The Journal of Emergency Medicine, Vol. 80, No. ■, pp. 64–73, 2026
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0736-4679/$ - see front matter

https://doi.org/10.1016/j.jemermed.2025.10.024

Ultrasound in Emergency Medicine

Reliability of Alternative Sonographic Approaches for Inferior Vena Cava: Comparison of Subcostal, Transhepatic, and Coronal Windows

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□ **Abstract—Background: Ultrasonographic evaluation of the inferior vena cava (IVC) is widely used in critical care settings; however, the standard subcostal (SC) approach is not always feasible. Objectives: This study aimed to assess the agreement of IVC diameter and collapsibility index (cIVC) measurements obtained from the SC, anterior transhepatic (TH), and right coronal (CR) ultrasonographic windows. Methods: In this prospective, single-center study conducted in an emergency department, IVC ultrasonography was performed on 219 adult patients using SC, TH, and CR approaches. Clear visualization of the anterior and posterior IVC walls was considered essential, while the visualization of IVC entry into the right atrium and the hepatic vein were supportive. Image acquisition time, operator-assessed ease, body mass index, and intermethod agreement were assessed using intraclass correlation coefficients (ICCs) and Bland–Altman analysis. Results: The mean image acquisition times were 24.26 ± 24.77 s for SC, 28.89 ± 25.85 s for TH, and 35.66 ± 29.52 s for CR. ICC analysis demonstrated strong correlation across all methods, with the highest correlation observed between SCmin and THmin ($r = 0.952$). Bland–Altman plots showed acceptable limits of agreement, indicating good agreement. ICC analysis found to be positive and highly significant correlation across body mass index categories. More than half of the images obtained via each window were rated as "easy" or "very easy" by the operators. Conclusion: While the SC window remains the first-line approach for IVC assessment, the TH and CR windows offer reliable and practical alternatives when SC imaging is limited.** **© 2025 Elsevier Inc. All rights are reserved, including those for text and data mining, AI training, and similar technologies.**

□ **Keywords—inferior vena cava; ultrasonography; subcostal; anterior transhepatic; coronal**

Introduction

Accurate assessment of intravascular volume status is a critical component in the management of critically ill patients. Inadequate fluid resuscitation may lead to hypovolemia, resulting in tissue hypoperfusion, shock, and renal dysfunction (1–3). Conversely, fluid overload can cause complications such as pulmonary edema, elevated intra-abdominal pressure, and organ damage, ultimately worsening clinical outcomes. In septic shock patients, a positive fluid balance has also been associated with increased hospital mortality, prolonged mechanical ventilation in acute respiratory distress syndrome, and longer intensive care unit (ICU) stays (4–6). Therefore, volume monitoring plays a central role not only in diagnosis and treatment planning but also in evaluating therapeutic response. Achieving optimal fluid balance is essential for preventing adverse outcomes.

Among the various techniques used to assess volume status, ultrasonography is notable for being noninvasive, rapid, accessible, and repeatable (7,8). In particular, eval-

Received: 9 September 2025; Final submission received: 9 October 2025;
Accepted: 18 October 2025

uation of the inferior vena cava (IVC) via ultrasonography is widely employed in critical care settings. IVC diameter and collapsibility index (cIVC) serve as noninvasive estimators of central venous pressure (CVP), and serial measurements guide fluid management during resuscitation. A cIVC greater than 50% with a collapsed IVC suggests low CVP and fluid responsiveness, supporting fluid administration. Conversely, a cIVC of less than 50% with a dilated IVC indicates high CVP and volume overload, favoring fluid restriction or diuresis. This examination requires only basic ultrasonographic skills, is supported by a substantial body of evidence, and is frequently incorporated into multi-organ point-of-care ultrasound (PoCUS) protocols (9,10).

The standard subcostal (SC) approach is the primary technique for IVC imaging, but is not always feasible due to bowel distention, obesity, or postoperative changes. In these cases, alternative imaging routes such as the anterior transhepatic (TH) or right coronal (CR) approaches may be considered. However, the literature comparing these windows presents conflicting evidence and is notably incomplete regarding the TH approach. While some studies have concluded that SC and CR windows are not equivalent in assessing IVC diameter (11–13), others have reported a strong correlation between them (14–16). This discrepancy, coupled with the scarcity of data on the TH window, creates significant uncertainty in clinical practice.

This study aims to evaluate the agreement between the SC, TH, and CR ultrasonographic approaches in assessing the IVC and to determine whether the TH and CR windows can serve as practical and reliable alternatives to the SC approach.

Methods

Participants and Settings

This single-center prospective study was conducted in the emergency department (ED) of a tertiary-care university hospital. The institution serves as a major academic and referral center, with an annual ED census of approximately 65,000 patient visits. Adults aged 18 years and older who presented to the ED between May 2023 and November 2023 and required ultrasonographic evaluation of intravascular volume status for any reason were included. Informed consent was obtained from all participants or their legal representatives. Exclusion criteria were pregnancy, refusal to participate, and inability to obtain any IVC image via the standard SC approach. The study was approved by the local ethics committee (protocol number: 2023-333).

Protocol

Although the SC window is commonly used for IVC assessment, there is no universally accepted standard imaging method. To ensure standardization, the research team defined three imaging criteria applicable to all three windows. Among these, clear visualization of the anterior and posterior walls of the IVC was considered mandatory, while visualization of the IVC's entry into the right atrium and the hepatic vein were accepted as supportive findings (Figure 1). Despite anatomical variations in hepatic veins, the most frequent configuration includes a single right hepatic vein and a common trunk of the middle and left hepatic veins (17). At least one of these branches can typically be visualized from each window (Figure 2).

For the SC view, the probe was positioned vertically in the subxiphoid area, slightly left of midline, with the marker oriented cephalad. For the TH view, the probe was placed vertically below the right nipple in the midclavicular line, again with the marker directed toward the head, typically visualizing the IVC between the 6th and 8th intercostal spaces. For the CR view, the probe was held vertically along the right midaxillary line and adjusted between the 6th and 8th intercostal spaces to capture a clear image of the IVC walls (Figure 1). Diameter measurements were taken at a standardized point 3 cm distal to the IVC's junction with the right atrium. In cases where this junction was not clearly visualized, an alternative point 2 cm distal to the hepatic vein-IVC junction was used. For spontaneously breathing patients, the collapsibility index (cIVC) was calculated as (IVCmax – IVCmin)/IVCmax during quiet breathing. For intubated patients, the distensibility index (dIVC) was calculated as (IVCmax – IVCmin)/IVCmin.

Before initiating the study, a pilot phase was conducted. An academic emergency physician, as a trainer in the Ultrasound Working Group of the Emergency Medicine Association of Türkiye for over 8 years, provided a minimum of 4 h of theoretical and practical training to two senior emergency medicine residents. These residents performed SC, TH, and CR imaging on 20 individuals, yielding 60 images. The study proceeded only after image quality was reviewed and approved by the supervising physician.

During the study, all ultrasonographic examinations were performed using a single device (Logiq S7, GE Medical Systems, Milwaukee, Wisconsin) with a 2 to 5 MHz convex transducer, with the bed angled between 0° and 45°. For each patient, the two trained residents obtained at least 8-s video recordings from each of the three windows. The supervising physician subsequently performed diameter measurements on the recorded images.

Additional data collected included age, sex, height, weight, and body mass index (BMI). The time required

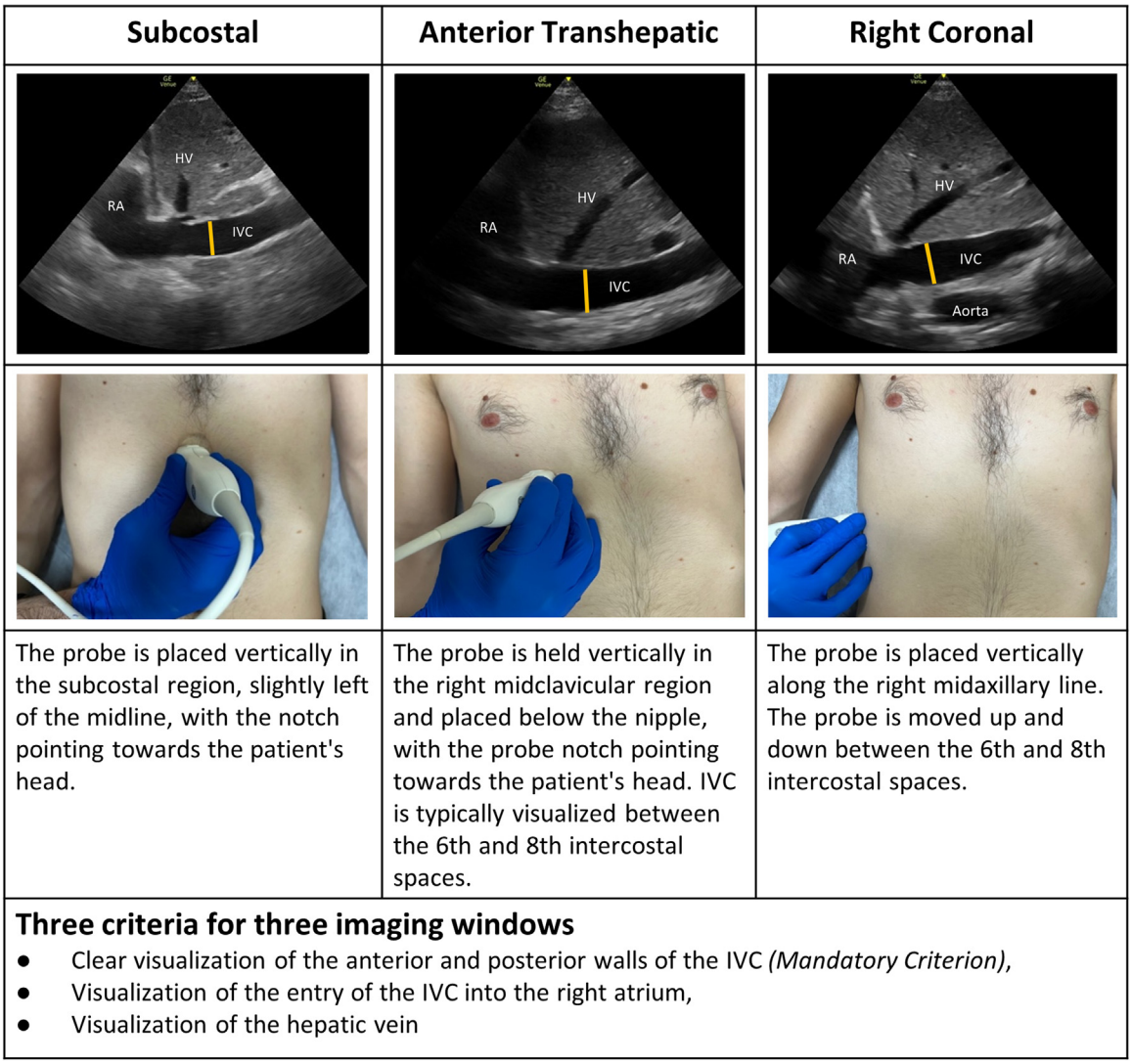


Figure 1. Ultrasonographic probe positioning and imaging windows used for the evaluation of the inferior vena cava (IVC). The illustrations show the probe placement for the subcostal, anterior transhepatic, and right coronal ultrasonographic windows. The yellow line on the IVC indicates the standardized location where diameter measurements were taken.

to acquire each view was recorded by the residents, who also rated the difficulty of each image acquisition using a 5-point Likert scale: "very easy," "easy," "moderate," "difficult," and "very difficult."

Statistical Analysis

To maintain a study power of 95% and account for possible data loss, the minimum required sample size was determined as 130 participants using G*Power version 3.1.9.2.

Continuous variables (e.g., age, BMI) were summarized using means and standard deviations, while categorical variables (e.g., sex) were presented as frequencies and percentages. Normality for continuous variables (IVCmax, IVCmin, and cIVC) was assessed using the Shapiro–Wilk test. Differences among SC, TH, and CR windows for these variables were analyzed using the Kruskal–Wallis test.

The Likert scale scores, image acquisition times, and number of criteria met in each window were analyzed using the Kruskal–Wallis or Chi-square test, as appropriate. Agreement between the three windows was assessed using intraclass correlation coefficients (ICCs). Bland–Altman analysis was used to evaluate pairwise agreement between measurement techniques.

All statistical analyses were performed using IBM SPSS Statistics version 21.0 (IBM Corp®, Armonk, NY) and Jamovi version 2.4.11. A p value of <0.05 was considered statistically significant.

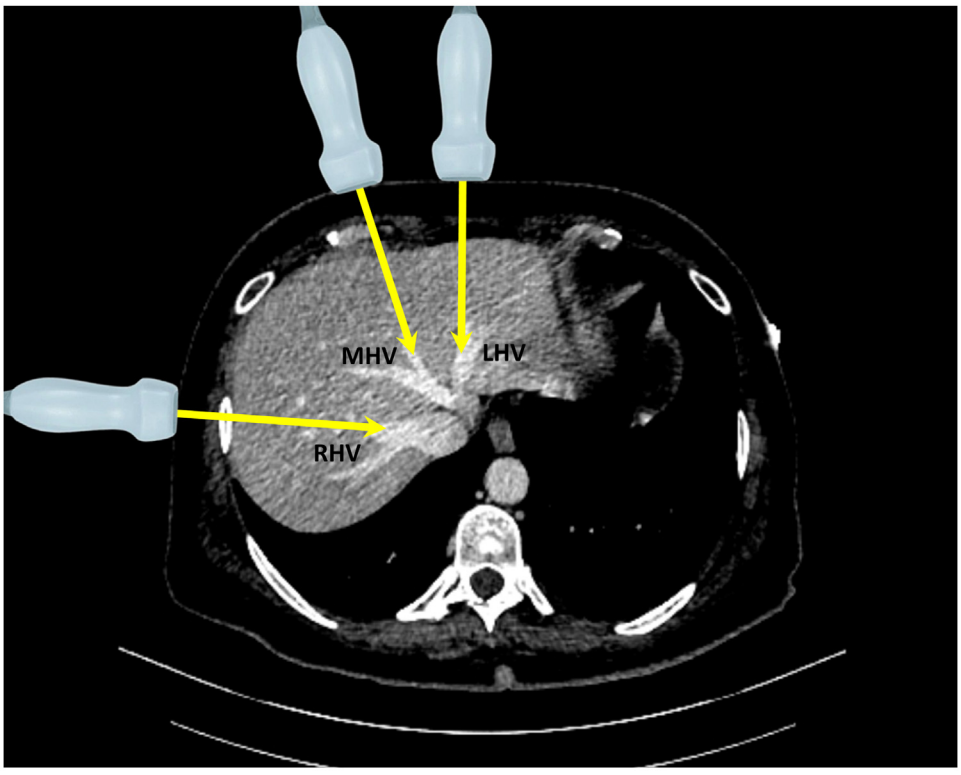


Figure 2. Anatomical representation of hepatic venous structures.

Results

Of the 256 patients who underwent imaging during the study period, 219 were included in the final analysis (Figure 3). The mean age was 59.45 ± 20.67 years, and 53% of the participants were male. The mean BMI was 24.99 ± 4.87; 3.2% of the patients were classified as underweight, 50.7% as normal weight, and 46.1% as overweight.

There were no statistically significant differences in IVCmax, IVCmin, or cIVC values among the three imaging windows (SC, TH, and CR) (Table 1). ICC values for all measurements were positive and highly statistically significant. The strongest correlation was observed between SCmin and THmin diameters ($r = 0.952$), while the weakest was between SCmin and CRmin diameters ($r = 0.876$) (Table 2).

Bland–Altman analysis was used to evaluate agreement between the SC window and the alternative TH and CR approaches for IVCmax and IVCmin measurements. The mean difference between SCmax and THmax was 0.6 mm, with 95% limits of agreement ranging from –3.3 to 4.4 mm. For SCmin and THmin, the mean difference was 0.3 mm, with limits from –4.2 to 4.8 mm. Between SCmax and CRmax, the mean difference was 0.5 mm (limits: –3.9 to 4.9 mm), and for SCmin and CRmin, 0.1 mm (limits: –5.0 to 4.9 mm). The differences were evenly distributed around the mean and remained within acceptable agreement limits, indicating strong concordance between the standard SC window and alternative approaches (Figure 4).

When the correlation between SC, TH, and CR windows was analyzed by BMI category, ICC values for IVCmax, IVCmin, and cIVC were found to be positive and highly significant across underweight, normal, and overweight groups (Table 3). A subgroup analysis of intubated patients ($n = 9$) revealed a similar correlation pattern, with the strongest agreement observed between SCmin and THmin diameters ($r = 0.972$), and the weakest correlation between SC-derived and CR-derived distensibility indices ($r = 0.739$).

The mean image acquisition times were 24.26 ± 24.77 s for SC, 28.89 ± 25.85 s for TH, and 35.66 ± 29.52 s for CR window. All three predefined imaging criteria were met in 79% of SC windows, 20.6% of TH windows, and 30.4% of CR windows. For each window, the majority of images were rated as “very easy” or “easy” by the emergency physicians (Table 4). When analyzed by BMI category, the SC view showed a trend of being rated as easier to acquire in lower BMI patients, while the TH and CR views maintained more consistent ease of acquisition and success rates across all BMI categories.

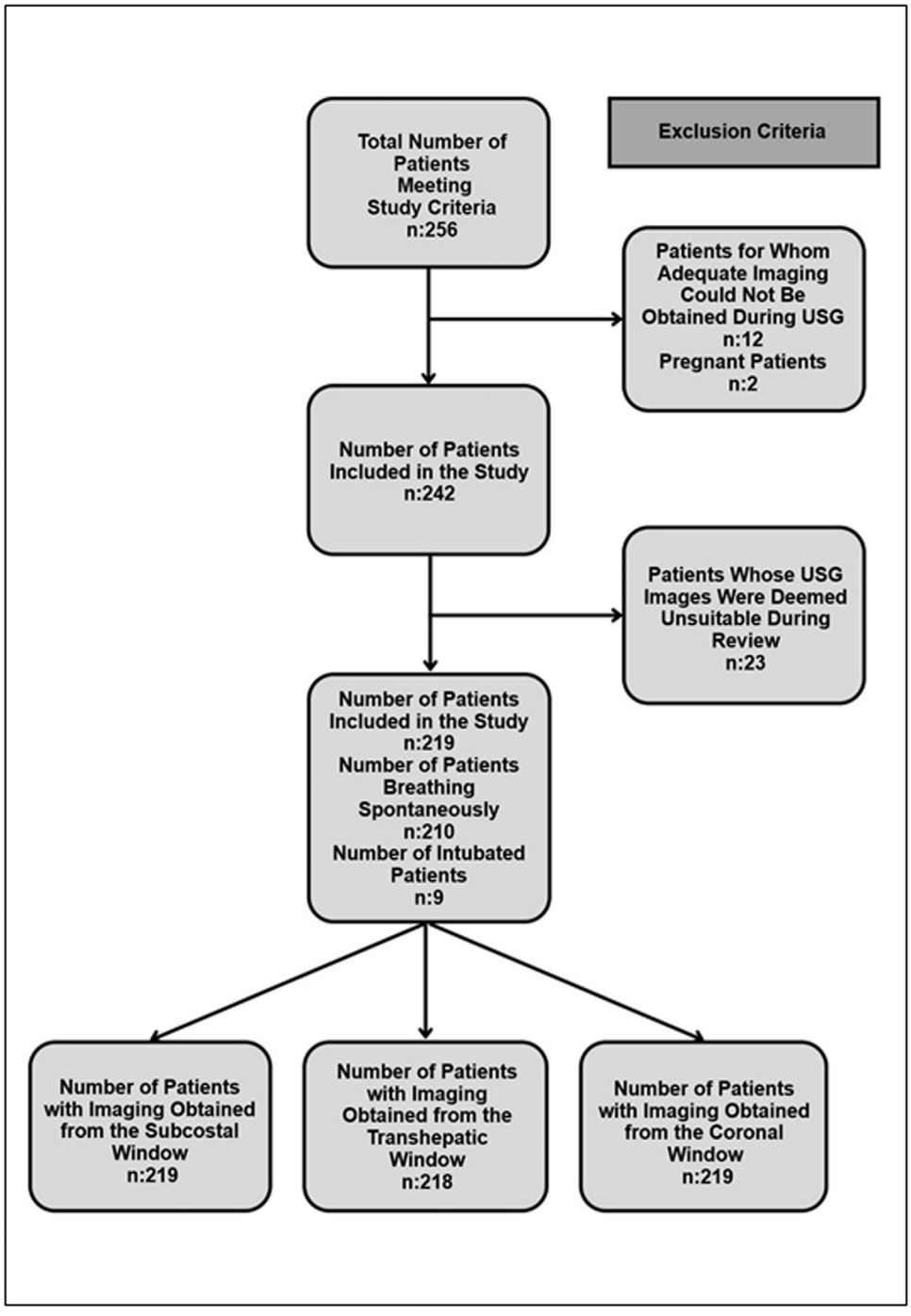


Figure 3. Patient enrollment flowchart with inclusion and exclusion criteria. USG = ultrasonography.

Discussion

This study evaluated the agreement between the SC, TH, and CR ultrasonographic windows in assessing IVC diameters and cIVC, aiming to determine the feasibility of using alternative imaging approaches when the standard SC view is suboptimal. The findings demonstrated a high level of correlation and acceptable agreement between SC and both TH and CR windows, indicating that these alternatives can be reliably utilized in clinical settings where SC imaging is limited or not feasible.

The literature presents conflicting results regarding the reliability of IVC evaluation through different ultrasonographic windows. The studies by Kulkarni et al.

Table 1. Comparison of Variables by Three Imaging Windows

Variables	Anatomical Sites			Test Statistic
	Subcostal Median (Min–Max)	Transhepatic Median (Min–Max)	Coronal Median (Min–Max)	*p*
IVCmax	17.00 (4.00–36.00)	16.00 (5.00–37.00)	16.30 (4.00–35.00)	0.286
IVCmin	11.00 (1.00–32.00)	10.00 (1.00–32.00)	11.00 (1.00–32.00)	0.756
cIVC	31.57 (2.33–92.31)	33.33 (5.56–92.31)	30.38 (4.76–88.89)	0.441

IVCmax = inferior vena cava maximum diameter; IVCmin = inferior vena cava minimum diameter; cIVC = inferior vena cava collapsibility index.
Kruskal–Wallis nonparametric test.

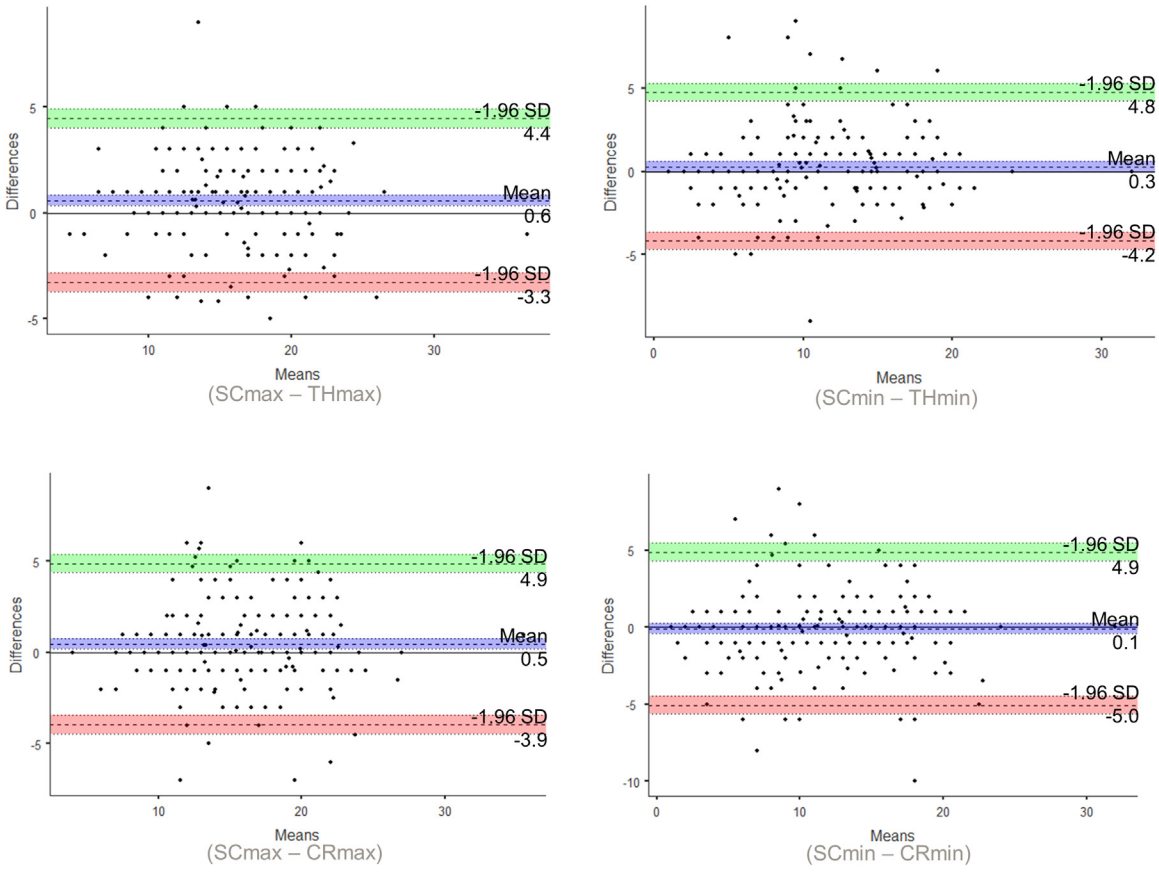


Figure 4. Bland–Altman analysis of measurement differences across imaging windows. SCmax = subcostal maximum diameter; THmax = transhepatic maximum diameter; SCmin = subcostal minimum diameter; THmin = transhepatic minimum diameter; CRmax = coronal maximum diameter; CRmin = coronal minimum diameter.

and Finnerty et al. reported that CR window could provide comparable measurements to the SC window and may be used interchangeably (14,15). In a prospective cohort study by Moreno Garijo et al. (18), which specifically assessed the correlation and agreement between SC and CR windows in spontaneously breathing cardiac surgical patients, the authors reported only moderate correlation for absolute IVC diameters (Dmax R = 0.46;

Table 2. Intraclass Correlation Analysis for the Three Imaging Windows

Variables**	r*	p
SCmax – THmax	0.906	<0.001
SCmin – THmin	0.952	<0.001
SCmax – CRmax	0.876	<0.001
SCmin – CRmin	0.890	<0.001

* r = intraclass correlation coefficient (ICC).
** SCmax = subcostal maximum diameter, THmax = transhepatic maximum diameter, SCmin = subcostal minimum diameter, THmin = transhepatic minimum diameter, CRmax = coronal maximum diameter, CRmin = coronal minimum diameter.

Dmin $R = 0.55$), but a higher correlation for IVC diameter variation ($R = 0.70$). On the contrary, La Via et al. (19) systematically reviewed the agreement between SC and CR longitudinal imaging, concluding that these windows are not equivalent in assessing IVC diameter and respiratory variation. This discordance is further supported by Haroun et al. and Shah et al., who demonstrated significant differences in both IVC diameter and collapsibility index between the SC and CR windows in spontaneously breathing adults and ICU patients. Their findings caution against applying SC-derived cut-off values to lateral views and suggest that the views are not interchangeable (11,13). Adding to this complexity, Valette et al. (12) reported wide limits of agreement between SC and CR windows in critically ill patients, advising careful interpretation of measurements obtained from the CR window.

In contrast to the SC-CR comparison, and to the best of our knowledge, no prior study has directly compared the SC with the anterior TH view. Our study addresses this gap and demonstrates that ICC values were positive and statistically significant across all three views. Notably, the strongest correlation was observed between SCmin and THmin diameters, likely due to their anatomical proximity and similar sonographic plane, while the slightly weaker correlation with the CR view may reflect its different imaging axis.

Terminological inconsistencies in the literature can lead to confusion. Terms such as coronal transhepatic, right lateral, and lateral transhepatic are often used interchangeably to describe approaches via the right intercostal space through the liver parenchyma (19,20). For clarity and consistency, this study used the terms anterior transhepatic, right coronal, and subcostal to refer to the respective ultrasonographic windows.

Qasem et al. defined an adequate IVC image as one clearly demonstrating the vessel's lumen with at least one of the following: its confluence with the right atrium, hepatic vein entry, or a well-defined intrahepatic segment. In their study of term pregnant women, the rate of adequate images was 25% for the SC view and 65% for the TH view (21). In our study, all three imaging criteria were met in 79% of SC images, compared to 20.6% in TH and 30.4% in CR images. These differences likely reflect variations in patient populations. In particular, SC imaging success was highest among underweight and normal BMI patients in our sample. Although TH and CR views yielded lower overall imaging success, they were less affected by BMI differences.

In the same study by Qasem et al. (21), the median time to acquire an adequate image was reported as 52 s for SC and 23 s for the right upper quadrant view. In contrast, our results showed shorter mean acquisition times: 24.26

Table 3. Intraclass Correlation Analysis for the Three Imaging Windows According to BMI*

Variables***	Underweight (BMI ≤ 18.4)		Normal (BMI 18.5–24.9)		Overweight (BMI ≥ 25)	
	r**	p	r**	p	r**	p
SCmax – THmax	0.964	<0.001	0.953	<0.001	0.946	<0.001
SCmin – THmin	0.957	0.001	0.939	<0.001	0.957	<0.001
SCcIVC – THcIVC	0.938	0.002	0.901	<0.001	0.907	<0.001
SCmax – CRmax	0.818	0.029	0.929	<0.001	0.947	<0.001
SCmin – CRmin	0.937	0.002	0.934	<0.001	0.945	<0.001
SCcIVC – CRcIVC	0.894	0.008	0.913	<0.001	0.885	<0.001

* BMI = body mass index.
** r = intraclass correlation coefficient (ICC).
*** SCmax = subcostal maximum diameter, THmax = transhepatic maximum diameter, SCmin = subcostal minimum diameter, THmin = transhepatic minimum diameter, CRmax = coronal maximum diameter, CRmin = coronal minimum diameter.

Table 4. Operator-Assessed Ease of Acquisition and Total Number of Criteria

	Subcostal *n* (%)	Transhepatic *n* (%)	Coronal *n* (%)
Operator Rating			
Very easy	121 (55.3)	83 (37.9)	74 (33.8)
Easy	56 (25.6)	94 (42.9)	89 (40.6)
Moderate	22 (10.0)	26 (11.9)	35 (16.0)
Difficult	12 (5.5)	9 (4.1)	14 (6.4)
Very difficult	8 (3.7)	6 (2.7)	7 (3.2)
Total number of criteria met*			
1	22 (10.0)	64 (29.4)	38 (17.5)
2	24 (11.0)	109 (50.0)	115 (52.1)
3	173 (79.0)	45 (20.6)	66 (30.4)
Total	219 (100)	218 (100)	219 (100)

* The total number of criteria successfully met for each view, rather than individual criteria.

± 24.77 s for SC, 28.89 ± 25.85 s for TH, and 35.66 ± 29.52 s for CR. These differences may reflect population characteristics or clinical context. Although acquisition times for TH and CR were slightly longer than for SC, they were still considered practical by resident physicians, with more than half of all attempts rated as "easy" or "very easy."

Acquisition ease was evaluated using a 5-point Likert scale. The SC received the highest ratings in patients with low and normal BMI. Although not statistically significant, a decline in "very easy" ratings was observed with increasing BMI. This trend aligns with previous studies reporting that subcutaneous tissue and abdominal morphology can impair SC imaging in obese patients (15,16,21). In comparison, TH and CR windows appeared less influenced by BMI..

Limitations

This study has several limitations. First, it was conducted at a single tertiary care center, which may limit the generalizability of the results to other institutions or patient populations. Second, although all ultrasonographic procedures were performed by senior emergency medicine residents who received standardized training and supervision, inter-operator variability was not quantitatively assessed. Third, the retrospective nature of diameter measurements from recorded videos, rather than real-time acquisition, may not fully capture the dynamic bedside assessment. Furthermore, image interpretation was not blinded; all images were reviewed by a single observer who was aware of the imaging approach used, which may have introduced observer bias. Lastly, the use of a subjective 5-point Likert scale to assess image quality and acquisition difficulty, without external validation, may limit the objectivity of these evaluations.

Conclusion

This study demonstrates that although the SC window remains the most effective and reliable method for IVC assessment, the TH and CR windows offer clinically acceptable alternatives when SC imaging is limited or not feasible, particularly in patients with high BMI or anatomical limitations. Bland–Altman analysis confirmed a high level of agreement between the methods, and all three approaches were rated favorably in terms of ease of use by physicians. These findings support the incorporation of alternative imaging windows into routine clinical practice, especially in emergency and critical care settings.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article.

CRediT authorship contribution statement

Aslihan Küçük Albayrak: Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Mehmet Ali Aslaner:** Writing – review & editing, Supervision, Methodology, Conceptualization. **Ömer Faruk Korkak:** Resources, Investigation, Data curation. **Fikret Bildik:** Writing – review & editing, Supervision, Resources, Data curation, Conceptualization.

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Article Summary

1. Why is this topic important?

Assessment of intravascular volume status is crucial in critical care, but the standard subcostal (SC) IVC window is often limited by patient factors.

2. What does this study attempt to show?

It investigates whether anterior transhepatic (TH) and right coronal (CR) windows can reliably substitute for the SC approach.

3. What are the key findings?

- Strong agreement was demonstrated between SC, TH, and CR measurements.
- TH and CR views provided reliable alternatives when SC imaging was not feasible.
- Image acquisition times and ease of use were acceptable for all approaches.

4. How is patient care impacted?

Incorporating TH and CR windows expands imaging options, enabling more consistent IVC assessment and improving clinical decision-making in emergency and critical care.