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Evaluating the cross-sectional area of the internal jugular vein in Turkish adults using ultrasonography

Doğa Özdemir Kalkan[1], Nezih Kavak[2]

[1]Department of Radiology, Etlik City Hospital, Ankara, Turkey; [2]Department of Emergency Medicine, Etlik City Hospital, Ankara, Turkey

ABSTRACT

Objectives: To assess the cross-sectional area (CSA) of the right and left internal jugular veins (IJVs) in the adult Turkish population.

Methods: The CSA of the IJVs was quantified at three anatomical landmarks: below the angle of the mandible, at the level of the cricothyroid membrane, and in the supraclavicular region. Measurements were taken under three conditions: at rest, during a deep breath hold, and throughout the Valsalva maneuver.

Results: The study encompassed 321 volunteers with a mean age of 30.40±7.75 years. At the anatomical landmarks of the angle of the mandible, cricothyroid, and supraclavicular regions, the CSA of the IJV in men was consistently larger than in women during rest, deep breath hold, and the Valsalva maneuver. During both the deep breath hold and the Valsalva maneuver at these landmarks, the right CSA of the IJV in both genders was greater than the left CSA. In both males and females, the CSA of the IJV at the supraclavicular location was superior to that at both the angle of the mandible and the cricothyroid regions. The CSA at the cricothyroid regions surpassed that at the angle of the mandible.

Conclusions: The CSA of the IJV was found to be the largest in the right supraclavicular region during the Valsalva maneuver in both genders. By accurately measuring the CSA of the IJV at the angle of the mandible, cricothyroid, and supraclavicular anatomical landmarks during a deep breath hold and the Valsalva maneuver, potential interventional and surgical risks can be mitigated.

Keywords: Internal jugular vein, ultrasonography, cross-sectional area

The internal jugular vein (IJV) is a major vein responsible for draining blood from the head and neck. Due to its potential as a large and superficial vein, it is frequently used for central venous catheter insertion to deliver intravenous medications, facilitate hemodialysis, volume resuscitation, and administer drugs and blood products [1]. It serves as a significant anatomical landmark in the head and neck region, especially during the dissection of the cervical lymph nodes in oncological surgeries [2]. In recent years, the diameter of the IJV has been recognized as a potential predictor of central venous pressure [3-5].

Ultrasonography (USG) has become the primary imaging modality for vascular diseases due to its non-invasive nature, ease of application, cost-effectiveness, and patient tolerance. It also aids in the catheterization process [6]. Recently, the use of ultrasound guidance has made it possible to insert a catheter safely and easily into the IJV. However, in emergency situations or in settings without access to an ultrasound machine,

Corresponding author: Doğa Özdemir Kalkan, MD,
E-mail: dr_dogaozdemir@yahoo.com

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the procedure relies on traditional methods based on external anatomical landmarks [7]. Moreover, many surgeons prefer using anatomical landmarks over ultrasound guidance, as three-dimensional, anatomy-based procedures play a pivotal role in the training process for surgeons, especially for the insertion of percutaneous central venous catheters [8].

A larger vein diameter is associated with a higher success rate of catheter procedures on the first attempt. It is well-documented that the size of the internal jugular vein changes in response to respiratory variations [9]. An increased cross-sectional area (CSA) of the IJV has been linked to enhanced cannulation success and reduced mechanical complications [10].

Blood flow alterations, attributable to different respiratory phases, maneuvers, and breathing patterns, can be effectively studied using ultrasonography. When assessing jugular vein diameters, it is more accurate to measure using USG which accounts for respiratory changes [11].

This study aimed to assess the CSA of the right and left IJV at three anatomical landmarks below the angle of the mandible, at the level of the cricothyroid membrane, and in the supraclavicular region. under three conditions: at rest, during a deep breath hold, and throughout the Valsalva maneuver, within the adult Turkish population sample.

METHODS

Study Design and Setting

This single-center prospective observational study was conducted with volunteers between 1 September and 1 November 2023, following the approval of the local Ethics Committee (date: 13.09.2023, no:2023-537) and in line with the Declaration of Helsinki. Each participant provided written informed consent after receiving a comprehensive explanation of the study's objectives and protocol.

Study Population

Healthy volunteers aged 18 and older were included in the study. Exclusion criteria encompassed individuals with known chronic diseases, abnormal neck anatomy, a history of neck puncture or surgery, pregnancy, a history of alcohol abuse, or those who were unable to communicate effectively. The study co-

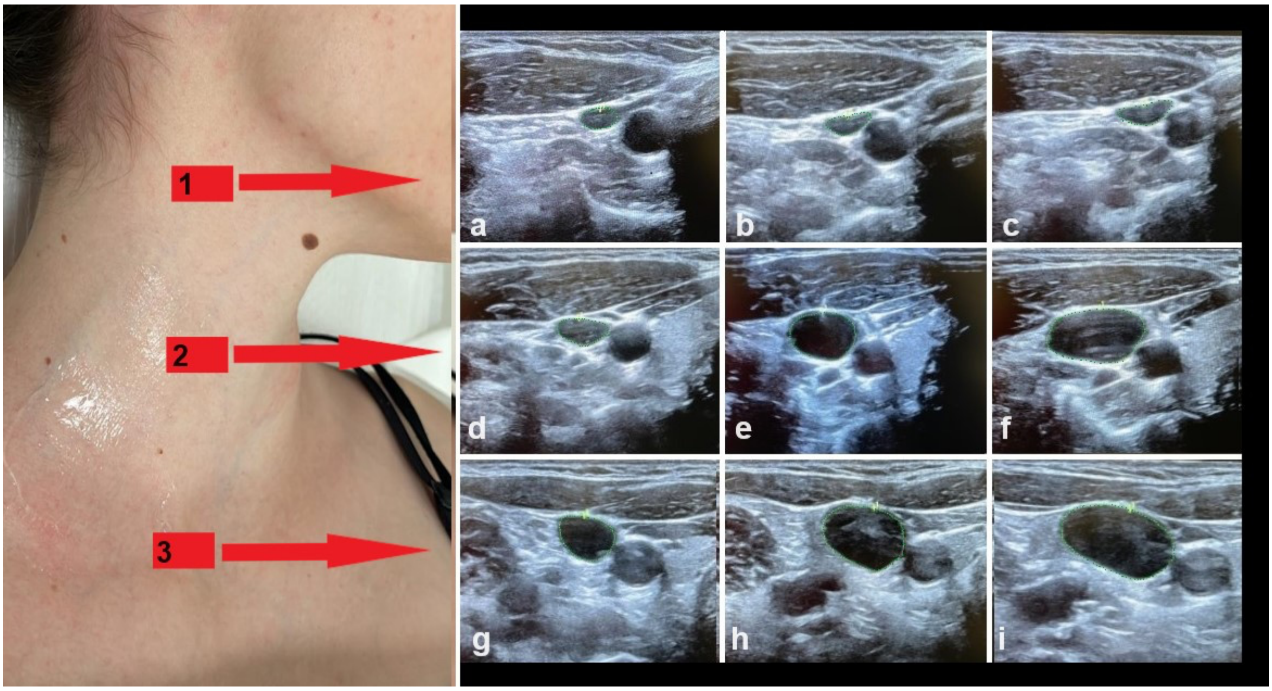

Fig. 1. The measurement of the cross-sectional area at three anatomical landmarks: below the angle of the mandible (1), at the level of the cricothyroid membrane (2), and in the supraclavicular region (3) are taken under three conditions: at rest (a, d, g), during a deep breath hold (b, e, h), and throughout the Valsalva maneuver (c, f, i).

hort comprised hospital staff, as well as spouses and relatives of patients undergoing treatment at our center.

Study Protocol and Measurements

The age (years), height (centimeters), and weight (kilograms) of the volunteers were documented. The body mass index (BMI) was computed using the formula: weight (in kilograms) divided by the square of height (in meters^2).

The CSA of the right and left IJV of the volunteers was assessed using a LOGIQ E10 ultrasound device

Table 1. The evaluation of the volunteer's cross-sectional area of the internal jugular vein is based on the anatomical locations in their necks and their responses to respiratory changes and the Valsalva maneuver

Anatomic landmark	Condition	Gender	Right (mean±SD)	Left (mean±SD)	P value
Angle of the mandible	Rest	Female	2.09±0.15	2.00±0.11	**<0.001**
		Male	2.17±0.14	2.08±0.20	**<0.001**
		P value	**<0.001**	**<0.001**	
	Deep breath - hold	Female	2.69±0.24	2.56±0.26	**<0.001**
		Male	2.75±0.21	2.62±0.24	**<0.001**
		P value	**<0.001**	**<0.001**	
	Valsalva maneuver	Female	2.86±0.42	2.64±0.48	**<0.001**
		Male	3.27±0.20	3.06±0.21	
		P value	**<0.001**	**<0.001**	**<0.001**
Cricothyroid	Rest	Female	2.44±0.23	2.30±2.24	**<0.001**
		Male	2.67±0.28	2.59±0.29	**<0.001**
		P value	**<0.001**	**<0.001**	
	Deep breath - hold	Female	2.77±0.23	2,68±0.25	**<0.001**
		Male	2.93±0.16	2.85±0.21	**<0.001**
		P value	**<0.001**	**<0.001**	
	Valsalva maneuver	Female	3.03±0.27	2.88±0.27	**<0.001**
		Male	3.11±0.19	2.94±0.24	**<0.001**
		P value	**<0.001**	**<0.001**	
Supraclavicular	Rest	Female	2.73±0.35	2.44±0.25	**<0.001**
		Male	3.20±0.22	2.83±0.33	**<0.001**
		P value	**<0.001**	**<0.001**	
	Deep breath - hold	Female	2.90±0.21	2.80±0.18	**<0.001**
		Male	3.24±0.16	3.05±0.21	**<0.001**
		P value	**<0.001**	**<0.001**	
	Valsalva maneuver	Female	3.18±0.26	3.03±0.27	**<0.001**
		Male	3.45±0.20	3.25±0.19	**<0.001**
		P value	**<0.001**	**<0.001**	

SD=standard deviation

(GE Healthcare) equipped with a 7 MHz linear probe operating at a frequency range of 4.0-20 MHz. During the examination, the volunteers' heads were rotated 15° contralateral to the cervical region being examined, ensuring clinical stability. Care was taken to apply the ultrasound probe gently to prevent distortion of the underlying low-pressure venous structures. A ten-year, experienced radiologist conducted the assessment of the IJV's CSA.

Consistent with existing literature, the CSA of the right and left IJV (m^2) was measured at three anatomical landmarks: below the angle of the mandible, at the level of the cricothyroid membrane, and in the supraclavicular region. Measurements were taken under three conditions: at rest, during a deep breath hold, and throughout the Valsalva maneuver, with the volunteers in a supine position [12] (Fig. 1).

Statistical Analysis

Analyses were conducted using IBM SPSS version 20 (Chicago, IL, USA). Descriptive statistics for continuous data were presented as mean±standard deviation, while categorical data were expressed as numbers and percentages. Comparisons of the CSA of the IJV across gender, side, region, and respiratory conditions were made using a two-way analysis of variance (ANOVA). The relationship between the CSA of the IJV with age and BMI was examined using Pearson's correlation coefficient. A P-value of less than 0.05 was considered statistically significant.

RESULTS

The study encompassed 321 volunteers with an average age of 30.40±7.75 years, ranging from 18 to 46 years. The mean BMI was 21.77±1.51 kg/m^2, with a range of 18.7 to 26 kg/m2. At the anatomical landmarks of the angle of the mandible, cricothyroid, and supraclavicular regions, during conditions of rest, deep breath hold, and the Valsalva maneuver, the CSA of the IJV in men was consistently larger than in women (P< 0.001 for all conditions). Specifically, at the angle of the mandible, the left CSA of the IJV in men was greater than in women during rest, deep breath hold, and the Valsalva maneuver (P<0.001, P<0.001 and P<0.001, respectively). In the cricothyroid region, the left CSA of the IJV in men was larger than in women during these conditions (P<0.001, P<0.001 and P<0.001, respectively). Similarly, in the supraclavicular region, the left CSA of the IJV in men exceeded that of women during all three conditions (P<0.001 for each) (Table 1).

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In both genders, during rest and deep breath hold, the CSA of the IJV in the right and left supraclavicular regions was found to be higher than both the right and left angle of the mandible and the right and left cricothyroid regions (P<0.001 for all). Additionally, the CSA in the right and left cricothyroid regions was greater than that of the right and left angles of the mandible (P<0.001 for all). (Table 2).

There was no significant difference in the CSA of the right and left IJV across all anatomical locations during rest, deep breath hold, and the Valsalva maneuver with respect to age and BMI (P>0.05 for all) (Table 3).

DISCUSSION

The knowledge of the CSA of IJV plays a pivotal role in patient management and treatment across various medical fields. This knowledge is particularly vital for radiologists, emergency physicians, surgeons, and anesthetists due to its clinical implications. General asymmetry between the right and left sides of the body is a well-recognized phenomenon, and this extends to the diameters of certain arteries and veins, which can also exhibit side-to-side variations [13]. Factors such as age, demographics, and respiratory changes might contribute to the diverse measurements reported in sci-

Table 2. **The volunteer's cross-sectional area of the internal jugular vein is evaluated based on their gender, anatomical locations in the neck, and their responses to respiratory changes and the Valsalva maneuver.**

Condition	Localization	Gender	Anatomic landmark			P value
			Angle of the mandible (mean±SD)	Cricothyroid (mean±SD)	Supraclavicular (mean±SD)	
Rest	Right	Female	2.09±0.15	2.44±0.23	2.73±0.35	**<0.001**
		Male	2.17±0.14	2.67±0.28	3.20±0.22	**<0.001**
		P value	**<0.001**	**<0.001**	**<0.001**	
	Left	Female	2.00±0.11	2.30±2.24	2.44±0.25	**<0.001**
		Male	2.08±0.20	2.59±0.29	2.83±0.33	**<0.001**
		P value	**<0.001**	**<0.001**	**< 0.001**	
Deep breath - hold	Right	Female	2.69±0.24	2.77±0.23	2.90±0.21	**<0.001**
		Male	2.75±0.21	2.93±0.16	3.24±0.16	**<0.001**
		P value	**<0.001-**	**<0.001**	**<0.001**	
	Left	Female	2.56±0.26	2.68±0.25	2.80±0.18	**<0.001**
		Male	2.62±0.24	2.85±0.21	3.05±0.21	**<0.001**
		P value	**<0.001**	**<0.001**	**<0.001**	
Valsalva maneuver	Right	Female	2.86±0.42	3.03±0.27	3.18±0.26	**<0.001**
		Male	3.27±0.20	3.11±0.19	3.45±0.20	**<0.001**
		P value	**<0.001**	**<0.001**	**<0.001**	
	Left	Female	2.64±0.48	2.88±0.27	3.03±0.27	**<0.001**
		Male	3.06±0.21	2.94±0.24	3.25±0.19	**<0.001**
		P value	**<0.001**	**<0.001**	**<0.001**	

SD=standard deviation

entific literature [9]. Recognizing these potential variations is crucial, especially when considering adult groups within the healthy Turkish population.

Yoon *et al*. [14] observed that the mean CSA of the right and left IJV were 165±81 mm2 and 119±57 mm2, respectively, highlighting a relatively larger CSA for the right IJV compared to the left. Similarly, Botero *et al*. [15] reported a greater CSA for the right IJV than the left. Such asymmetry between the right and left IJVs can be attributed to the differential blood drainage patterns through the dural venous sinuses, often resulting in the right IJV being larger than its left counterpart [16]. As the IJVs descend towards the thorax, the cumulative blood flow increases, leading to the largest CSA observed at the lower cervical levels. Furthermore, the CSA of the right IJV has been consistently reported to be significantly larger than the left across all cervical levels [17]. Consistent with these findings, our study also determined that the CSA of the right IJV was significantly larger than the left at all examined levels.

Although the IJV is often represented as having a cylindrical shape, some studies suggest that it assumes a conical form, decreasing in size from the subclavian vein towards the cranial vault [17, 18]. However, in a study by Jeon *et al*. [7], where the CSA of the right and left IJV was measured using computed tomography at the levels of the hyoid bone, cricoid cartilage, and the first thoracic vertebra, the IJV was observed to have a rhomboid shape. This shape was larger at the middle level and tapered both above and below [7]. It's noteworthy that in this study, the median age of the

Table 3. Pearson correlation coefficients for age and body mass index variables

Anatomic landmark	Condition	Localization	Age		Body mass index	
			r*	P value	r*	P value
Angle of the mandible	Rest	Right	0.054	0.106	0.109	0.133
	Rest	Left	0.057	0.109	0.058	0.301
	Deep breath - hold	Right	0.029	0.601	0.109	0.133
	Deep breath - hold	Left	0.025	0.661	0.104	0.063
	Valsalva maneuver	Right	0.090	0.106	0.108	0.053
	Valsalva maneuver	Left	0.047	0.108	0.113	0.137
Cricothyroid	Rest	Right	0.071	0.214	0.066	0.239
	Rest	Left	0.054	0.110	0.019	0.735
	Deep breath - hold	Right	0.036	0.658	0.065	0.249
	Deep breath - hold	Left	0.031	0.558	0.012	0.825
	Valsalva maneuver	Right	0.070	0.212	-0.074	0.189
	Valsalva maneuver	Left	0.015	0.786	-0.070	0.214
Supraclavicular	Rest	Right	0.064	0.145	-0.059	0.290
	Rest	Left	0.067	0.264	0.018	0.743
	Deep breath - hold	Right	0.063	0.261	-0.018	0.742
	Deep breath - hold	Left	0.082	0.144	0.064	0.255
	Valsalva maneuver	Right	0.020	0.723	-0.094	0.094
	Valsalva maneuver	Left	0.045	0.420	-0.053	0.344

patients was 65.0, many had chronic illnesses, a history of chemotherapy, and not all patients were in the same physiological conditions. Moreover, the measurements were taken during full inspiration. In our study, we found that the CSA of the IJV in the supraclavicular region was higher than at the angle of the mandible and cricothyroid, irrespective of gender. Another CT-based study reported a larger CSA in males compared to females, though the difference was not statistically significant. Contrarily, in our study, across all anatomical landmarks, the CSA of IJV values for males were statistically higher than those for females. Zamboni *et al*. [19] investigated the impact of respiration on intracranial venous flow and demonstrated that deep inspiration, in comparison to regular breathing, augments the blood return from the brain. Judickas *et al*. [19] observed a significant increase in the CSA of both the RIJV and LIJV during a deep breath hold. Both studies observed similar results, with an even more pronounced increase in CSA, during the Trendelenburg maneuver. Furthermore, hypothesized that the elevated intra-abdominal pressure, pushing the diaphragm upwards, leads to increased intrathoracic and right intracardiac pressures. This rise in intra-abdominal pressure was thought to be associated with a larger CSA [10]. In our study, the CSA of the IJV was elevated during the Valsalva maneuver across all anatomical landmarks.

Both age and BMI have been identified as significant factors influencing the size of blood vessels [7]. Research by Belov *et al*. [20] indicated that the CSA of the IJV in the lower neck tends to increase with age in both men and women. Furthermore, as BMI rises, there's a corresponding expansion of the IJVs, a trend that persists irrespective of the individual's age [20]. Another study by Magnano *et al*. [17] highlighted that after adjusting for factors related to cardiovascular health, the IJV's CSA showed a notable increase with age. This growth was more distinct in the right IJV than its left counterpart and was more pronounced in males. Studies postulated that as people age, the gradual increase in BMI might be a contributing factor to the enhanced CSA observed in the elderly [17]. In contrast, this study did not observe any notable variations in the IJV's CSA across different anatomical points during various respiratory conditions when considering age or BMI. This discrepancy might be due to our participants being generally younger and having a lower average BMI.

Limitations

A significant strength of this study is the inclusion of a large number of healthy volunteers. However, our study does have certain limitations. While the USG utilized offers the advantage of delivering real-time structural images and showcasing hemodynamics, its accuracy, and reproducibility largely hinge on the operator's expertise. Additionally, the absence of standardized pressure application on the USG probe presents another limitation to our research.

CONCLUSION

In conclusion, our study offers valuable insights into the variations in the CSA of the IJV among the adult population. Notably, both male and female participants exhibited the largest CSA in the right supraclavicular region during the Valsalva maneuver. This observation underscores the dynamic nature of the IJV's morphology in response to physiological changes. Furthermore, our findings emphasize the importance of understanding these variations, especially when considering anatomical landmarks such as the angle of the mandible, cricothyroid, and supraclavicular regions. By accurately identifying and distinguishing the CSA of the IJV during procedures like deep breath holds and the Valsalva maneuver, clinicians can make more informed decisions, potentially reducing interventional and surgical risks. As the medical community continues to prioritize patient safety and procedural efficacy, such knowledge becomes indispensable, paving the way for improved clinical outcomes.

Ethics Committee Approval

This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Etlik City Hospital Clinical Research Ethics Committee (Ankara, Türkiye) (date: 13.09.2023, no:2023-537)

Authors' Contribution

Study Conception: DÖK, NK; Study Design: DÖK, NK; Supervision: DÖK, NK; Funding: DÖK, NK; Materials: DÖK, NK; Data Collection and/or Processing: DÖK, NK; Statistical Analysis and/or Data Interpretation: DÖK, NK; Literature Review: DÖK; Manuscript Preparation: DÖK, NK and Critical Review: DÖK.

Conflict of interest

The authors disclosed no conflict of interest during the preparation or publication of this manuscript.

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