# Assessment of Interrater Reliability in Point-of-Care Ultrasound for Assessing Congestion in Cardiovascular Intensive Care

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## Abstract

**Background:** **The assessment of congestion is critical for managing patients with cardiovascular conditions, including heart failure (HF). Traditional methods often lack sensitivity, whereas point-of-care ultrasound (POCUS) provides an objective bedside alternative.**

**Objective:** **To evaluate the interrater reliability (IRR) of key POCUS variables used to assess hemodynamic, pulmonary, and venous congestion.**

**Methods:** **This single-center, prospective study was conducted from January to June 2023 in a cardiovascular intensive care unit (CICU) in Brazil. Adult patients underwent standardized POCUS examinations. Three trained investigators independently assessed lung ultrasound (LUS) (B-lines), left ventricular filling pressures (LVFP) (E/A and E/e′ ratios), inferior vena cava (IVC) measurements, hepatic and portal vein Doppler flow, and modified Venous Excess Ultrasound (mVExUS) Score. IRR was analyzed using intraclass correlation coefficient (ICC).**

**Results:** **A total of 23 patients were included, with a median age of 65 years, each undergoing three independent POCUS examinations (69 total assessments). LUS and IVC measurements showed excellent IRR (ICC 0.903). Hepatic and portal vein flows demonstrated good IRR (ICCs 0.808 and 0.796, respectively). mVExUS grading achieved the highest IRR (ICC 0.957). The E wave showed excellent IRR (ICC 0.934), while the A wave and e′ velocity had lower IRRs (0.512 and 0.399, respectively). E/e′ and E/A ratios demonstrated moderate-to-good IRR (ICCs 0.662 and 0.852, respectively). The median exam duration was 10 minutes.**

**Conclusion:** **POCUS variables demonstrated high reproducibility, particularly for LUS and mVExUS. The reproducibility of LUS and mVExUS was higher than that of LVFP parameters, suggesting they may be more reliable than traditional measures such as E/e′. These findings support the use of POCUS for standardized assessment of congestion. Further studies are needed to validate its prognostic value.**

**Keywords:** **Ultrasonics; Intensive Care Units; Heart Failure; VExUs, modified VExUS.**

## Introduction

Accurate assessment of hemodynamic and fluid status is critical in critically ill patients, particularly those with cardiovascular diseases such as heart failure (HF).[1] Traditional approaches, including clinical examination and radiological imaging, often fail to provide precise information due to their subjective nature and limited sensitivity,[2] highlighting the need for more objective bedside tools. Lung ultrasound (LUS), echocardiography (TTE), and derived parameters have been developed to enhance the evaluation of these patients.[3]

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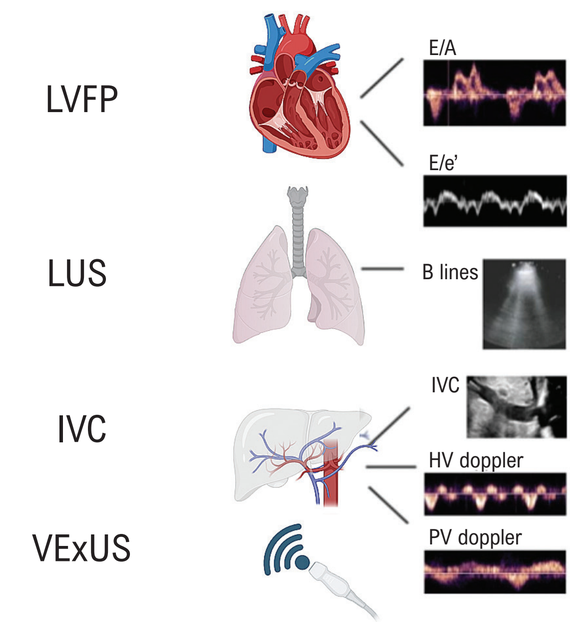
LUS has been widely used for over a decade and has demonstrated utility in detecting pulmonary congestion, particularly in HF.[4-6] However, the appearance of B-lines is not exclusive to pulmonary edema and can sometimes be misleading. Therefore, combining LUS findings with other congestion parameters is recommended.[7,8] TTE enables the assessment of hemodynamic congestion through parameters such as the transmitral flow (E/A ratio) and the E/e′ ratio. These relatively simple TTE measures are easy to learn and can be applied at the bedside.[8,9] Venous Excess Ultrasound (VExUS) Score is used to assess systemic venous congestion by evaluating the size and flow patterns of the inferior vena cava (IVC), hepatic vein, and renal vein. Evaluation of systemic congestion through VExUS has also proven useful in predicting cardiorenal syndrome (CRS).[10,11] Integrating pulmonary and hemodynamic congestion parameters, particularly the E/e′ ratio, has been shown to be more accurate than LUS alone for diagnosing HF in emergency settings.[12] Adding systemic congestion parameters would likely further enhance diagnostic accuracy.

**Central Illustration: Assessment of Interrater Reliability in Point-of-Care Ultrasound for Assessing Congestion in Cardiovascular Intensive Care**

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*Key POCUS parameters assessed in this study included LVFP, LUS, IVC measurements, and venous congestion evaluation using the mVExUS Score. The variables analyzed were E/A and E/e’ ratios for LVFP, B-lines for LUS, IVC diameter and collapsibility, and hepatic vein (HV) and portal vein (PV) Doppler assessments for mVExUS. Created with BioRender.com.*

Despite its growing use, the reproducibility of individual point-of-care ultrasound (POCUS) components remains a concern. Interrater reliability (IRR) is essential to ensure consistency across different operators and clinical settings. Most previous studies have evaluated pulmonary, hemodynamic, and systemic congestion parameters individually, aiming to correlate them with congestion severity or clinical outcomes. However, it is important to determine whether the POCUS variables commonly used for congestion assessment demonstrate good IRR and whether the combined evaluation of these selected parameters is feasible in clinical practice.

This study aims to evaluate the IRR of key POCUS variables — specifically LUS, left ventricular filling pressure (LVFP) parameters (E/A and E/e′ ratios), IVC measurements, hepatic and portal venous Doppler assessments, and modified VExUS grading (mVExUS) — in patients admitted to a cardiovascular intensive care unit (CICU), assessing their potential for standardized bedside application (Central Illustration).

## Methods

### Study design

This was a single-center, prospective study conducted in the CICU at a tertiary hospital in Brazil. The study period spanned from January to June 2023 and included adult patients (≥18 years) admitted with various cardiovascular conditions, including HF, acute coronary syndromes, and arrhythmias. The only exclusion criterion was lack of consent to participate.

The study protocol was approved by the Research Ethics Committee of Hospital de Clínicas de Porto Alegre (HCPA) under approval no. 6.468.353 and conducted in accordance with the Brazilian National Health Council Resolution no. 466/12.

### Ultrasound assessment

US examinations were performed using a portable US machine (Mindray ME Series; Shenzhen, China) equipped with a 2.5-MHz phased-array sector transducer. Patients were positioned supine with a 30-degree head elevation to standardize imaging conditions. Vital signs were recorded immediately before each evaluation to ensure consistency in hemodynamic status during the examinations. All assessments were conducted with concurrent ECG monitoring. Investigators were blinded to each other’s results to minimize bias.

### Ultrasound parameters

The following key parameters commonly used to assess pulmonary, hemodynamic, and systemic venous congestion were assessed:

- LUS: assessment of B-lines in eight lung zones.
- LVFP: measurement of E/A and E/e′ ratios from the apical four-chamber view.
- IVC: measurement of diameter and collapsibility index.
- Venous Doppler: assessment of hepatic and portal venous flow patterns using pulsed-wave Doppler (PWD).
- mVExUS: grading modified VExUS score based on findings from hepatic and portal venous Doppler flow.

## Assessment of hemodynamic congestion

The objective of the hemodynamic evaluation was to detect an increased LVFP. From the apical four-chamber view, the mitral inflow pattern was assessed using PWD at the tips of the mitral valve leaflets. The E/A ratio was categorized into three grades: grade 1 (E/A ≤0.8 and E velocity ≤50 cm/s), considered normal; grade 3 (E/A ≥2), indicating elevated LVFP; and grade 2 (E/A ≤0.8 with E velocity >50 cm/s, or E/A between 0.8 and 2), classified as indeterminate. In cases with a grade 2 E/A ratio, the septal E/e′ ratio was used to further differentiate between normal and elevated LVFP.[13]

In the same apical four-chamber view, with angulation to align with the interventricular septum, the medial e′ velocity was measured at the mitral annulus using PWD after tissue Doppler imaging (TDI).[14] Medial e′ was selected for its feasibility and because most published data on the E/e′ ratio are based on this measurement. It is considered the most reliable parameter for estimating LVFP.[15] Increased LVFP was defined as medial E/e′ >15 in sinus rhythm or >11 in atrial fibrillation (Figure 1).[16]

## Assessment of lung congestion

The chest wall was divided into eight zones, with one scan obtained for each zone. The cardiac transducer was positioned perpendicularly to the ribs along the intercostal spaces, at a depth of approximately 12-18 cm depending on body habitus.[17] Each zone (two anterior and two lateral per hemithorax) was evaluated independently. A zone was considered positive if three or more B-lines were present, and pulmonary congestion was assumed when two or more zones were positive (Figure 2).[6]

## Assessment of peripheral venous congestion

The final step included the evaluation of IVC for diameter and collapsibility, along with hepatic and portal venous flows assessed using PWD.

The IVC was evaluated through the subcostal window, approximately 1 cm caudal to its junction with the hepatic vein, to estimate central venous pressure (CVP). CVP was inferred based on IVC diameter and inspiratory variability: a normal CVP of approximately 3 mmHg was suggested when both an IVC diameter ≤2.1 cm and collapsibility ≥50% were present; conversely, an IVC diameter >2.1 cm with <50% collapsibility corresponded to a CVP of approximately 15 mmHg. An intermediate CVP of around 8 mmHg was assigned when only one of these two criteria was met.[18]

If the IVC diameter was ≥2 cm, a modified VExUS assessment was performed using hepatic and portal vein Doppler evaluations. PWD was used in the hepatic vein to assess flow patterns, graded as follows: grade 1 (normal) when the systolic (S) wave was higher than the diastolic (D) wave; grade 2 (mild congestion) when the S wave was lower than the D wave; and grade 3 (severe congestion) when S-wave reversal was present. Portal vein flow was also assessed with PWD and classified into three grades: grade 1 (normal) if nonpulsatile with a maximum-minimum velocity variability <30%; grade 2 (mild congestion) if the pulsatility index was between 30-50%; and grade 3 (severe congestion) if the pulsatility index was ≥50%.[11]

Venous congestion severity by mVExUS was classified into four grades based on IVC diameter and PWD findings. A non-dilated IVC (<2 cm) indicated no significant venous congestion (grade 0). An IVC diameter ≥2 cm with normal or mildly abnormal hepatic or portal vein flow corresponded to mild congestion (grade 1). A plethoric IVC associated with one severely abnormal venous flow pattern (either S-wave reversal in the hepatic vein or ≥50% pulsatility index in the portal vein) defined moderate congestion (grade 2). Severe congestion (grade 3) was diagnosed when severely abnormal flow patterns were present in both the hepatic and portal veins (Figure 3).[19]

## Assessment of IRR

Three trained investigators, blinded to each other's evaluations, independently performed real-time POCUS assessments to evaluate IRR. All investigators had received standardized training, consisting of a 4-hour theoretical-practical session followed by a one-month supervised period in the CICU. During this time, each cardiology resident completed at least 50 ultrasound examinations. Exams were not recorded, thereby eliminating retrospective bias and ensuring that IRR reflected real-world clinical practice.

## Difficulty scoring

To further characterize the practical applicability of the US protocol, each investigator rated the difficulty of each patient's assessment as easy, average, or hard. An "easy" assessment was defined by clear imaging and straightforward interpretation; an "average" assessment required moderate effort and interpretation; and a "hard" assessment involved significant challenges related to imaging acquisition or interpretation. This subjective evaluation provided additional insight into the feasibility of protocol implementation across varying patient anatomies and clinical conditions.

## Statistical analysis

Sample size was calculated assuming a minimum acceptable intraclass correlation coefficient (ICC) of 0.65 and an expected ICC of 0.90. With three raters per subject, a sample of 23 patients provided 90% power at a 0.01 significance level. Continuous variables were reported as mean (standard deviation [SD]) or median (interquartile range [IQR]), according to distribution symmetry assessed by the Shapiro-Wilk test. Categorical variables were presented as

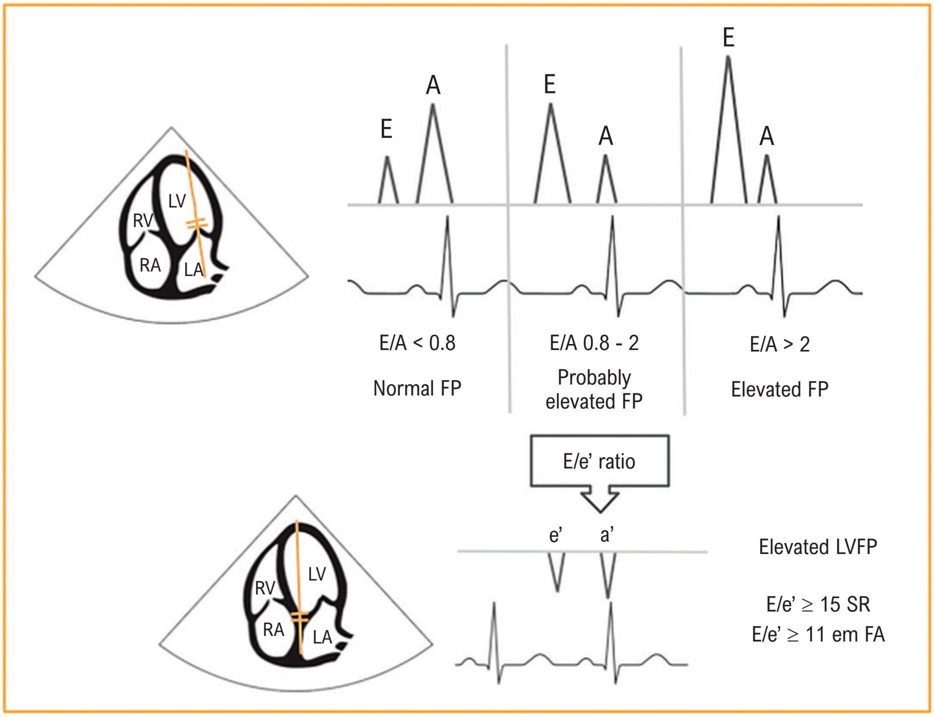


**Figure 1 –** *The aim of the hemodynamic evaluation is to identify elevated LVFP. The E/A ratio is categorized into three grades, reflecting different levels of LVFP. Patients with a grade 1 E/A ratio are assumed to have normal LVFP, while those with a grade 3 E/A ratio (restrictive pattern) are associated with elevated LVFP. For patients with a grade 2 E/A ratio, the septal E/e' ratio is used to differentiate between normal and elevated LVFP. RV: right ventricle; RA: right atrium; LV: left ventricle; LA: left atrium; FP: LVFP: left ventricular filling pressures; SR: sinus rhythm; AF:atrial fibrillation.*

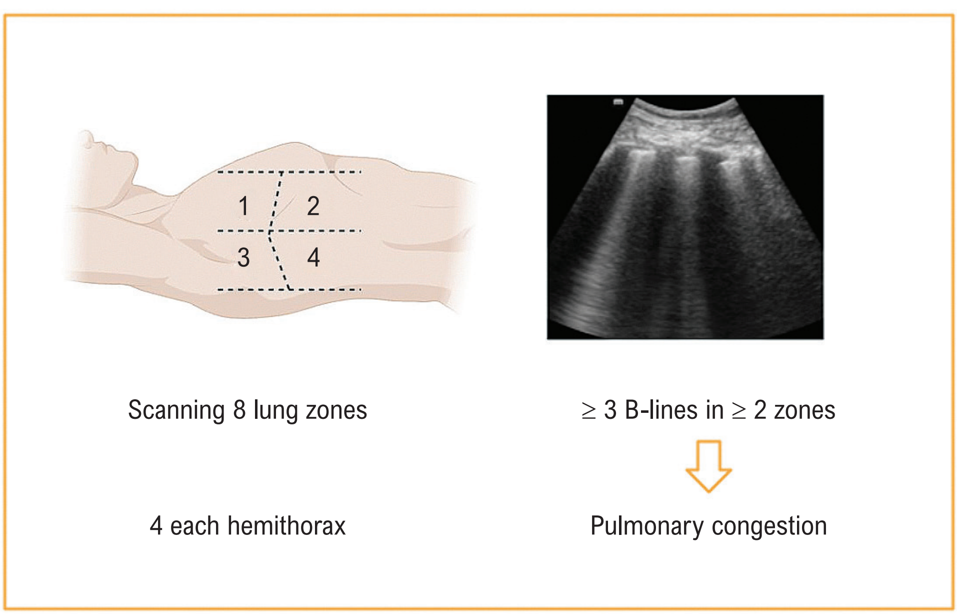


**Figure 2 –** *For assessing lung congestion, the chest wall is divided into eight zones, with one scan obtained for each zone. Each zone (two anterior and two lateral per hemithorax) is evaluated independently. A zone is considered positive if three or more B-lines are present, and pulmonary congestion is assumed when two or more zones are positive.*

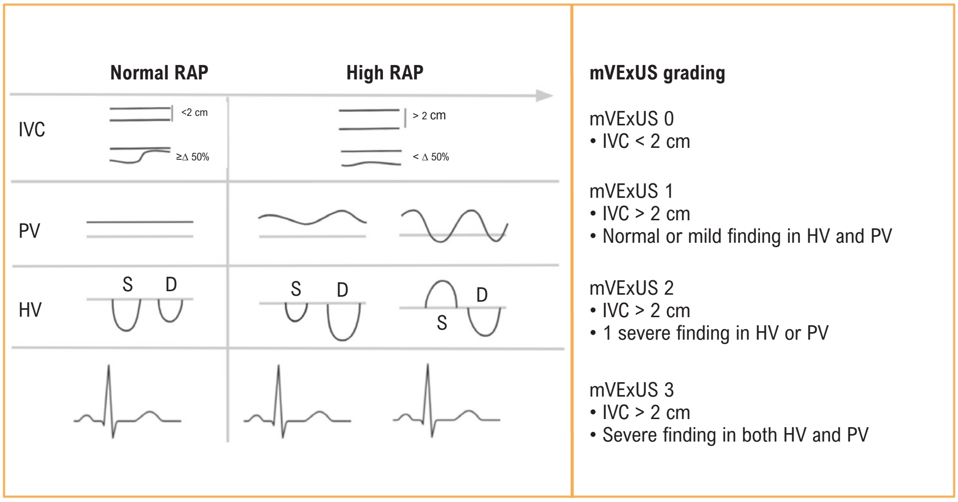


**Figure 3 –** *Venous congestion by mVExUS is classified into four grades based on IVC assessment and PWD findings. A nondilated IVC (<2 cm) indicates no significant venous congestion (grade 0). When the IVC is ≥2 cm with normal or mildly abnormal findings on hepatic or portal vein Doppler, congestion is considered mild (grade 1). A plethoric IVC associated with one severely abnormal pattern (S-wave reversal in the hepatic vein or ≥50% pulsatility index in the portal vein) defines moderate congestion (grade 2). Severe congestion (grade 3) is indicated by severely abnormal flow patterns in both hepatic and portal veins.*
*IVC: inferior vena cava; RAP: mVExUS: modified Venous Excess Ultrasound; HV: hepatic vein; PV: portal vein.*

absolute and relative frequencies. ICCs were calculated using a two-way mixed-effects model to assess agreement among the three raters for both continuous and ordinal variables. IRR was classified as poor (<0.50), moderate (0.50-0.75), good (0.75-0.90), or excellent (>0.90). Statistical analyses were performed using SPSS Statistics for macOS, version 29.0 (IBM Corp., Armonk, NY, USA), with significance set at 0.05 (two-tailed).

## Results

Between January and June 2023, 23 patients were enrolled in the study. Each patient underwent three independent POCUS assessments, resulting in a total of 69 ultrasound examinations evaluated for IRR. The median age was 65 years (IQR, 53-70), and 60.9% were male. Most admissions to the CICU were due to decompensated HF (65%), followed by ST-elevation myocardial infarction (STEMI) (17%). Parenteral vasodilators were used in 43.5% of patients, inotropes in 21.7%, and vasopressors in 13%.

Regarding cardiac function, 17.4% of patients had preserved left ventricular ejection fraction (LVEF), while 82.6% exhibited reduced LVEF (≤50%). HF etiology was classified as ischemic in 39.1%, nonischemic in 30.4%, and valvular due to severe aortic stenosis in 8.7%. The median LVEF was 33.5% (IQR, 21.7-46.2). During the ultrasound examinations, atrial fibrillation was present in 9% of patients, left bundle branch block in 13%, and 17.4% had an implantable cardioverter-defibrillator. Severe or moderate mitral regurgitation was observed in 43.5% of patients, and severe or moderate tricuspid regurgitation in 39.1%.

A detailed description of the demographic and clinical characteristics of the study population is provided in Table 1, while Appendix Table 1 and Appendix Table 2 summarize POCUS measurements.

### IRR

Regarding the IRR of US measurements, excellent agreement was observed for lung positive zone assessments (ICC, 0.903; 95% CI, 0.818-0.954; p<0.001) and IVC measurements (ICC, 0.903; 95% CI, 0.820-0.954; p<0.001), indicating consistent evaluations for pulmonary congestion assessment and CVP estimation.

Subsequent analyses of venous congestion components, including hepatic vein flow, portal vein flow, and mVExUS grading, also demonstrated substantial IRR. Hepatic vein assessment yielded an ICC of 0.808 (95% CI, 0.662-0.906; p<0.001), while portal vein assessment showed an ICC of 0.796 (95% CI, 0.641-0.899; p<0.001). mVExUS grading, reflecting an integrated evaluation of venous congestion, exhibited the highest IRR with an ICC of 0.957 (95% CI, 0.914-0.981; p<0.001) (Table 2).

Further assessments of hemodynamic congestion parameters revealed varying levels of IRR. The E wave demonstrated excellent consistency, with an ICC of 0.934 (95% CI, 0.873-0.969; p<0.001). In contrast, the A wave and septal e′ velocity showed lower IRR, with ICCs of 0.512 (95% CI, 0.176-0.799; p<0.001) and 0.399 (95% CI, 0.146-0.650; p<0.001), respectively. Despite the lower IRR of isolated e′ measurements, the E/e′ ratio demonstrated moderate IRR (ICC, 0.662; 95% CI, 0.449-0.824; p<0.001). The overall classification of the E/A ratio demonstrated good IRR, with an ICC of 0.852 (95% CI, 0.731-0.928; p<0.001) (Table 2). We additionally evaluated the interobserver agreement for the velocity-time integral (VTI) of the left ventricular outflow tract (LVOT), which, although not part of the standard congestion assessment, has been widely used in ICU settings as a surrogate for cardiac output. Its reproducibility was considered good, with an ICC of 0.820 (95% CI: 0.680–0.912; p<0.001).

The overall examination duration was 10.0 minutes (IQR, 8.0-12.0), reflecting the protocol's efficiency and highlighting its practicality for clinical settings where timely assessments are critical. The concise duration supports the feasibility of integrating the protocol into routine clinical workflows without significant disruption.

Overall, the ICC values for most parameters indicated good to excellent reproducibility among investigators, confirming the protocol's IRR for clinical application. A comprehensive summary of the ICC values for all assessed parameters is provided in Appendix Table 2.

### Assessment difficulty

The difficulty ratings assigned by investigators varied, with most assessments classified as easy (50.7%), indicating that the protocol is generally manageable. An additional 36.2% of assessments were rated as average, suggesting the protocol is straightforward in many cases. Only 10.1% were rated as hard, indicating that the protocol remains a reliable tool even under suboptimal imaging conditions. These findings support its practical applicability and suggest it can be effectively implemented across diverse clinical settings, even when ideal acoustic windows are not available.

## Discussion

The results of this study underscore the high IRR of the proposed US protocol across its various components, with most ICC values ranging from good to excellent. Furthermore, the findings confirm the feasibility of implementing a novel protocol for hemodynamic assessment at the bedside within a CICU. The high ICC values for lung positive zone assessments indicate excellent IRR in evaluating pulmonary congestion, consistent with previous studies that have demonstrated substantial agreement among observers following short-term training.[20-22]

The IVC diameter and collapsibility also demonstrated excellent IRR, reflecting consistent agreement in estimating CVP as low, normal, or high. However, it is well known that the accuracy of IVC measurements for CVP estimation is greater at the extremes of volume status and less reliable at intermediate values. Additionally, accuracy can be compromised in patients with comorbid conditions such as pulmonary or hepatic disease, obesity, or in those receiving positive pressure ventilation, leading to reduced clinical utility in these scenarios.[23,24]

Evaluating peripheral venous congestion using VExUS is valuable because, in addition to identifying systemic

**Table 1 – Clinical characteristics of the sample**

| Variable | Total (n = 23) |
|---|---|
| **Age, years** | 65 (53-70) |
| **Male sex (n, %)** | 14 (60.9%) |
| **Smoking status** | |
| Active smoker (n, %) | 2 (8.7%) |
| Former smoker (n, %) | 7 (30.4%) |
| **HF etiology** | |
| Preserved ejection fraction (n, %) | 4 (17.4%) |
| Ischemic (n, %) | 9 (39.1%) |
| Nonischemic (n, %) | 7 (30.4%) |
| Aortic stenosis (n, %) | 2 (8.7%) |
| **Previous myocardial infarction (n, %)** | 13 (56.5%) |
| **Implantable cardioverter-defibrillator (n, %)** | 4 (17.4%) |
| **Atrial fibrillation (n, %)** | 2 (8.7%) |
| **Left bundle branch block (n, %)** | 3 (13%) |
| **LVEF, %** | 33.5 (21.7-46.2) |
| **Severe or moderate mitral regurgitation (n, %)** | 10 (43.5%) |
| **Severe or moderate tricuspid regurgitation (n, %)** | 9 (39.1%) |
| **Diagnosis at admission** | |
| Decompensated HF (n, %) | 15 (65.3%) |
| Acute STEMI (n, %) | 4 (17.4%) |
| Unstable angina (n, %) | 1 (4.3%) |
| Cardiogenic shock (n, %) | 1 (4.3%) |
| Complete atrioventricular block (n, %) | 1 (4.3%) |
| Post-percutaneous coronary intervention (n, %) | 1 (4.3%) |
| **Parenteral drugs** | |
| Vasopressor (n, %) | 3 (13%) |
| Venodilator (n, %) | 10 (43.5%) |
| Inotropic (n, %) | 5 (21.7%) |
| **Creatinine, mg/dL** | 2 (1.2-2.6%) |
| **Brain natriuretic peptide, pg/mL** | 1375 (218.5-2668.5) |

*Results are expressed as n (%) or median (interquartile range). HF: heart failure; STEMI: ST-elevation myocardial infarction; LVEF: left ventricular ejection fraction.*

congestion and predicting CRS, it appears to correlate well with CVP.[24] While the isolated assessment of hepatic and portal vein flows showed good IRR, mVExUS grading demonstrated even better agreement. Our results indicate that although observers did not always agree on the classification of specific hepatic or portal flow patterns, the mVExUS grading still exhibited excellent IRR. This suggests that, for mVExUS grading, the most critical factor is the identification of severely abnormal patterns that shift the congestion category.

Comparing our findings with those from previous studies evaluating IRR in VExUS, it is evident that available data are relatively scarce. One study reported an ICC of 0.83 ($p<0.001$) for the overall VExUS grade, indicating substantial agreement among interpreters. For individual VExUS components, ICCs were 0.71 ($p<0.001$) for the hepatic vein, 0.74 ($p<0.001$) for the portal vein, and 0.48 ($p<0.001$) for the renal vein, reflecting a range from poor to moderate IRR.[25] Additionally, another study reported good IRR for portal pulsatility fraction assessment by transthoracic ECG, with a mean difference of 5.6% between repeated measurements and an ICC of 0.824 ($p<0.001$).[26] This finding aligns with our results and highlights the robustness of portal vein assessments. In our study, similar patterns were observed, with even higher IRR for the hepatic and portal veins. This improvement may be attributed to the consistent use of ECG tracing during all examinations, a practice previously associated with increased concordance.[25] Due to the previously reported poor concordance and time-consuming nature of renal vein assessment,[25] it was excluded from our protocol to streamline the process and improve IRR. This decision is further supported by evidence that a mVExUS score excluding renal venous Doppler has already been validated in patients with CRS admitted to the intensive care unit in a single-center prospective study.[27]

In the evaluation of hemodynamic congestion, the lower ICC values for the A wave and e′ measurements may be attributed to challenges such as patient tachycardia and the prevalence of arrhythmias during the study, both of which can affect the consistency of measurements related to atrial contraction and early diastolic velocities at the septal mitral annulus. Although TDI e′ velocity is generally more robust than transmitral flow assessment, it still presents challenges, particularly in patients with regional myocardial dysfunction.[13,28] Measurement inconsistencies could also result from the US probe not being perfectly aligned parallel to the interventricular septum in the supine position. Including only patients with HF and reduced LVEF could potentially improve the performance and reproducibility of e′ measurements.[29]

The overall classification of the E/A ratio demonstrated good IRR, with an ICC of 0.852 (95% CI, 0.731-0.928; $p<0.001$), while the evaluation of the E/e′ ratio showed moderate IRR (ICC, 0.662; 95% CI, 0.449-0.824; $p<0.001$). Although the E/A and E/e′ ratios are widely used for the assessment of diastolic function in ECG and have been proposed for bedside application, their use by non-echocardiographers in clinical practice has not been extensively studied.[15,30,14]

**Table 2 – IRR for each POCUS parameter**

| Variable | ICC | 95% CI | p-value |
|---|---|---|---|
| Lung positive zones | 0.903 | 0.818-0.954 | <0.001 |
| IVC | 0.903 | 0.820-0.954 | <0.001 |
| CVP estimation | 0.955 | 0.817-0.954 | <0.001 |
| E wave | 0.934 | 0.873-0.969 | <0.001 |
| A wave | 0.512 | 0.176-0.799 | <0.001 |
| Septal e' wave | 0.399 | 0.146-0.650 | <0.001 |
| E/A ratio | 0.852 | 0.731-0.928 | <0.001 |
| E/e' ratio | 0.662 | 0.449-0.824 | <0.001 |
| Hepatic vein Doppler | 0.808 | 0.662-0.906 | <0.001 |
| Portal vein Doppler | 0.796 | 0.641-0.899 | <0.001 |
| mVExUS grading | 0.957 | 0.914-0.981 | <0.001 |
| LVOT-VTI | 0.820 | 0.680- 0.912 | <0.001 |
| Difficulty rating | 0.298 | 0.030-0.584 | 0.014 |

*CI: confidence interval; CVP: central venous pressure; ICC: intraclass correlation coefficient; mVExUS: modified Venous Excess Ultrasound Score ; LVOT-VTI : left ventricular outflow tract velocity-time integral; IVC: inferior vena cava.*

### Strengths and limitations

This single-center study with a relatively small sample size may limit generalizability and sensitivity to detect subtle variations. Operator dependence could affect reproducibility in less experienced settings; however, the high ICCs observed suggest that adequate training mitigates this concern. Methodological rigor was maintained through real-time, blinded assessments performed by trained investigators, with ECG integration, minimizing biases typically associated with retrospective or video-based analyses. These strengths reinforce the robustness and clinical applicability of the evaluated POCUS variables.

## Conclusion

This study demonstrates POCUS variables used to assess hemodynamic, pulmonary, and peripheral venous congestion exhibit high IRR across their components. High reproducibility was observed for lung positive zones, LVFP parameters, IVC measurements, and mVExUS grading. The reproducibility of LUS and mVExUS was higher than that of LVFP assessment, suggesting these parameters may offer greater consistency than traditional measures such as the E/e′ ratio.

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## Author Contributions

Conception and design of the research: Saadi MP, Machado GP, Silvano GP, Telo G, Silveira AD; acquisition of data: Saadi MP, Silvano GP, Barbato JPR, Almeida RF; analysis and interpretation of the data: Saadi MP, Machado GP, Silvano GP, Telo G; statistical analysis: Saadi MP, Machado GP, Silvano GP; writing of the manuscript: Saadi MP, Silvano GP; critical revision of the manuscript for intellectual content: Saadi MP, Scolari FL, Telo G, Silveira AD.

### Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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There were no external funding sources for this study.

### Study Association

This article is part of the thesis of Doctoral submitted by Marina Petersen Saadi, from Universidade Federal do Rio Grande do Sul.

### Ethics Approval and Consent to Participate

This study was approved by the Ethics Committee of the Hospital de Clínicas de Porto Alegre under the protocol number 6.468.353. All the procedures in this study were in accordance with the 1975 Helsinki Declaration, updated in 2013. Informed consent was obtained from all participants included in the study.

### Use of Artificial Intelligence

The authors did not use any artificial intelligence tools in the development of this work.

### Research Data

All datasets supporting the results of this study are available upon request from the corresponding author.

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### *Supplemental Materials

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