

Reproducibility and inter-observer variability of the internal jugular vein ultrasonographic assessment: a multicenter cross-sectional study

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Abstract

This study evaluates inter-observer variability in measuring internal jugular vein (IJV) ultrasonographic parameters using images obtained from medical ward patients.

A cross-sectional study was conducted across 4 Italian hospitals. After brief training, 8 expert sonographers and 11 novices measured at the supraclavicular, cricoid, and submandibular levels the anteroposterior expiratory maximum diameter (AP-IJV max), maximum cross-sectional area (CSA-IJV max), aspect ratio (AP-IJV max to latero-lateral diameter), and collapsibility index (IJV-c) on 60 IJV ultrasound images from 10 patients. Inter-observer reliability was assessed using the intraclass correlation coefficient.

No significant differences were observed between experts and novices for AP-IJV max, CSA-IJV max, or aspect ratio across the different views. The lowest inter-examiner variability was found for AP-IJV max and CSA-IJV max at the supraclavicular level. Aspect ratio showed moderate reliability among experts but poor reproducibility among novices. The IJV-c demonstrated the highest inter-examiner variability in both groups.

To our knowledge, this is the first multicenter study aimed at evaluating the reliability of different non-invasive acoustic measurements and windows to better identify IJV dimensions, mainly in case of hypovolemia or fluid challenge.

The AP-IJV max and the CSA-IJV max measurements showed excellent inter-observer reproducibility, suggesting the use of point-of-care ultrasound protocols for non-invasive volume assessment, particularly at the neck's base or cricoid level.

Key words: internal jugular vein, volume status, central venous pressure, ultrasound, inter-rater reliability.

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Introduction

Many studies suggest that the ultrasound measurement of the internal jugular vein (IJV) is a valid method for predicting volume status and central venous pressure (CVP) among critical patients, making its assessment especially crucial for fluid management.^{1,2} Since this is a very easy, fast, and applicable method in several settings, IJV ultrasound could play an important role in clinical practice once its role in volume estimation and patient prognosis is definitively confirmed.

The IJV changes its size during the respiratory cycle, enlarging during expiration and reducing during inspiration, affecting the

venous return to the heart. Researchers have primarily used expiratory maximum diameters and areas to evaluate the accuracy of IJV ultrasound in predicting CVP and volume status.^{1,2}

Many ultrasound measures of IJV have been tested,³⁻¹⁰ including the anteroposterior, end-expiratory IJV diameter (AP-IJV Dmax); the end-expiratory IJV area (maximal area in transversal section, CSA); the ratio between the AP-IJV Dmax and transversal IJV diameter (LL-IJV max), *i.e.*, the aspect ratio = AP-IJV/LL-IJV; the collapsibility index of IJV as the respiratory variation percentage calculated as in the following formula: maximum diameter – minimum diameter/maximum diameter × 100.

According to the literature, low values of the collapsibility

index, along with large diameters and areas of IJV, may indicate high CVP.^{1,4-7} However, a lack of standardization in ultrasound technique exists due to the use of various protocols by researchers.

Our hypothesis posits that IJV ultrasound may exhibit significant inter-rater variability and may not be reliable. Therefore, we aimed to assess the inter-rater reliability among ultrasound measurements of the IJV using a group of images recorded from various acoustic views of the neck of patients admitted to medicine departments. The secondary objective was to measure differences among ultrasound measurements in different acoustic views and between beginner and expert sonographers.

Materials and Methods

We conducted a cross-sectional study, including 4 Italian hospitals from 01/03/2024 to 30/09/2024. We followed the STROBE checklist and guidelines to plan and conduct the study.¹¹ The flow diagram according to STROBE guidelines is shown in Figure 1.

The study was approved by the Ethical Committee Area Vasta Emilia Centro (AVEC) with code 725-2023-OSS-AUSLBO and uploaded on ClinicalTrials.gov with ID number NCT06563427.

Initially, we enrolled 12 adult patients admitted to the medicine

departments of Hospital Maggiore in Bologna: 12 students and 8 expert sonographers with ultrasound certification from Hospital Maggiore and Policlinico S. Orsola in Bologna, Hospital of the University Federico II in Naples, and Hospital of the University of Foggia, Italy.

Exclusion criteria for patients were inability to provide consent, presence of a central venous catheter in the IJV, and thrombosis of the vein.

Finally, we included 10 patients: 2 were excluded because they did not give consent, and 1 student did not complete the assignment (Figure 1). For each patient, the following variables were collected: age, sex, weight, height, body mass index, body surface area, cause of hospitalization, and ultrasound measurements of the jugular vein described below.

Ultrasound imaging and protocol

During the ultrasound examination, performed using an Esaote Mylab system (Esaote S.p.A., Genoa, Italy), patients were assessed with the trunk positioned at 45° of elevation. The examination was performed in the lateral region of the right neck, using the following acoustic windows: supraclavicular one (2 cm above the clavicle), cricoid one, and the third one at the apex of the sternocleidomastoid muscle (mandibular angle).

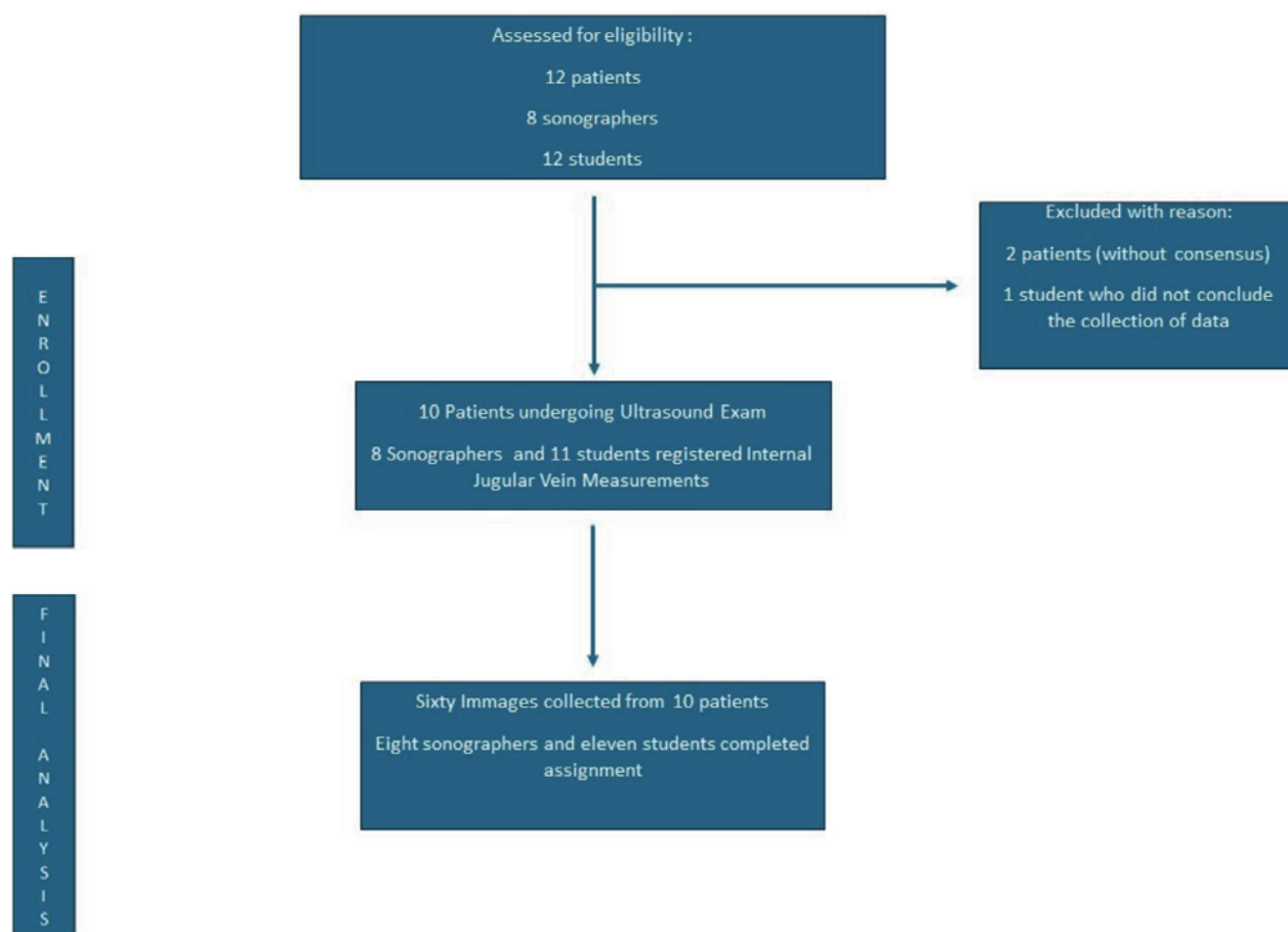


Figure 1. Flow diagram according to STROBE guidelines.

A vascular probe (10 MHz linear array) was used in B-mode and M-mode echocardiographic settings.

Six images per patient were recorded for ten recruited patients, yielding 60 images.

The students and sonographers, after a short theoretical and practical course (one hour of theory and one hour of practice), measured, on the images previously recorded, independently and without communicating with each other, the four ultrasound measurements to be tested (*Supplementary Figure 1*): the anteroposterior expiratory max diameter (AP-IJV max) (*Supplementary Figure 1A*); the aspect ratio (*i.e.*, the ratio between the AP-IJV max and the latero-lateral IJV diameter) (*Supplementary Figure 1B*); the maximum area (CSA-IJV max) (*Supplementary Figure 1C*) and the collapsibility index (IJV-c) (*Supplementary Figure 1D*).

All patients admitted for any cause to the study center were recruited to avoid selection bias. Neither did ultrasound researchers know the purpose of the study, the causes of hospitalization of the patient, nor the values of measurements made by the other researchers-echographers. The researcher who collected clinical-anthropometric data and ultrasound variables differed from the one performing the ultrasound protocol. To minimize procedural and measurement biases, sonographers who performed the protocol were instructed before the study, with the same course conducted by the same teacher. Each researcher was unaware of the measurements recorded by the other researchers in the same session.

The intraclass correlation coefficient (ICC) statistics were used to evaluate inter-operator reliability. Measures with a range of values

between 0 (expression of maximum variability) and 1 (high reliability with minimum variability) were considered. In particular, we used the reliability level classification proposed by Koo TK *et al.*;¹² we considered poor reliability an ICC value less than 0.5, moderate an ICC value of 0.5-0.75, good an ICC of 0.75-0.9, and excellent an ICC >0.9.

To calculate the sample estimate, we predicted an expected value of ICC of 0.9; a minimum acceptable value of ICC=0.6, according to the literature;³⁻¹⁰ a statistical significance level of 0.05; a rater number of 8 raters; and a 10% share of lost data.

Thus, using the sample size calculation method,¹³ we estimated that a sample of ten groups of images would be needed for global reliability.

Comparison between sonographers and students was performed using medians and interquartile range, and the Wilcoxon Mann-Whitney test was used. A value of $p < 0.05$ was considered statistically significant. All the analyses were performed using R statistical software (R Core Team 2021).

Results

The baseline characteristics of patients across 10 groups of images are shown in *Supplementary Table 1*. There were no statistically significant differences between the measurements made by expert sonographers and students across all acoustic windows using the IJV ultrasound measures: the AP-IJV max, the CSA-IJV max, and the aspect ratio (Tables 1-3).

Table 1. Comparison of measurements registered from images using ultrasound of internal jugular vein in mandibular angle view: senior sonographers vs. students.

	Sonographers (n=8)	Students (n=11)	p
AP-IJV max, mm median [IQR]	4.20 [3.10, 5.88]	4.70 [3.40, 5.90]	0.318
Aspect ratio median [IQR]	0.53 [0.36, 0.80]	0.59 [0.35, 0.81]	0.706
CSA-IJV max, cm ² median [IQR]	0.23 [0.20, 0.46]	0.27 [0.20, 0.60]	0.117
IJV-c, % median [IQR]	29.06 [19.54, 38.95]	21.95 [16.54, 34.11]	0.018

IJV, internal jugular vein; AP-IJV max, antero-posterior, end-expiratory IJV diameter; CSA-IJV max, the end-expiratory IJV area; aspect ratio, the ratio between the AP-IJV Dmax and transversal IJV diameter (LL-IJV max); IJV-c (%), the collapsibility index of IJV = the respiratory variation percentage calculated as [(maximum diameter minus minimum diameter) / maximum diameter]; IQR, interquartile range.

Table 2. Comparison of measurements registered from images using ultrasound of internal jugular vein in cricoid view: senior sonographers vs. students.

	Sonographers (n=8)	Students (n=11)	p
AP-IJV max, mm median [IQR]	8.05 [5.60, 14.30]	8.00 [5.80, 14.28]	0.628
Aspect ratio median [IQR]	0.65 [0.45, 0.87]	0.69 [0.48, 0.89]	0.312
CSA-IJV max, cm ² median [IQR]	0.99 [0.34, 1.68]	1.03 [0.43, 1.68]	0.592
IJV-c, % median [IQR]	25.53 [11.78, 45.55]	20.59 [11.92, 38.37]	0.212

IJV, internal jugular vein; AP-IJV max, antero-posterior, end-expiratory IJV diameter; CSA-IJV max, the end-expiratory IJV area; aspect ratio, the ratio between the AP-IJV Dmax and transversal IJV diameter (LL-IJV max); IJV-c (%), the collapsibility index of IJV = the respiratory variation percentage calculated as [(maximum diameter minus minimum diameter) / maximum diameter]; IQR, interquartile range.

Table 3. Comparison of measurements registered from images using ultrasound of internal jugular vein in supraclavicular view: senior sonographers vs. students.

	Sonographers (n=8)	Students (n=11)	p
AP-IJV max, mm median [IQR]	9.05 [7.60, 13.62]	9.25 [7.62, 13.50]	0.982
Aspect ratio median [IQR]	0.82 [0.62, 0.89]	0.81 [0.62, 0.91]	0.933
CSA-IJV max, cm ² median [IQR]	0.93 [0.43, 1.76]	0.92 [0.46, 1.82]	0.615
IJV-c, % median [IQR]	19.23 [12.87, 42.20]	15.64 [10.75, 33.41]	0.052

IJV, internal jugular vein; AP-IJV max, antero-posterior, end-expiratory IJV diameter; CSA-IJV max, the end-expiratory IJV area; aspect ratio, the ratio between the AP-IJV Dmax and transversal IJV diameter (LL-IJV max); IJV-c (%), the collapsibility index of IJV = the respiratory variation percentage calculated as [(maximum diameter minus minimum diameter) / maximum diameter]; IQR, interquartile range.

The IJV-c registered at the mandibular angle view differed between the sonographers' and students' groups (Table 1).

The supraclavicular view was the best for performing the IJV

ultrasound exam because the measurements' median was similar among the sonographers (Figure 2).

The measurements that showed the lowest variability among the

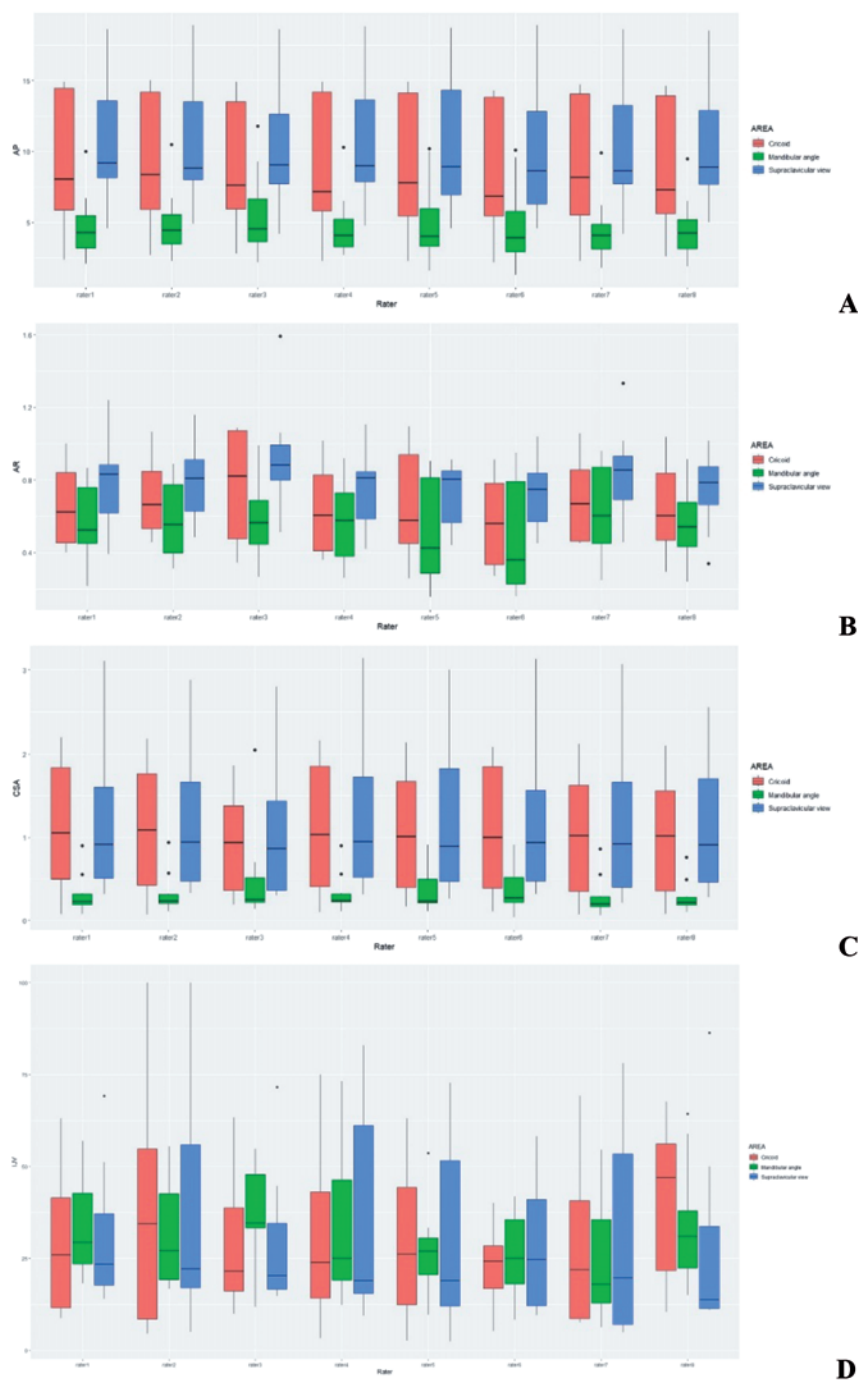


Figure 2. A) Antero-posterior maximum diameter of internal jugular vein (AP-IJV max); B) aspect ratio (AR = AP-IJV max/LL-IJV max) of internal jugular vein; C) the maximum area of internal jugular vein (CSA-IJV max); D) the collapsibility index of internal jugular vein (IJV-c). Blue box = supraclavicular view; green = mandibular angle; red = cricoid. AP in Figure 2a is the antero-posterior expiratory max diameter (AP-IJV max). AR in Figure 2b is the aspect ratio derived by the formula: AP-IJV max / LL-IJV max. CSA in Figure 2c is the maximum area (CSA-IJV max). IJV-c is the collapsibility index of the internal jugular vein, IJV-c, registered using the M-Mode, derived by the formula: [(max diameter, D1 in the figure – min diameter, D2 in the figure)/(max diameter, D1 in the figure)] × 100%. Raters are the sonographers: raters 1 and 2 are from Center 1; raters 3 and 4 from Center 2; raters 5 and 6 from Center 3; raters 7 and 8 from Center 4. The ultrasound IJV values are shown as the median, the black line inside the boxes.

different views were the AP-IJV max and the CSA-IJV max since their medians were similar among the sonographers in all the views (Figure 2A and C).

In both the sonographers' and students' measurements, the values of AP-IJV max, aspect ratio, and CSA-IJV max differ in the various acoustic views of the neck as they increase in the craniocaudal direction (Tables 1-3).

The CSA max and AP-IJV max showed similar and excellent inter-rater reliability in both groups at the cricoid and supraclavicular views (Tables 4 and 5). Among students, CSA max had an ICC of 0.98 [95, confidence interval (CI): 0.97-0.99] and 0.98 (95, CI: 0.96-0.99) at the cricoid and supraclavicular level respectively; AP-IJV max had an ICC of 0.93(95, CI: 0.88-0.98) and of 0.97(95, CI: 0.94-0.99) in the previous views (Tables 1 and 2). Among expert sonographers, CSA max had an ICC of 0.98 (95, CI: 0.96-0.99) and 0.97(95, CI: 0.95-0.99) at the cricoid and supraclavicular; AP-IJV max had an ICC of 0.98(95, CI: 0.95-0.99) in both previous views.

The aspect ratio showed moderate-good inter-rater reliability in all the views among the sonographers but a poor value among the students (Tables 4 and 5). The IJV-c showed the worst inter-rater reliability values in both groups in all views. These results were also confirmed after a global analysis of the inter-rater reliability between sonographers and students in all views (Table 6).

Discussion

To our knowledge, this is the first multicenter study aimed at evaluating the reliability of different non-invasive acoustic measurements and windows to better identify IJV dimensions mainly in the

case of hypovolemia or fluid challenge. In particular, this is the first study to evaluate the inter-operator reliability of different ultrasound examination jugular vein approaches.

Only a few reports with a limited number of patients, not designed to assess the method's reliability as the primary outcome, are present in the literature.^{3,10} Thus, there is no direct comparator for the reliability of IJV ultrasound methods. Nevertheless, the limited published data on the reliability of jugular vein ultrasound suggests that CSA-IJV max and AP-IJV maximum diameter could be reliable parameters in predicting both hypervolemia and euvoemia.^{1,3-5}

The main findings from our study are that the anteroposterior, end-expiratory IJV diameter (AP-IJV Dmax) and the end-expiratory area of the IJV (maximal area in transversal section, CSA-IJV max), recorded in cricoid or supraclavicular views, are the most reliable measurements among those evaluated. This evidence suggests that point-of-care ultrasound protocols could be developed for non-invasive volume assessment, particularly at the base of the neck or cricoid level.

A lot of previous reports suggest that many ultrasound measures of the IJV could be valid for predicting volume status and CVP.^{1,2} In particular, simple and quick-to-perform measurements such as the AP diameter of the IJV and its area could be useful for fluid management among critical patients.³⁻⁷ Nevertheless, an ultrasound method should, before being proposed in clinical practice, also show good reliability. That is, a low inter-operator variability in execution and reporting. This characteristic would make it possible to improve the reproducibility of the method and justify its diffusion in clinical practice.

Unfortunately, so far, few studies have evaluated the variability

Table 4. Intraclass correlation coefficient comparison among students in different views.

	AP-IJV-max	CSA-max	Aspect ratio	IJV-c
Mandibular angle ICC (95% CI)	0.69 (0.52-0.86)	0.45 (0.27-0.71)	0.37 (0.21-0.64)	0.13 (0.03-0.36)
Cricoid ICC (95% CI)	0.93 (0.88-0.98)	0.98 (0.97-0.99)	0.63 (0.45-0.83)	0.37 (0.21-0.64)
Supraclavicular ICC (95% CI)	0.97 (0.94-0.99)	0.98 (0.96-0.99)	0.23 (0.09-0.49)	0.25 (0.12-0.52)

IVJ, internal jugular vein; AP-IJV max, antero-posterior, end-expiratory IJV diameter; CSA-IJV max, the end-expiratory IJV area; aspect ratio, the ratio between the AP-IJV Dmax and transversal IJV diameter (LL-IJV max); IJV-c (%), the collapsibility index of IJV = the respiratory variation percentage calculated as [(maximum diameter minus minimum diameter) / maximum diameter]; CI, confidence interval. Classification of inter-rater reliability level using intraclass correlation coefficients (ICC) (reference 12): ICC<0.5 = poor; ICC=0.5-0.75 = moderate; ICC=0.75-0.9 = good; ICC>0.9=excellent.

Table 5. Intraclass correlation coefficient comparison among expert sonographers in different views.

	AP-IJV-max	CSA-max	Aspect ratio	IJV-c
Mandibular angle ICC (95% CI)	0.77 (0.61-0.9)	0.44 (0.25-0.71)	0.78 (0.63-0.91)	0.59 (0.39-0.81)
Cricoid ICC (95% CI)	0.98 (0.95-0.99)	0.98 (0.96-0.99)	0.81 (0.67-0.92)	0.63 (0.44-0.83)
Supraclavicular ICC (95% CI)	0.98 (0.95-0.99)	0.97 (0.95-0.99)	0.72 (0.54-0.88)	0.68 (0.5-0.86)

IVJ, internal jugular vein; AP-IJV max, antero-posterior, end-expiratory IJV diameter; CSA-IJV max, the end-expiratory IJV area; aspect ratio, the ratio between the AP-IJV Dmax and transversal IJV diameter (LL-IJV max); IJV-c (%), the collapsibility index of IJV = the respiratory variation percentage calculated as [(maximum diameter minus minimum diameter) / maximum diameter]; CI, confidence interval. Classification of inter-rater reliability level using intraclass correlation coefficients (ICC) (reference 12): ICC<0.5 = poor; ICC=0.5-0.75 = moderate; ICC=0.75-0.9 = good; ICC>0.9=excellent.

Table 6. Global intraclass correlation coefficient of expert sonographers and students in different views.

	AP-IJV-max	CSA-max	Aspect ratio	IJV-c
Mandibular angle ICC (95% CI)	0.92 (0.80-0.98)	0.56 (0.34-0.82)	0.35 (0.16-0.67)	0.11 (0.03-0.39)
Cricoid ICC (95% CI)	0.97 (0.94-0.99)	0.90 (0.80-0.97)	0.61 (0.39-0.85)	0.36 (0.16-0.68)
Supraclavicular ICC (95% CI)	0.98 (0.97-0.99)	0.96 (0.91-0.99)	0.19 (0.05-0.50)	0.24 (0.08-0.56)

IVJ, internal jugular vein; AP-IJV max, antero-posterior, end-expiratory IJV diameter; CSA-IJV max, the end-expiratory IJV area; aspect ratio, the ratio between the AP-IJV Dmax and transversal IJV diameter (LL-IJV max); IJV-c (%), the collapsibility index of IJV = the respiratory variation percentage calculated as [(maximum diameter minus minimum diameter) / maximum diameter]; CI, confidence interval. Classification of inter-rater reliability level using intraclass correlation coefficients (ICC) (reference 12): ICC<0.5 = poor; ICC=0.5-0.75 = moderate; ICC=0.75-0.9 = good; ICC>0.9=excellent.

in the measurement of only some ultrasound variables of the internal jugular: that of the diameter AP max and the area max.^{3,10}

The results of our study confirm the conclusions of the previous studies,^{3,10} and there are no studies comparing multiple ultrasound IJV measures. In the previous studies, the AP-IJV max as the CSA max seems to show low variability and excellent reliability, especially when measured at the base of the neck.

Our starting hypothesis was that the ultrasound of the IJV could have shown great variability among sonographers, as the method could be influenced by many factors (patient's decubitus position, the acoustic window in which the measurement is performed, and the pressure exerted on the skin during the examination) and previous validation studies have used different ultrasound protocols.

Thus, a standardized and more reliable method should be established to evaluate jugular vein dimension, particularly during hypovolemia when the jugular vein size could be variable.

If the results of this study are confirmed using real patients, it could be proposed to conduct further studies to validate the accuracy in predicting systemic congestion of an ultrasound protocol based on the ultrasound of the jugular vein and inferior vena cava, the current ultrasound gold standard.

The ultrasound protocol based on IJV that we proposed is easy to learn, fast, and easy to perform in different settings, and has good accuracy in predicting the volemic state of the patient,^{1,2,14} becoming a potentially valuable tool for clinicians. Indeed, after a brief training course, even inexperienced sonographers could accurately measure the proposed ultrasound parameters, achieving excellent reliability compared to an experienced researcher for the CSA-IJV max and AP-IJV max measured in the cricoid and supraclavicular view.

Nevertheless, differences in the values of all ultrasound measurements between the different views are present in both beginner and expert sonographers' assignments (Tables 1-3).

Interestingly, the size of the IJV appears greater at the base of the neck, suggesting that this evidence should be considered during the ultrasound measurements recording to estimate the intravascular volume state.

The only measure that seemed less affected by the measurement site in this study was the IJV-c. This characteristic could be advantageous in clinical practice, but unfortunately, this measure does not exhibit good inter-rater reliability.

This study presents some limitations. The main limitation of this study is that images, rather than patients, were used for the outcome evaluation. However, this methodology has often been used to measure inter-rater reliability, especially in large multicenter trials.^{15,16} Furthermore, to avoid heterogeneity in the interpretation of images, we have followed the Food and Drug Administration guidelines,¹⁷ paying particular attention to data collection, data transfer, and imaging analysis. Another limitation is the challenge to generalize conclusions regarding differences in measurements in different acoustic views, as the images used for the assignment were obtained only from the right side of the neck and only with the patient in a 45° trunk; both decubitus and laterality could affect the size of the IJV. Unfortunately, there are no observational studies comparing ultrasound dimensions of the jugular vein in the different decubitus and laterality, probably due to the complexities of conducting such studies. However, our data (*Supplementary Table 2*) suggest that laterality does not influence the measurements tested in this study. Finally, the choice of ultrasound variables for the jugular to be evaluated was arbitrary, based only on their predictive efficacy of volemic estimation shown in previous studies.¹

Conclusions

This study suggests that the inter-rater reliability of AP-IJV max and CSA-IJV max, measured at the base of the neck or laterally at the cricoid, is excellent, even among inexperienced sonographers after brief training. It appears that the size of the IJV is larger at the base of the neck and that the ultrasound measurements of the IJV differ in the different views. Future, more extensive studies are warranted to confirm our findings on a larger population regarding the reliability of this method, as the ultrasound of the jugular could be used as an alternative to other methods in the management of many critical patients in which estimating volemia and the effectiveness of fluid or diuretic therapy is crucial.

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Online supplementary material:

Supplementary Figure 1. Ultrasound measurements of the internal jugular vein.

Supplementary Table 1. Baseline characteristics of the patients.

Supplementary Table 2. Comparison of measurements registered from patients using ultrasound of internal jugular vein in different views: right vs. left side.

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Conflict of interest: the authors declare that they have no competing interests.

Ethics approval and consent to participate: the study was conducted in accordance with the Declaration of Helsinki and approved by the Ethical Committee Area Vasta Emilia Centro (AVEC) with the code 725-2023-OSS-AUSLBO.

Informed consent: prior to recruitment, patients signed an informed consent form provided by the ethics committee and a privacy form consenting to the processing of personal data.

Patient consent for publication: patient consent was not required as no identifiable patient data were used.

Availability of data and materials: the data supporting the findings of this study are available from the first author upon reasonable request.

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