lung should also be explored, either for pleural effusion detection or while performing a 14-zone protocol, which may be of choice if other causes of dyspnea such as pneumonia, pneumothorax, atelectasis or pulmonary embolism are being considered (25-27). Importantly, B-lines may be present (up to 2) more frequently in posterior and basal zones, even in “dry” lungs (28).
- ❖ In each zone, the largest possible surface area should be explored, with clips recommended to last 6 seconds and counting the maximum number of B-lines in each zone explored. It should be noted that the sensitivity of the technique will decrease with shorter exploration times.

The typical pattern of pulmonary congestion consists of multiple B-lines (≥3), diffuse (in several explored areas), and bilateral (in both hemithoraxes). In order to quantify B-lines in HF patients, two main approaches are proposed (*Figure 1*):

- ❖ A counting method, where the total number of B-lines in each explored intercostal space is reported.
- ❖ A scoring system, where a minimum number of

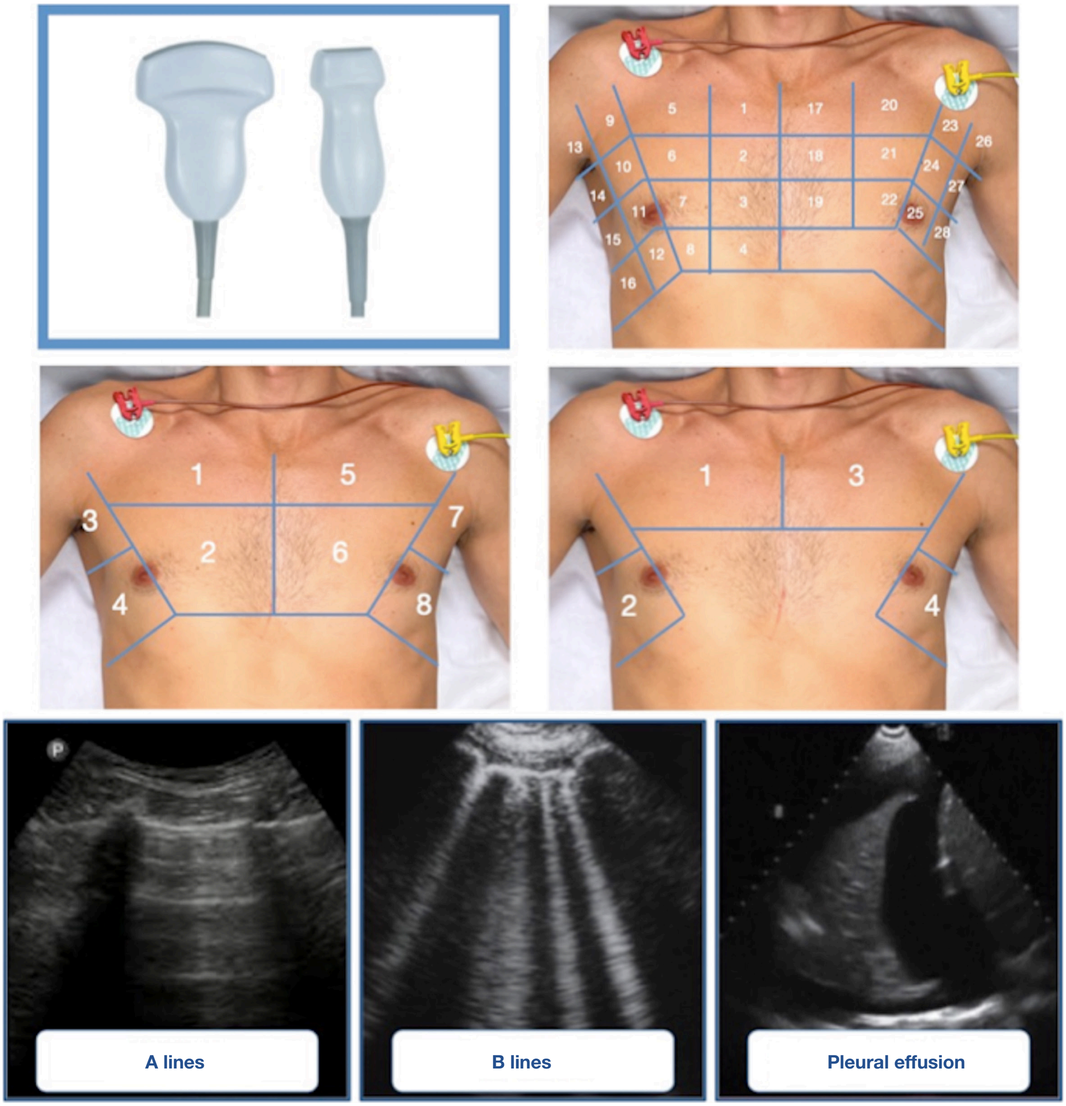

Figure 1 Lung ultrasound. Convex (left) and phased-array (right) probes. Lung ultrasound protocol examples: 28-zone, 8-zone and 4-zone lung ultrasound protocol examples. Main lung ultrasound findings.

B-lines in an intercostal space per zone is used to define a "positive" zone, generally ≥3. The positive zones are summed up to obtain a score to classify the patient's degree of congestion.

There is consistent evidence addressing the reproducibility of both approaches, with good to excellent intra and inter observer reproducibility, as well as a good correlation between expert visual assessment and automatic B-line counting systems (29,30). Both, quantitative and semi-quantitative methods, showed similar accuracy in pulmonary congestion assessment (31).

When B-lines are very numerous and confluent, an estimation method based on the percentage of the explored zone occupied on the screen is proposed. For example, if 60% of the screen is occupied by B-lines, the estimated number of B-lines would be 6 (23).

Vascular Doppler

The evaluation of venous anatomy and flows using vascular Doppler has gained relevance in recent years for estimating CVP and the degree of systemic intravascular congestion. This assessment can be performed at various levels throughout the venous system, providing different information depending on the vascular bed studied.

Elevated CVP, as well as Doppler patterns of severe congestion, have been linked to poor clinical outcomes in both critically ill (32) and HF patients (33,34).

Among the available ultrasound options for CVP estimation, the venous excess ultrasound (VExUS) score system stands out. Initially developed for fluid management and predicting acute kidney injury in critically ill patients (35,36), the VExUS score exhibits increasing application in cardiology and nephrology. The combined analysis of flow patterns at the hepatic, portal, and intrarenal veins allows for a more precise estimation of CVP than isolated IVC dilation and collapsibility (37). Additionally, VExUS has shown a correlation with both mean pulmonary pressure and PCWP (37). Combined venous assessment overcomes the limitations of evaluating each vascular bed separately, such as the influence of severe tricuspid regurgitation on hepatic vein flow, or the dilation of the IVC or portal vein observed in healthy athletes (36).

To obtain reliable information, studies should follow a material and acquisition protocol with the following essential elements (38) (*Figure 2*):

- ❖ The use of convex transducers is recommended, although phased array transducers are acceptable.
- ❖ Ultrasound frequency should range between 2 and 5 MHz. A scan depth of 10–16 cm is preferred, which may be adjusted depending on the structure studied. A sweep speed for pulsed Doppler of around 50 mm/s is recommended.
- ❖ It is preferable to limit the color Doppler box to the studied venous structure and adjust the velocity scale to a low range of around 40 cm/s for the hepatic and portal veins and about 20 cm/s for the intrarenal veins.
- ❖ The insonation angle should be as close to 0º as possible to obtain a reliable velocity and venous flow variation.
- ❖ For IVC assessment, the subxiphoid window is recommended, while for hepatic, portal, and intrarenal veins, the right lateral window is preferred.
- ❖ It is advisable to analyze venous flows at the end of expiration to minimize the influence of intrathoracic pressure.

VExUS score performance should start by assessing the IVC diameter. We will only proceed if it is ≥2 cm; otherwise, a VExUS score of 0 will be allocated. Again, a smaller IVC diameter may be considered in this regard to indicate increased CVP in patients with a low body surface area (13). Subsequently, venous flow will be evaluated at the hepatic, portal, and intrarenal veins with the following considerations in each case (38,39) (*Figure 2*):

- ❖ Hepatic veins:

The Doppler sample should be positioned in the middle of the vessel for a reliable recording. Three incremental grades of congestion will be identified: systolic and diastolic flow with systolic predominance (pattern 1, normal), systolic and diastolic flow with diastolic predominance (pattern 2, mildly abnormal), or systolic flow reversal (pattern 3, severely abnormal).

- ❖ Portal vein:

The Doppler sample should be positioned in the middle of the vessel for a reliable recording. To differentiate a portal vessel from a hepatic vein, the greater echogenicity of the portal vein wall can be useful regardless of the insonation angle, while the hepatic vein wall will only appear hyperechoic at angles around 90° (40).

Three incremental grades of congestion are identified based on the pulsatility of the flow [(Vmax – Vmin)/Vmax]: pulsatility <30% (pattern 1, normal), pulsatility 30–50% (pattern 2, mildly abnormal), or pulsatility >50% (pattern 3, severely abnormal). It is important to rule out the phenomenon of pseudo-pulsatility in the portal vein, which is secondary to interruptions in the Doppler signal caused by respiratory movements. To exclude this phenomenon, the electrocardiographic co-registration is particularly important.

- ❖ Renal veins:

The Doppler sample should be positioned at the level of the interlobular veins, within the renal parenchyma, since recordings at the level of the main renal vein can be pulsatile under euvolemic conditions. This is the most complex evaluation within the VExUS score, with a failure rate of up to 25% (41).

It should be noted that a pulsatile arterial flow, moving in the opposite direction, will often overlap in the same recording.

Three incremental grades of congestion are identified: continuous venous flow (pattern 1, normal), biphasic venous flow with systolic and diastolic components (pattern 2, mildly abnormal), and monophasic venous flow with a single diastolic component (pattern 3, severely abnormal).

Based on these findings, the VExUS score will range between 0 and 3, indicating progressively higher degrees of congestion (*Figure 2*):

- ❖ VExUS score 0: IVC <2 cm.
- ❖ VExUS score 1: IVC ≥2 cm and any combination

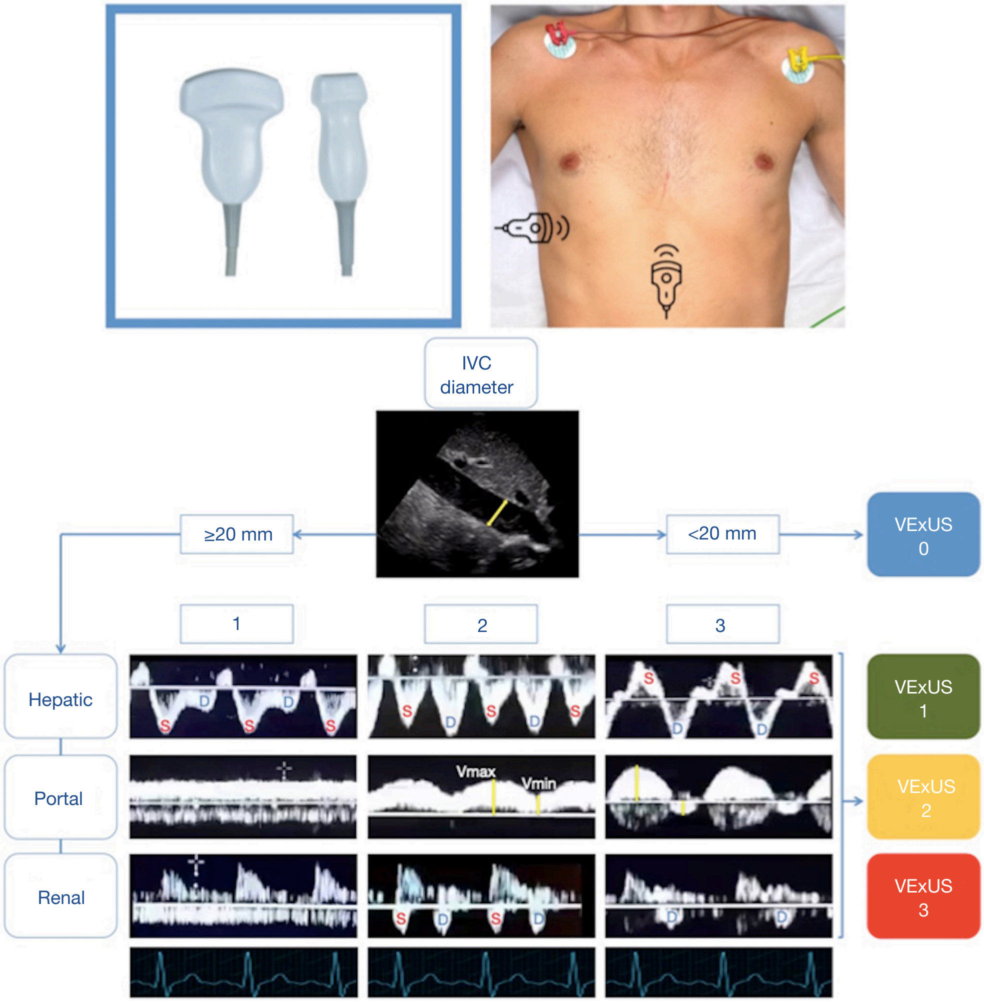

Figure 2 VExUS score. Convex (left) and phased-array (right) probes. Preferred scanning sites (right lateral and subxiphoid). VExUS score protocol: Start by measuring IVC diameter. If lower than 20 mm, VExUS score will be 0 and no further assessment will be performed. If IVC diameter is ≥20 mm, suprahepatic, portal and renal vessels should be explored. VExUS 0: IVC <20 mm; VExUS 1: IVC ≥20 mm AND any combination of normal [1] or mildly abnormal [2] findings; VExUS 2: IVC ≥20 mm AND only one severely abnormal [3] finding; VExUS 3: IVC ≥20 mm AND at least two severely abnormal [3] findings. D, diastole; IVC, inferior vena cava; S, systole; VExUS, venous excess ultrasound.

of normal or mildly abnormal patterns.

- VExUS score 2: IVC ≥2 cm and only one severely abnormal pattern.
- VExUS score 3: IVC ≥2 cm and at least two severely abnormal patterns.

Venous Doppler can also be applied to other vascular beds, such as the internal jugular vein (IJV), in a semi-recumbent position at 45°. An increase in its area <17% after performing the Valsalva maneuver implies a CVP greater than 12 mmHg (42). Similarly, the ratio between the IJV diameter or area in response to the Valsalva maneuver and the baseline state (IJV ratio) can be studied, with different cut-off points to better identify elevated CVP (*Figure 3*).

Some studies have recently been published regarding the analysis of femoral vein pulsatility to detect congestion, right ventricular dysfunction, pulmonary hypertension, or severe tricuspid regurgitation; however, its clinical application is not yet well defined (43,44).

The information obtained from vascular Doppler assessment could complement that provided by LUS by studying different congestion phenotypes, systemic

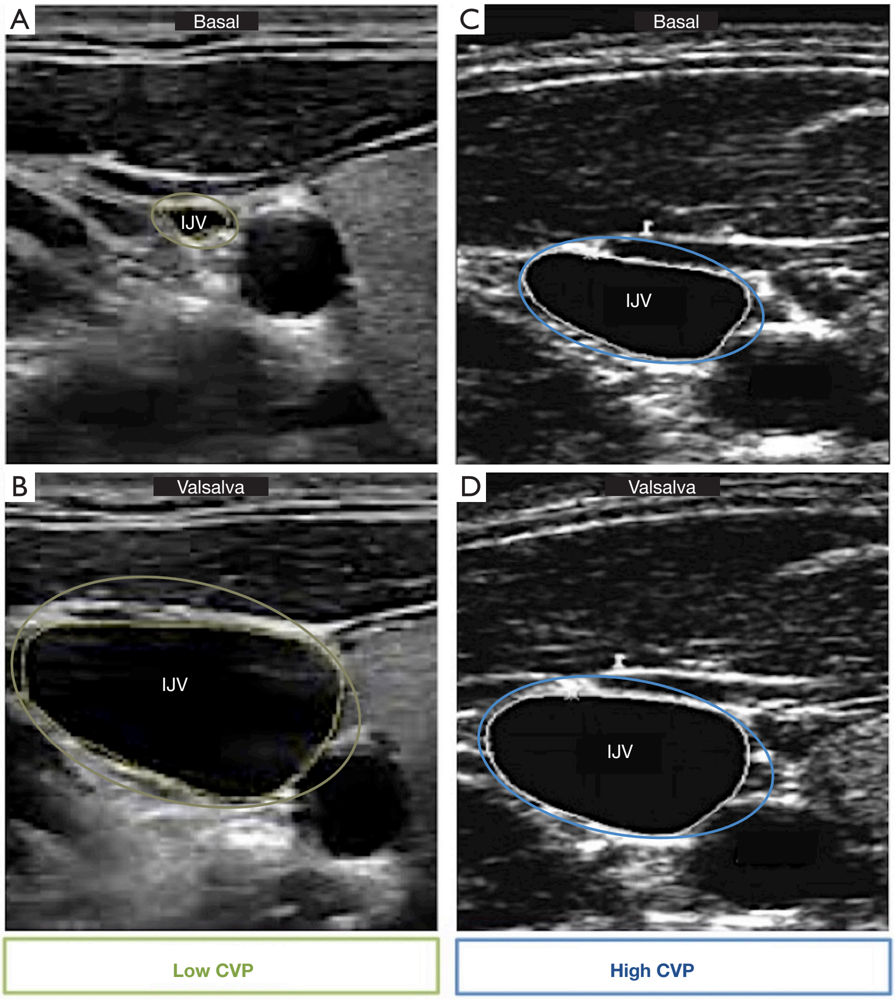

Figure 3 Internal jugular vein ratio. Normal IJV dilation in response to Valsalva maneuver (A: basal, B: after Valsalva). Reduced IJV dilation in response to Valsalva maneuver (C: basal; D: after Valsalva) identifying patients with high CVP. IJV distensibility may be addressed by the ratio between IJV diameters or cross-sectional areas. IJV, internal jugular vein; CVP, central venous pressure.

intravascular and pulmonary interstitial, respectively. Although patients usually present with both types of congestion, one may predominate over the other, and detailed study using these techniques in combination could help achieve personalized management of patients with HF (2).

Assessment of congestion in different clinical scenarios (Figure 4)

Acute heart failure (AHF). Prehospital and emergency department assessment of congestion

Clinical ultrasound techniques have proven to be accessible and very useful tools for diagnostic orientation and targeted treatment of patients presenting to the Emergency Department with dyspnea or edema. However, recent global surveys highlight that only about 20% of professionals use these techniques to assess congestion in the acute setting (73).

Delayed initiation of targeted treatment has been associated with an increase in hospital mortality in a registry of patients with AHF (74). Additionally, correct dosing of diuretic treatment appears to be a key factor, for which clinical ultrasound could be useful. Higher diuretic doses seem to provide greater and faster symptomatic relief at the expense of transient deterioration of renal function (75), with a controversial increase in mortality (76).

LUS

In the registry published by Maisel and colleagues (74), the presence of crackles facilitated the diagnosis of HF and

		Emergency	Admission	Discharge	Early follow-up	Outpatient
			Acute heart failure			Chronic heart failure
LUS	**Prognosis**	**>30 in 28 zones** HF-related readmission or mortality in HFpEF (45)	**≥45 in 28 zones** HF-related readmission or mortality (47)	**>15 in 28 zones** HF-related readmission **≥1 positive in 8 zones** **≥30 in 28 zones** HF-related mortality (48,52-54)	**≥1 positive in 8 zones** HF-related emergency visits, readmission or mortality (55,56)	**≥1 positive in 8 zones** **≥30 in 28 zones** HF-related admission, mortality (59-61)
LUS	**Guided diuretic therapy**	**RCT** Faster decongestion, similar evolution (46)	**RCT** Faster decongestion and discharge, lower HF-related readmission or mortality (49-51)	†	**RCT** Lower HF-related emergency visits, readmission or mortality * (55,56;*57,58)	**RCT** Lower HF-related emergency visits or admission * (62;*63)
Venous Doppler	**Prognosis**	**VExUS 3** In-patient mortality, HF-related readmission or mortality (64)	**VExUS 3** In-patient mortality (65,66)	**VExUS 2 or 3,** IJV ratio HF-related emergency visits or readmission (68,69)	**VExUS 3** HF-related readmission (66)	**Monophasic intrarenal flow, IJV ratio** HF-related admission or mortality (70-72)
Venous Doppler	**Guided diuretic therapy**	†	**RCT** CRS1, faster decongestion, similar renal recovery (67)	†	†	†

Figure 4 Prognostic and therapeutic implications of LUS (45-63) and vascular Doppler (64-72) findings in different clinical settings. †, no evidence available regarding the specific sonographic technique and clinical scenario. *, later studies with neutral results. LUS, lung ultrasound; HF, heart failure; HFpEF, heart failure with preserved ejection fraction; IJV, internal jugular vein; RCT, randomized clinical trial; VExUS, venous excess ultrasound; CRS1, cardio-renal syndrome type 1.

the consequent early initiation of diuretics. It is expected that the higher sensitivity and specificity of LUS (19,20) could speed-up and optimize this process. LUS associated with clinical evaluation showed better diagnostic accuracy than traditional chest X-ray and natriuretic peptide-based methods in a randomized clinical trial (19). In the light of these findings, some recent documents propose LUS as an early diagnostic tool when AHF is suspected in the emergency department (77,78). However, a careful evaluation is required to avoid false positive tests, specially in patients with interstitial lung disease who may show B-lines in basal posterior lung fields (78,79).

An observational prospective study demonstrated that, as compared to low-dose chest tomography, scanning for both B-lines and pleural effusion resulted in higher sensitivity and specificity than just scanning for B-lines (80).

This strategy of early diagnosis and treatment can be applied in the prehospital setting with sensitivity and specificity values for the diagnosis of HF exceeding 85% for both physicians and paramedics (81). Prehospital syndromic orientation increased the rate of early diuretic treatment by 40% (82).

It is known that a greater number of B-lines (>30 in 28 zones) at the time of admission is associated with a higher risk of cardiovascular mortality or HF-related readmission in patients admitted for heart failure with preserved ejection fraction (HFpEF) (45). The number of B-lines at admission did not vary depending on left ventricle ejection fraction (LVEF), as already described in other series (83), Despite this, the presence of >30 B-lines did not predict cardiovascular mortality or HF-related readmissions in patients admitted for heart failure with reduced ejection fraction (HFrEF) (45).

In the same study, patients admitted for a reason other than HF with a B-line count >30 also showed a worse prognosis, highlighting the prognostic relevance of subclinical congestion (45). In line with these findings, patients admitted for acute coronary syndrome with LUS-detected congestion had higher rates of worsening HF, mechanical ventilation, in-hospital mortality, readmission and 30-day mortality (84,85). These findings have led to revisiting the Killip scale creating a new category, Killip I pLUS, which includes Killip I patients with ≥1 positive zone (≥3 B-lines) and Killip II with 0 positive zones (86).

Despite the diagnostic and prognostic information provided, the quantification of B-lines and pleural effusion does not seem to add value in guiding diuretic treatment in the first hours of admission for AHF. In the study published by Pang and colleagues, no greater reduction in B-lines was achieved at 6 hours, and a similar out-of-hospital survival at 30 days was found (46). While greater decongestion was evident in the first 48 hours, pulmonary congestion data equalized in both groups before hospital discharge.

There is growing interest in the potential application of artificial intelligence (AI)-based algorithms for the interpretation of LUS in the AHF setting, where a good agreement between AI and expert B-line quantification was observed (87-89).

Vascular Doppler

There is very limited evidence on the utility of vascular Doppler in patients presenting to the Emergency Department with symptoms suggestive of HF, and there is no information regarding the prehospital setting.

Very recently, a study has shown that up to half of the patients presenting to the Emergency Department with symptoms of AHF have a VExUS score of 3, with higher rates of hospital admission, higher mortality during hospitalization, and higher rates of readmission within the first 30 days (64).

Some publications highlight the utility of the VExUS system for managing diuretic treatment in patients with congestive signs and aggravated renal impairment, potentially facilitating early identification of congestive nephropathy as part of a cardiorenal syndrome type 1 (CRS1) (90).

Additionally, measuring the IJV could facilitate the early diagnosis of HF, especially with IJV area variability of <50% throughout the respiratory cycle (91).

Assessment of congestion during hospital admission for AHF

Reevaluating the congestion status during admission on patients with AHF is crucial for properly adjusting diuretic treatment, avoiding both volume overload and dehydration, and thus improving clinical outcomes. Physical examination, though fundamental, has significant limitations due to its subjectivity and interobserver variability. Repeated chest X-rays, while useful, expose the patient to radiation and may not detect subtle changes in congestion. A reduction of >50% in serial measurement of natriuretic peptides (NP) during admission has significant prognostic relevance. However, NP levels can be influenced by factors such as renal function and may not reflect rapid changes in the patient's hemodynamic status (92).

In this context, LUS and the VExUS score emerge as accessible and reliable alternatives. These non-invasive and reproducible techniques allow continuous and accurate monitoring of congestion, optimizing therapeutic management and potentially reducing the rate of hospital readmissions.

LUS

The degree of pulmonary congestion at the time of admission has prognostic relevance, since the presence of ≥45 B-lines in the first days has been associated with a 9-fold increased risk of cardiovascular mortality or HF-related rehospitalization within the first 90 days post-discharge (47). It should be noted that patients with HFrEF seem to present with higher B-line count (93).

Patients who respond well to diuretic treatment show signs of pulmonary decongestion in the form of a reduction in the number of B-lines during hospitalization (46,94-96), which was associated with a lower risk of cardiovascular mortality or HF-related rehospitalization in the first 30 days post-discharge (97). Effective decongestion during admission confers a beneficial prognosis across the entire spectrum of LVEF (98). Another study demonstrated that a reduction of more than 50% in the number of B-lines from admission to discharge was predictive of a lower risk of cardiovascular mortality or HF-related rehospitalization within 180 days post-discharge, provided that the number of B-lines at discharge was less than 15 (48).

Recent studies have demonstrated the utility of LUS in guiding diuretic treatment, leading to shorter hospital stays (49,50). In the study published by Öhman and colleagues, a LUS and echocardiography algorithm was used to assess congestion through the presence of ≥3 B-lines in at least one region in each hemithorax, bilateral pleural effusion >5 mm, E/e'>15, or IVC >21 mm and/or with collapsibility <50%. These parameters were reassessed daily, and if persistent, diuretic or vasodilator treatment increase was encouraged. A patient was considered no longer congested once all these parameters were normalized. This strategy allowed for a reduction in the duration of hospitalization, prevention of rehospitalizations, and a reduction in the combined event of HF-related rehospitalization or cardiovascular mortality within 180 days post-discharge. LUS-guided treatment did not result in a higher rate of renal failure, or adverse effects associated with hypotension or hypoperfusion (49).

A recent randomized study highlighted the utility of diuretic treatment guided by a combined assessment of B-lines (8 zones) and the diameter and collapsibility of the IVC. Patients in the ultrasound-guided group had less residual congestion at discharge and showed a lower rate of HF-related rehospitalization, emergency visits for HF, or mortality in the first 90 days post-discharge (51).

Vascular Doppler

Similar to observations at the pulmonary level, a higher degree of intravascular congestion (VExUS grade 3) at the time of admission has been correlated in several studies with an up to 8-fold increased risk of in-hospital mortality (65,66).

Among the components of the VExUS score, the intrarenal monophasic pattern at admission had the greatest predictive capacity for in-hospital mortality or HF-related rehospitalization, followed by >50% pulsatility at the portal level at admission (66). The authors of this study concluded that the complete VExUS assessment does not seem to provide additional information beyond renal or portal evaluation in this particular scenario.

Diuretic treatment and the consequent decongestion during hospitalization consistently translate into an improvement in ultrasound parameters with a reduction in IVC diameter and a decrease in VExUS grade. Although in the study by Torres-Arrese and colleagues, the variation during admission did not provide additional information beyond the initial characterization regarding patient outcomes (66), other studies have demonstrated that an improvement in the intrarenal venous Doppler pattern (99) is associated with a lower rate of rehospitalization or mortality in the first 60 days post-discharge.

Regarding the utility of vascular Doppler to guide diuretic treatment, the evidence focuses on patients with CRS1 (100). A randomized study showed the VExUS score-guided treatment resulted in a greater degree of both clinical and biochemical decongestion; however, renal function recovery was similar in both groups (67).

Assessment of congestion at hospital discharge

Following an HF hospitalization, readmission rates of 10% within the first 30 days and up to 25–30% at 90 days have been documented, leading to worse prognosis and to high costs and resource consumption. Two-thirds of total readmissions are, again, HF-related. Patients who have residual congestion experience worse clinical outcomes, not only with higher readmission rates but also with higher mortality (101).

Importantly, residual congestion may be clinically inapparent but detectable by ultrasound in up to 40% of patients considered euvolemic at discharge (102).

Detecting residual congestion before discharge is crucial for identifying higher-risk patients and adapting treatment. In fact, international associations have issued specific statements to address this important subject (52). The phenotype of congestion, whether pulmonary interstitial or systemic intravascular, could influence treatment adjustments beyond the use of diuretics.

LUS

The detection of residual pulmonary congestion at discharge has been linked to a higher risk of adverse events in the medium-term (103). Evolution in the first 180 days after discharge seems similar for patients with ultrasound-detected pulmonary congestion, whether they present with clinical congestion or not (102,104).

Various studies have used different methods to quantify pulmonary congestion, identifying high-risk cut-off points for cardiovascular mortality or HF-related readmission within 30, 90, or 180 days after discharge: ≥7 B-lines in 4 explored zones (21), ≥7 in 6 explored zones (105), ≥5 in 8 explored zones (102), or >15 B-lines in 28 explored zones (53).

In a study published by Coiro and colleagues (54), an increased risk of cardiovascular mortality or HF-related readmission within the first 90 days post-discharge was highlighted, whether using a B-line quantification system (≥30 in 28 zones) or a scoring system (one positive zone out of 8 with ≥3 lines in each hemithorax). Another more recent study demonstrated a higher risk of this combined event within the first 180 days post-discharge in patients with a B-line count ≥15 for any LVEF value, especially if the reduction in the number of B-lines during admission was <50% (48).

Recent official recommendations by the European

Society of Cardiology set a high-risk limit of ≥15 B-lines in 28 explored zones or ≥2 positive zones (≥3 lines) among 8 explored (52).

However, the finding of persistent pleural effusion at discharge does not appear to increase the risk of readmission (106).

Vascular Doppler

Residual intravascular congestion at the time of discharge also carries a poor short-term prognosis, and characterizing the VExUS pattern at discharge has proven to be a good tool for detecting it. The presence of VExUS score 2 or 3 predicted a higher rate of HF-related readmission or emergency visits (68). When evaluating each part of the VExUS score separately, an intrarenal monophasic pattern seemed to have the highest predictive capacity for readmission (66).

Beyond VExUS score, an increase of <66% of the IJV area in response to the Valsalva maneuver at the time of discharge has been shown to be a predictor of HF-related readmission within the first 30 days post-discharge (69).

Assessment of congestion during early follow-up after a hospitalization for HF

Close early follow-up after an HF hospitalization should be standard routine in HF specialized units, with explicit recommendations in clinical practice guidelines (52). This is a period of particular vulnerability, during which up-titration of prognostic medication should be attempted and early reassessment of congestion should be conducted. During this period, a correct adjustment of diuretic treatment is key to preventing readmissions and minimizing the risk of kidney injury. Whether echographic evaluation of congestion facilitates prognostic drug titration is yet unclear.

LUS

Two single-center randomized studies evaluated the benefit of adjusting diuretic treatment guided by the presence of congestive findings on LUS with at least 1 positive zone in each hemithorax (≥3 lines, 8 zones), proving that this strategy resulted in a lower risk of emergency visits, HF-related hospitalizations, or mortality during a 180-day follow-up period (55,56). The benefit was mainly due to fewer emergency visits and was not associated with worsening renal function. This benefit appears to depend on improved diuretic treatment adjustment, a finding also supported by a subsequent study (107).

Similar strategies of monitoring and adjusting treatment through LUS have yielded neutral results in other studies, although this could be due to a smaller sample size and insufficient power (57) or because patients were concurrently following a close monitoring program by nursing staff, which could override the benefit of LUS (58).

Vascular Doppler

In this clinical setting, the simplest assessment is also the most studied. There is evidence that persistent IVC dilation carries a higher risk of HF-related readmission and mortality during follow-up (15,94).

Regarding VExUS, a score of 3 during follow-up predicted a higher risk of readmission within the next 30 days. The same study revealed that, independently, the presence of a renal monophasic pattern or reversal of the systolic component in the hepatic veins also had this predictive capacity for readmission (66).

Evaluation of congestion in stable HF outpatients

Although the most recent clinical practice guidelines for the management of HF (1) and its subsequent update (70) do not recommend the routine use of LUS or VExUS in outpatient follow-up, suggesting LUS only in cases of clinical deterioration, it may still be valuable to consider these techniques. Up to 50% of patients deemed stable and dry during follow-up exhibit ultrasound evidence of congestion (108). Early detection of subclinical pulmonary interstitial or systemic intravascular congestion could facilitate treatment adjustments and potentially help prevent hospitalizations.

LUS

LUS can be easily integrated into routine follow-up visits, allowing the detection of B-lines and subsequent adjustment in diuretic therapy (109) in the early stages of HF decompensation.

The presence of pulmonary congestion with various cut-off points (≥3 in 8 zones; >3 in 5 zones, or ≥30 in 28 zones) indicates a higher risk of HF hospitalization or mortality over follow-up periods ranging from 30 to 180 days (59-61).

In a study conducted in stable outpatients with optimized medical therapy, the addition of LUS to physical examination allowed the detection of pulmonary congestion and helped increase diuretic treatment, hence reducing HF hospitalization rate by 56% during a 90-day follow-up (62). A reduction in NP levels and an improvement in quality of life were also documented in the LUS-managed cohort.

A later meta-analysis found similar rates of hospitalization, mortality or acute kidney injury when diuretic therapy was guided by LUS; while urgent care visits were significantly reduced in these patients (63).

Educating patients on self-monitoring of symptoms and vital signs is crucial in managing HF, enabling early intervention in case of potential decompensations. It has been shown that after short and simple training, the interpretability of patient-obtained LUS images is similar to that of experts (110,111). The possibility of including LUS into home-monitoring strategies or home visits by paramedic personnel is still theoretical but appears promising and could become feasible in the near future.

Vascular Doppler

In the absence of specific data on the utility of the VExUS score in this clinical context, a more simplified assessment focusing solely on the intrarenal venous pattern also allows for the identification of a higher risk of HF hospitalization or mortality in patients with discontinuous and monophasic flow (71). This finding was also associated with greater deterioration in renal function during follow-up.

Reduced IJV dilation in response to the Valsalva maneuver has been shown to identify chronic HF patients at higher risk of HF hospitalization or mortality during follow-up of up to 250 days (70,72). The cut-off used in this study was a ratio between the maximum diameter during Valsalva and at rest of <4.

Among patients with advanced HF, an IJV ratio of <1.6 corresponded to a CVP >7 mmHg in right heart catheterization and was associated with a higher risk of mortality or left ventricular assist device implantation (112).

Strengths and limitations

This review addresses a topic that is both highly relevant and routine in daily clinical practice in cardiology. The body of literature surrounding the diagnosis and management of congestion has grown exponentially in recent years, which is why we consider this review to be not only useful but also necessary. The main strength of this review is its highly practical nature, as it presents the most appropriate methodology for performing the various ultrasound techniques analyzed, as well as their interpretation, prognostic implications, and utility for guiding therapy at different stages of the clinical evolution of HF patients. This approach aims to facilitate the application of these techniques in routine practice, leading to improved detection and management of congestion.

Furthermore, this review identifies gaps in knowledge and points toward potential areas for future research that could strengthen and expand the understanding of this topic.

While this review offers valuable contributions, it also has limitations, notably the ongoing publication of research in this field. The literature reviewed includes publications up to July 2024, potentially excluding relevant articles published thereafter. Additionally, evaluating the quality and impact of previous research can involve a degree of subjectivity and may differ among readers. Nonetheless, every effort has been made to offer a balanced, informative and rigorous perspective on the topic.

Conclusions

Congestion is a dynamic phenomenon throughout the clinical evolution of HF patients. Clinically evident congestion is the leading cause of emergency visits and hospital admissions for HF. On the other hand, subclinical congestion is associated with poor prognosis, manifesting as worsening quality of life, deterioration of renal function, higher readmission rates, and even increased mortality.

Recent advances have introduced several ultrasound techniques for detecting and quantifying congestion at both the pulmonary interstitial and systemic intravascular levels. These techniques provide valuable information for assessing patient risk and consistently improve diagnostic accuracy, even though caution should be exercised when evaluating respiratory patients to avoid LUS false positives.

Regarding treatment fine-tuning, particularly with diuretics, several randomized clinical trials have demonstrated the utility of LUS to guide diuretic therapy in both acute and chronic HF. Evidence form randomized studies on diuretic adjustment guided by venous Doppler analysis is yet scarce.

While individual techniques have shown their utility, their moderate correlation suggests that a combined approach may offer enhanced insights. We advocate for such an integrated assessment to better understand congestion physiology and more accurately identify high-risk patients.

Clinical trials have already demonstrated the utility of combined and multiparametric assessment in managing congestion at specific stages of the clinical evolution of HF patients. It is anticipated that forthcoming high-quality evidence will support the routine use of these techniques, making them a standard part of clinical practice in the near future.

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