Ultrasonographic assessment of internal jugular vein diameter and its relationship with the carotid artery at the apex, middle, and base of the triangle formed by two heads of sternocleidomastoid muscle: A pilot study in healthy volunteers

ABSTRACT

Background: Anteroposterior (AP) diameter of internal jugular vein (IJV) and its relative position with carotid artery (CA) varies in the triangle formed by two heads of sternocleidomastoid muscle, which is the site of insertion of needle for IJV cannulation. This study assessed the maximum AP diameter of the IJV in supine and Trendelenburg positions and during Valsalva maneuver (supine position) at the apex, middle, and base of the triangle and to study the relationship of the IJV with the CA.

Materials and Methods: Twenty-five healthy volunteers were included and ultrasonography of IJV was performed in supine and Trendelenburg positions and during Valsalva maneuver (supine position) at the apex, middle, and base of the triangle bilaterally. The AP diameter of IJV was measured. The relative anatomical position of IJV was assessed as anterior (A), anterolateral (AL), or lateral (L) to CA in neutral head position and 30°, 45°, and 90° head rotation to the contralateral side in supine position.

Results: The difference in right IJV diameter was significant (P = 0.001) between supine vs. Trendelenburg position at the base of the triangle. Within one position there was significant difference between apex and base of the triangle. The left IJV diameter was significantly different between supine vs. Trendelenburg position at the apex (P = 0.004), middle (P = 0.003), and base of the triangle (P-value = 0.001). There was significant difference between supine vs. Valsalva maneuver at the middle (P = 0.011) and base (P = 0.014) of the triangle. The right IJV was more L or AL to the CA in apex with head in neutral or 30° rotation. The left IJV was more L or AL to the CA in middle with head in neutral position.

Conclusion: Trendelenburg and Valsalva increase diameter of IJV on both right and left side. Diameter of IJV is greater at the base of the triangle. IJV is lateral or anterolateral when the head is either neutral or turned 30° to the contralateral side.

Key words: Healthy volunteers; jugular veins; rotation, ultrasonography; Valsalva maneuver

Introduction

The internal jugular veins (IJVs) are commonly used to obtain central vascular access. The right IJV is generally preferred
over the left IJV because the right IJV leads straight into the superior vena cava and the pleural dome is lower on the right side. In addition, cannulation attempts of the left IJV may have the risk for injury to the thoracic duct.

In the absence of ultrasound imaging, this procedure is traditionally performed using external landmarks and the carotid artery (CA) pulsation as a guide. The technique has been associated with a 6–9% rate of CA puncture.[1,2] CA puncture may be due, in part, to anatomic variation of the IJV; specifically, its size, location, and relationship to the CA.[3,4] Ultrasound studies suggest that clinical maneuver, such as the Valsalva, an abdominal binder, or the Trendelenburg position alone or in combination, increases the cross-sectional area of the IJV, whereas extreme head rotation, carotid palpation, and needle advancement can distort or collapse the vein.[1,3] A higher rate of successful puncture may be more likely when the IJV is maximally distended and rendered less compressible.

Anteroposterior (AP) diameter of IJV and its relative position with CA varies even in the triangle formed by two heads (clavicular head and sternal head) of sternocleidomastoid muscle, which is the site of insertion of needle for IJV cannulation. IJV cannulation is done in this triangle but the exact site of insertion of the needle in this triangle is still not clear because the diameter of the IJV may differ in the apex, middle, and base of the triangle and the correlation between IJV and CA may also differ.

The primary objective of this study was to know the maximum diameter of the IJV on ultrasound in supine and Trendelenburg positions and during Valsalva maneuver (supine position) at the apex, middle, and base of the triangle formed by two heads of the sternocleidomastoid muscle. We also assessed the relative position (lateral, anterolateral, or anterior) of IJV with respect to the CA.

**Materials and Methods**

This study was conducted after approval from the Institutional Ethics Committee and prospectively registered with Clinical Trial Registry-India (CTRI/2014/09/005043). A convenient sample size of 25 normal healthy volunteers, between age of 18 and 60 years and American Society of Anesthesiologist Grade 1 were included in this nonrandomized single-arm, observational pilot study. Volunteers with a previous history of IJV cannulation or known allergy to ultrasound jelly were excluded from the study.

A written and informed consent was taken from all the healthy volunteers regarding participation in this study. Ultrasoundographic study of the IJV and CA was performed by a consultant expert in ultrasound of IJV and CA with a SonoSite ultrasound machine, using the linear (7.5 MHz) probe. Volunteers were placed in supine position, and the triangle formed by two heads of sternocleidomastoid muscle was marked in all volunteers on both sides [Figure 1]. The AP diameter of IJV was measured at the apex, middle, and base of the triangle bilaterally. Similar measurements were done in 15° Trendelenburg position and after application of Valsalva maneuver in the supine position. The relative anatomical position of IJV was assessed as anterior, anterolateral, or lateral to CA in neutral head position and 30°, 45°, and 90° head rotation to the contralateral side in supine position [Figure 2].

All variables were expressed in terms of the mean ± standard deviation or the percentage. Data were expressed as mean change in diameter of IJV from supine to Trendelenburg position and during Valsalva maneuver (supine position). Paired comparisons were assessed using paired t-test and one-way analysis of variance with Bonferroni post hoc test. \( P < 0.05 \) is considered statistically significant. IBM SPSS 24.0 (IBM Co., Armonk, NY, USA) was used for analysis.

**Results**

All 25 volunteers completed the study. All volunteers were males. The mean age of volunteers was 29.6 ± 5.94 years, mean height was 162.68 ± 7.63 cm, and mean weight was 66.28 ± 11.59 kg.

The mean AP diameters of IJV on both sides in supine and Trendelenburg position and during Valsalva maneuver (supine position) at the apex, middle, and base of the triangle formed by two heads of sternocleidomastoid muscle are mentioned in Table 1. Within one position (supine, Trendelenburg or Valsalva in supine position), IJV diameter significantly increases as we go down from apex to base of the triangle [Tables 1 and 2]. The right IJV diameter in Trendelenburg position was significantly higher than in supine position at the base of the triangle \( (P = 0.001) \) [Table 3].

![Figure 1: Surface marking of the triangle formed by 2 heads of sternocleidomastoid muscle and markings of apex, base and middle of the triangle](image-url)
The left IJV diameter in Trendelenburg position was significantly higher than in supine position at apex ($P$-value: 0.004), middle ($P = 0.003$), and base of the triangle ($P = 0.001$) formed by two heads of sternocleidomastoid muscle [Table 3]. The left IJV diameter was also significantly higher during Valsalva maneuver in supine position compared to supine position at the middle ($P = 0.011$) and base ($P = 0.014$) of the triangle [Table 3].

The right IJV is lateral or anterolateral to CA in 96% cases, both at neutral position and 30° head rotation at the apex of the triangle as compared to in 92 and 46% cases in 45° and 90° head rotations, respectively. The left IJV is lateral or anterolateral to CA in 72, 80, 64, and 44% cases at the apex of the triangle’s neutral position, 30°, 45°, and 90° head rotations, respectively. The left IJV is lateral or anterolateral to CA in 84% of cases in the middle of the triangle with the head in the neutral position. The relative positions of the IJV in relation to CA (lateral, anterolateral, or anterior) are mentioned in Table 4.

### Discussion

In this study, we found that right IJV diameter does not significantly change from supine to Trendelenburg position except at the base of the triangle formed by two heads of sternocleidomastoid muscle. Within one position as we go down from apex to base of the triangle, diameter of IJV increases significantly. On left side, IJV diameter increases significantly from supine to Trendelenburg position at apex, middle, and base of the triangle. On left side, IJV diameter increases significantly during Valsalva maneuver in supine position as compared to supine position at middle and base of the triangle. Results of our study are somewhat contrary to previous studies, which showed a significant difference between supine to Trendelenburg and Valsalva maneuver in supine positions. One recent study in children showed that Trendelenburg position and Valsalva maneuver increases IJV diameter significantly. In another study, Trendelenburg alone increased IJV cross-sectional area by 96% with simulated venipuncture and 40% without simulated venipuncture. Schreiber et al. demonstrated that cross-sectional area of IJV after the immediate increase does not further change even after 20 min in Trendelenburg position. Studies showed that Valsalva maneuver increases the intrathoracic pressure, which then increases the diameter of the IJV. With change of head position, change of IJV relation from lateral to anterolateral and anterolateral to anterior, increases overlap over CA and increases chance of carotid puncture.

On the right side, the more favorable position (IJV is lateral or anterolateral to the CA), is the apex of the triangle with head in neutral (0°) or 30° rotation to the opposite side. At this position and head rotation, the IJV is lateral or anterolateral to CA in 96% of cases. In neutral position of head (0° rotation), IJV is significantly more lateral or anterolateral to CA ($P = 0.021$) at the apex of the triangle as compared to middle and base of triangle, which makes apex of the triangle most favorable position for IJV cannulation on right side. At apex...
Solanki, et al.: USG assessment of IJV and carotid artery

Table 2: Post hoc test and mean difference of anteroposterior diameter of IJV, 95% confidence interval (CI), and P for comparison between apex, middle, and base of triangle on right and left side

| Side of neck | Position       | Apex vs. Middle | Apex vs. Base | Middle vs. Base |
|--------------|----------------|-----------------|---------------|-----------------|
| Right        | Supine         | −2.284          | −2.920        | −0.636          |
|              | 95% CI         | −4.817 to 0.249 | −5.453 to −0.382 | −3.169 to 1.897 |
|              | P              | 0.091           | 0.018*        | 1.000           |
|              | Trendelenburg  | −2.372          | −4.116        | −1.744          |
|              | 95% CI         | −4.935 to 0.191 | −6.679 to −1.553 | −4.307 to 0.819 |
|              | P              | 0.079           | 0.001*        | 0.299           |
|              | Valsalva in supine | −2.136          | −3.516        | 1.380           |
|              | 95% CI         | −4.718 to 0.446 | −6.098 to −0.934 | −1.202 to 3.963 |
|              | P              | 0.139           | 0.004*        | 0.583           |
| Left         | Supine         | −1.472          | −1.672        | −0.200          |
|              | 95% CI         | −3.704 to 0.760 | −3.904 to 0.560 | −2.432 to 2.032 |
|              | P              | 0.331           | 0.211         | 1.000           |
|              | Trendelenburg  | −1.560          | −1.912        | −0.352          |
|              | 95% CI         | −3.950 to 0.830 | −4.302 to 0.478 | −2.742 to 2.038 |
|              | P              | 0.342           | 0.161         | 1.000           |
|              | Valsalva in supine | −2.252          | −2.360        | −1.080          |
|              | 95% CI         | −5.261 to 0.757 | −5.369 to 0.649 | −3.117 to 2.901 |
|              | P              | 0.212           | 0.175         | 1.000           |

Mean diff: Mean difference; CI: 95% confidence interval; P: P value. *Statistical significance

Table 3: IJV diameter mean difference between various positions, standard deviation, and 95% CI at apex, middle, and base of triangle

| Position          | Apex of triangle | Middle of triangle | Base of triangle |
|-------------------|------------------|--------------------|-----------------|
|                   | Right            | Left               | Right           | Left               | Right          | Left               |
| Supine vs. Trendelenburg |                 |                    |                 |                   |                |
| Mean diff         | −0.312           | −1.576             | −0.400          | −1.664             | −1.508         | −1.816             |
| SD                | 2.617            | 2.509              | 3.045           | 2.53               | 1.883          | 2.30               |
| 95% CI            | −1.392 to 0.768  | −2.612 to −0.54    | −1.657 to 0.857 | −2.708 to −0.62    | −2.285 to −0.730 | −2.764 to −0.867 |
| P                 | 0.557            | 0.004*             | 0.518           | 0.003*             | 0.001*         | 0.001*             |
| Supine vs. Valsalva |                 |                    |                 |                   |                |
| Mean diff         | −0.408           | −1.068             | −0.260          | −1.848             | −1.004         | −1.756             |
| SD                | 3.432            | 2.37               | 3.75            | 3.35               | 3.632          | 3.31               |
| 95% CI            | −1.824 to 1.00   | −2.195 to 0.059    | −1.809 to 1.289 | −3.23 to −0.462    | −2.303 to 0.495 | −3.125 to −0.387 |
| P                 | 0.558            | 0.062              | 0.732           | 0.011*             | 0.180          | 0.014*             |
| Trendelenburg vs. Valsalva |                 |                    |                 |                   |                |
| Mean diff         | −0.096           | 0.508              | 0.140           | −0.184             | 0.504          | 0.060              |
| SD                | 3.499            | 2.44               | 4.040           | 3.59               | 3.299          | 3.27               |
| 95% CI            | −1.540 to 1.348  | −0.50 to 1.516     | 1.527 to 1.807  | −1.665 to 1.297    | −0.857 to 0.764 | −1.292 to 1.412 |
| P                 | 0.892            | 0.309              | 0.864           | 0.800              | 0.452          | 0.928              |

Mean diff: Mean difference; SD: Standard deviation; CI: 95% Confidence interval; P: P value. *Statistical significance

and middle of the triangle, IJV is significantly more lateral or anterolateral to CA at neutral or 30° head rotations as compared to 45° or 90°. The next favorable position is the middle of the triangle with head in neutral (0°) or 30° rotation to the opposite side, where IJV is lateral or anterolateral to CA in 88% of cases.
On the left side, IJV is lateral or anterolateral to CA in 84% of cases in middle of the triangle with head in neutral (0°) position and in 80% cases at the apex of the triangle with head in 30° rotations.

On the left side, IJV is significantly more lateral or anterolateral to CA at the apex of the triangle as compared to middle and base of triangle at 0°, 30°, and 45° of head rotations, which makes apex of the triangle most favorable position for IJV cannulation. At apex and middle of the triangle, IJV is significantly more lateral or anterolateral to CA at neutral or 30° head rotations as compared to 45° or 90°.

In any position of the neck and at all positions of triangle, IJV is placed more anteriorly on left side as compared to right side, hence making right IJV more preferable vein for cannulation than left IJV. Results of our study with regards to position of IJV with CA are in agreement with study by Hong et al., who showed that in 40% patients IJV was lateral to CA on right side and 27% on left side of neck and when the patient’s head was turned to the contralateral side, the incidence of the IJV being lateral to the CA decreased to 21 and 11%, respectively. Troianos et al. studied 1100 patients in far lateral head turn position and showed that 54% of patients had >75% overlap of CA and IJV. Sulek et al. had shown that head rotation increases the overlap between IJV and CA at 40° and 80° both on left and right side (P < 0.01). The percent overlap was larger on left side than right side. The increased overlap of CA and IJV with head rotation >40° increases the risk of inadvertent puncture of the CA.

There is no study that showed diameter and relationship of IJV and CA at three different areas (apex, middle, and base) of triangle formed by two heads of sternocleidomastoid muscle through which IJV and CA traverse.

Limitation of our study is that we conducted this study on healthy volunteers, so fluid and volume status of the volunteers were not known and that could have affected the IJV diameter. Secondly, our sample size was a convenient sample size and needs more robust data to confirm our findings. Thirdly, this study was done in awake and spontaneously breathing healthy volunteers, and we had not instituted any measure to ensure adequacy of Valsalva maneuver and that may have affected the results. Lastly, all our volunteers were males, so these data cannot be generalized for female volunteers also.

**Conclusion**

Our study showed that diameter of IJV is greater at the base of the triangle formed by two heads of sternocleidomastoid muscle. At 0° and 30° of head rotations, IJV is significantly more lateral or anterolateral to CA at neutral or 30° head rotations as compared to 45° or 90°.

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**Conflicts of interest**

There are no conflicts of interest.

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