Italian Journal of Medicine

https://www.italjmed.org/ijm

eISSN 1877-9352

Publisher's Disclaimer. E-publishing ahead of print is increasingly important for the rapid dissemination of science. The Early Access service lets users access peer-reviewed articles well before print/regular issue publication, significantly reducing the time it takes for critical findings to reach the research community.
These articles are searchable and citable by their DOI (Digital Object Identifier).

The **Italian Journal of Medicine** is, therefore, E-publishing PDF files of an early version of manuscripts that have undergone a regular peer review and have been accepted for publication, but have not been through the copyediting, typesetting, pagination, and proofreading processes, which may lead to differences between this version and the final one.

The final version of the manuscript will then appear in a regular issue of the journal.

The E-publishing of this PDF file has been approved by the authors.

Ital J Med 2026 [Online ahead of print]

Please cite this article as:

Parenti N, Guidetti E, Allegri D, et al. **Reproducibility and inter-observer variability of the internal jugular vein ultrasonographic assessment: a multicenter cross-sectional study**. *Ital J Med* doi: 10.4081/itjm.2026.2547

Submitted: 11-04-2026
Accepted: 22-06-2026

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

Nicola Parenti,[1] Elena Guidetti,[2] Davide Allegri,[3] Anna Lombardi,[4] Rita Verdoliva,[4] Paolo Vita,[1] Ripalta Amato,[5] Pasqualino Sirignano,[6,7] Mauro Silingardi,[1] Paolo Caraceni,[2,8] Roberta Esposito,[9] Francesco Bellanti,[5] Alberto Maria Marra,[4,10] Daniele Caggianiello,[5] Carmine Savoia[11]

[1]Department of Internal Medicine, Community Hospital Maggiore, Bologna; [2]Unit of Semeiotics Liver and Alcohol-related Diseases, IRCCS Azienda Ospedaliero-Universitaria di Bologna; [3]Department of Clinical Governance and Quality, Community Hospital Maggiore, Bologna; [4]Department of Translational Medical Sciences, Federico II University, Naples; [5]Department of Internal Medicine, University Hospital Policlinico Riuniti, Foggia; [6]Vascular and Endovascular Surgery Unit, Sant'Andrea Hospital of Rome; [7]Department of General and Specialistic Surgery, Sapienza University of Rome; [8]Department of Medical and Surgical Sciences, University of Bologna; [9]Department of Internal Medicine, University Hospital Policlinico Federico II, Naples; [10]Interdepartmental Center for Gender Medicine Research "GENESIS", Federico II University, Naples; [11]Clinical and Molecular Medicine Department, Sant' Andrea Hospital, Sapienza University of Rome, Italy

Correspondence: Nicola Parenti, Department of Internal Medicine, Community Hospital Maggiore, Largo Nigrisoli 2, 40133 Bologna, Italy. Tel.: +390516478074. E-mail: nipar71@yahoo.it

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

Contributions: Nicola Parenti: study concept and design, development of the study protocol and supervision. Elena Guidetti, Roberta Esposito, Francesco Bellanti, Rita Verdoliva, Paolo Vita, Ripalta Amato, Pasqualino Sirignano, Daniele Caggianello: data collection and image acquisition across participating centers. Mauro Silingardi: data validation. Davide Allegri: statistical analysis. Paolo Caraceni, Alberto Maria Marra, Carmine Savoia, Mauro Silingardi: interpretation of the results and draft of the initial version of the manuscript. Anna Lombardi: critical revision of the manuscript for important intellectual content. All authors contributed to the interpretation of the data, reviewed the manuscript, and approved the final version for publication.

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.

Declaration of generative artificial intelligence and artificial intelligence-assisted technologies in the writing process: the authors did not use generative artificial intelligence and AI-assisted technologies in the writing process.

Clinical trial registration: this study was registered at ClinicalTrials.gov (Identifier: NCT06563427)

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 method's reliability of different non-invasive acoustic measurements and windows to identify IJV dimensions better to use 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.

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 their 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 internal jugular vein 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 imaging 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 Clinical Trials 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 University of Foggia, Italy.

Exclusion criteria of 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 conclude 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 below described.

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).
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; an excellent 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; 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 ten 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 internal jugular vein ultrasound measures: the AP-IJV max, the CSA-IJV max, and the aspect ratio (Tables 1-3).
The IJV-c registered at the mandibular angle, and the supraclavicular view differed between the sonographers and students groups (Tables 1 and 3).
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 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 sonographer's 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=0.98 (95, 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= 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=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 has an ICC= 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 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 to evaluate the method's reliability of different non-invasive acoustic measurements and windows to identify IJV dimension better to use mainly in 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 euvolemia.[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 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 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 seem to show low variability and excellent reliability especially when measured at the base 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 settled to evaluate jugular vein dimension particularly during hypovolemia when the jugular vein size could be variable.
If the results of this study will be 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 which 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 FDA 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 with 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.

References

1. Wang MK, Piticaru J, Kappe C, et al. Internal jugular vein ultrasound for the diagnosis of hypovolemia and hypervolemia in acutely ill adults: a systematic review and meta-analysis. Intern Emerg Med 2022;17:1521-32.
2. Parenti N, Scalese M, Palazzi C, et al. Role of internal jugular vein ultrasound measurements in the assessment of central venous pressure in spontaneously breathing patients: a systematic review. J Acute Med 2019;9:39-48.
3. Simon MA, Kliner DE, Girod JP, et al. Detection of elevated right atrial pressure using a simple bedside ultrasound measure. Am Heart J 2010;159:421-7.

4. Simon MA, Schnatz RG, Romeo JD, Pacella JJ. Bedside ultrasound assessment of jugular venous compliance as a potential point-of-care method to predict acute decompensated heart failure 30-day readmission. J Am Heart Assoc 2018;7:e009185.
5. Tzadok B, Shapira S, Tal-Or E. Ultrasound of jugular veins for assessment of acute dyspnea in emergency departments and for the assessment of acute heart failure. Isr Med Assoc J 2020;20:308-10.
6. Vaidya GN, Ghafghazi S. Correlation of internal jugular and subclavian vein diameter variation on bedside ultrasound with invasive right heart catheterization. Indian Heart J 2021;73:231-5.
7. Ammirati E, Marchetti D, Colombo G, et al. Estimation of right atrial pressure by ultrasound-assessed jugular vein distensibility in patients with heart failure. Circ Heart Fail 2024;17:e010973.
8. Albaeni A, Sharma M, Ahmad M, Khalife WI. Accurate estimation of right-filling pressure using handheld ultrasound score in patients with heart failure. Am J Med 2022;135:634-40.
9. Parenti N, Bastiani L, Tripolino C, Bacchilega I. Ultrasound imaging and central venous pressure in spontaneously breathing patients: a comparison of ultrasound-based measures of internal jugular vein and inferior vena cava. Anaesthesiol Intensive Ther 2022;54:150-5.
10. Donahue SP, Wood JP, Patel BM, Quinn JV. Correlation of sonographic measurements of the internal jugular vein with central venous pressure. Am J Emerg Med 2009;27:851-5.
11. Von Elm E, Altman DG, Egger M, et al. The strengthening the reporting of observational studies in epidemiology (STROBE) statement: guidelines for reporting observational studies. J Clin Epidemiol 2008;61:344-9.
12. Koo TK, Li MY. A guideline of selecting and reporting intraclass correlation coefficients for reliability research. J Chiropr Med 2016;15:155-63.
13. Arifin WN. Sample size calculator. Available from: http://wnarifin.github.io.
14. Parenti N, Palazzi C, Parenti M, D'Addato S. Could internal jugular vein ultrasound be useful in the assessment of patients with heart failure? A systematic review. Ital J Med 2024;18:1726.
15. Dávila-Román VG, Toenjes AK, Meyers RM, et al. Ultrasound core laboratory for the household air pollution intervention network trial: standardized training and image management for field studies using portable ultrasound in fetal, lung, and vascular evaluations. Ultrasound Med Biol 2021;47:1506-13.
16. Yaegashi H, Watanabe T, Kaoku S, et al. Remote breast ultrasound image interpretation system for multicenter study (JABTS BC-04 study). Ultrasound Med Biol 2017;43:S320.
17. US Food and Drug Administration. Clinical trial imaging endpoint process standards: guidance for industry. 2018. Available from: https://www.fda.gov/media/81172/download.

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.

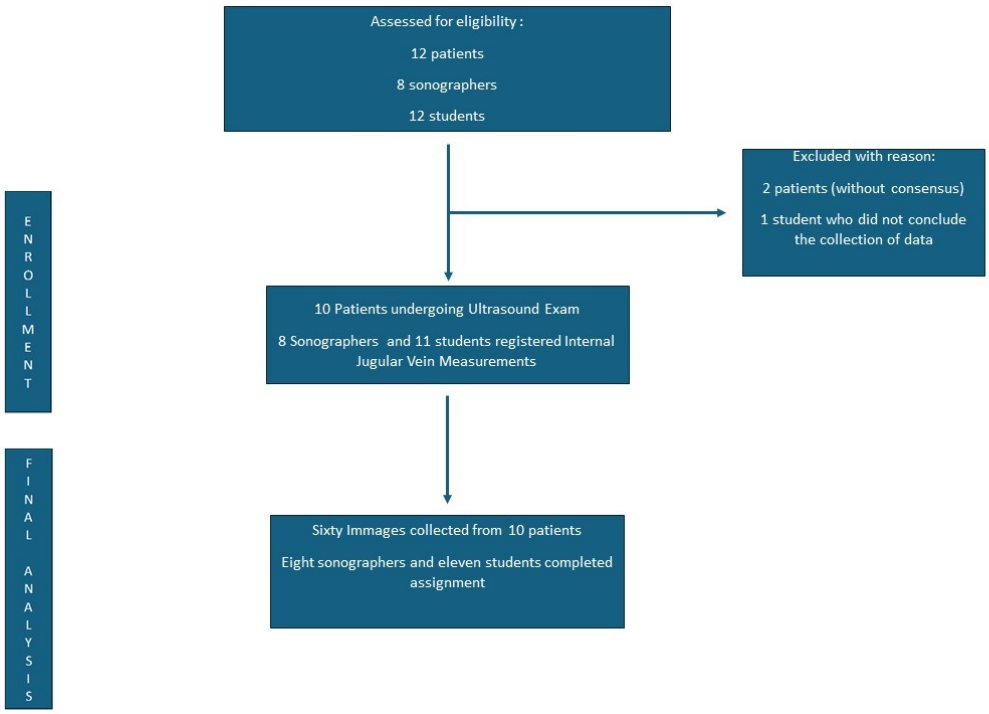
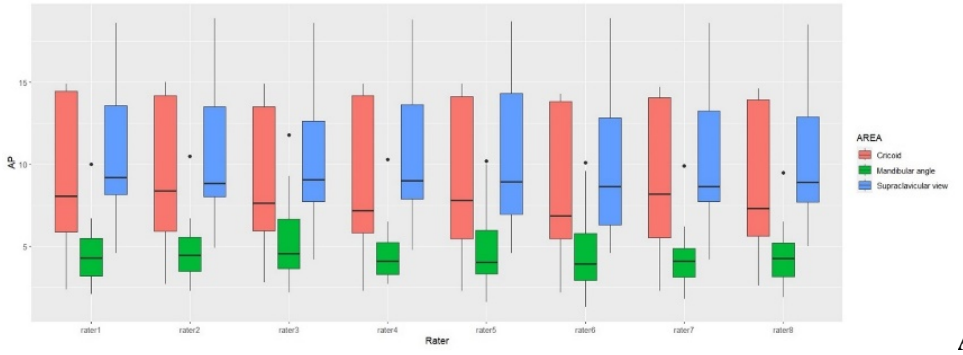
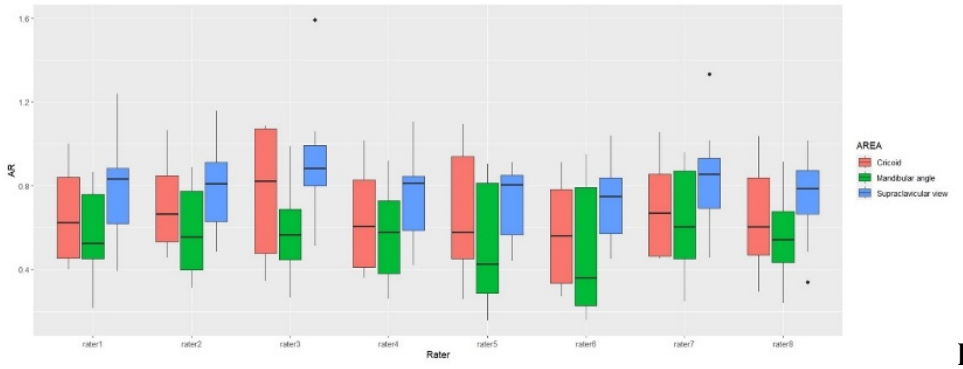


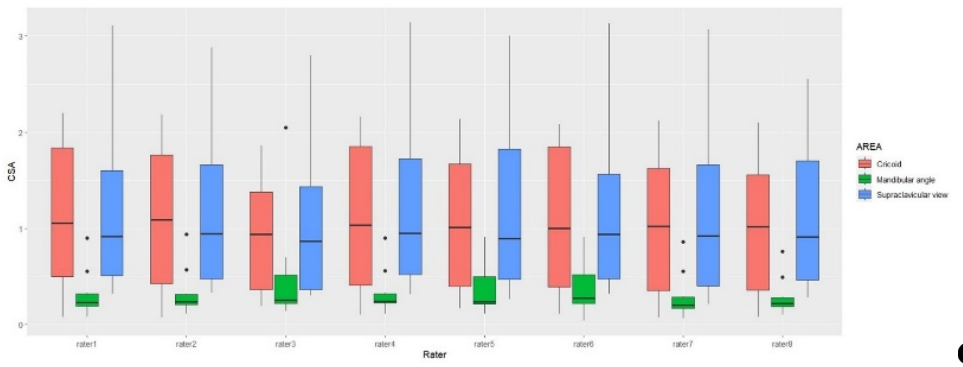
Figure 1. Flow diagram according to STROBE guidelines.



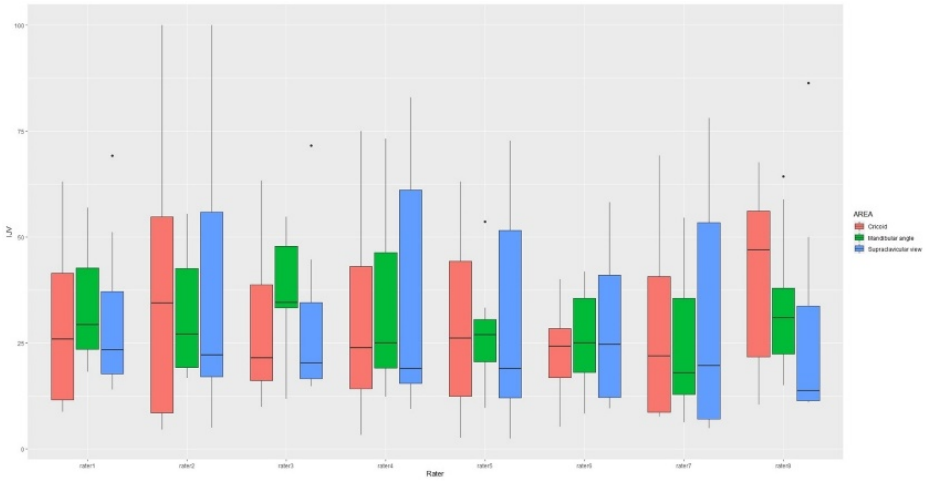
A



B



C



D

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 maximum area (CSA-IJV max). IJV-c is the collapsibility index of Internal Jugular Vein, IJV-c, registered using the M-Mode, derived by the formula: [(Max diameter, D1 in figure – Min diameter, D2 in figure)/(Max diameter, D1 in 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 median, the black line inside the boxes.

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, cm2 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

AP-IJV max, antero-posterior, end-expiratory internal jugular vein diameter; CSA-IJV max, the end-exipratory 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, inter quartile 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, cm2 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

AP-IJV max, antero-posterior, end-expiratory internal jugular vein diameter; CSA-IJV max, the end-exipratory 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, inter quartile 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, cm2 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

AP-IJV max, antero-posterior, end-expiratory internal jugular vein diameter; CSA-IJV max, the end-exipratory 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, inter quartile range

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)

AP-IJV max, antero-posterior, end-expiratory internal jugular vein diameter; CSA-IJV max, the end-exipratory 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, inter quartile range. Classification of inter-rater reliability level using 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)

AP-IJV max, antero-posterior, end-expiratory internal jugular vein diameter; CSA-IJV max, the end-exipratory 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, inter quartile range. Classification of inter-rater reliability level using 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 (0.16-68)
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)

AP-IJV max, antero-posterior, end-expiratory internal jugular vein diameter; CSA-IJV max, the end-exipratory 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, inter quartile range. Classification of inter-rater reliability level using ICC (reference 12): ICC < 0.5 = poor; ICC = 0.5-0.75= moderate; ICC= 0.75-0.9= good; ICC=0.9 = excellent.