Anatomical relationship between the common carotid artery and the internal jugular vein during head rotation

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Abstract

This study investigated the anatomical relationship between the common carotid artery and internal jugular vein during head rotation for the effective performance of percutaneous transjugular procedures. The subjects included 30 volunteers who had never undergone internal jugular vein cannulation. In the supine position, two-dimensional ultrasonographic images of the right internal jugular vein and common carotid artery were obtained, 2 and 4 cm above the clavicle, along the lateral border of the sternal head of the sternocleidomastoid muscle. Ultrasonographic images were examined for head rotation at 0°, 15°, 30°, 45°, 60°, and 75° from the midline to the left. The percentage of overlap of the common carotid artery by the internal jugular vein and the flattening of the internal jugular vein at each head rotation position were measured and evaluated. The overlap of the common carotid artery by the internal jugular vein significantly increased at $\geq 45^\circ$ of head rotation 2 cm above the clavicle ($P < 0.01$) and at $\geq 30^\circ$ of head rotation 4 cm above the clavicle ($P < 0.01$), compared with that observed in the neutral position. The flattening of the internal jugular vein significantly decreased at $\geq 45^\circ$ of head rotation 2 cm above the clavicle ($P < 0.01$) and at $\geq 30^\circ$ of head rotation 4 cm above the clavicle ($P < 0.01$). Head rotation should be kept to $< 45^\circ$ at 2 cm above the clavicle and $< 30^\circ$ at 4 cm above the clavicle to decrease the risk of accidental puncture of the common carotid artery during internal jugular vein puncture. Moreover, flattening of the internal jugular vein gradually decreases during head rotation to the side.

Keywords: Cannulation of the central veins, vascular anatomy, internal jugular vein, carotid artery, head rotation

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Introduction

Anesthesiologists, surgeons, and interventional radiologists routinely use percutaneous transjugular procedures involving cannulation of the central veins (CVs). Compared with the subclavian approach, percutaneous cannulation of the internal jugular vein (IJV) exhibits a lower incidence of serious complications, including pneumothorax and hemothorax.¹ Accidental puncture of the common carotid artery (CCA) is the most common complication during IJV punctures, with an incidence of 6.3–9.3%.^{1–4} The general anatomy, landmarks, and relationship of the IJV to the CCA are well known and the anatomic position of the IJV is generally lateral and anterior to the CCA.⁵ However, there are many variations in the position and relationship of the IJV with the artery. In an ultrasonographic study of 1100 patients, more than half demonstrated $>75\%$ overlap of the CCA by the IJV.⁶ Therefore, the risk of accidental CCA puncture cannot be eliminated.

The incidence of accidental CCA puncture may be due to anatomic variations in the IJV, specifically, its shape,

location, and relationship to the CCA.^{6,7} Using surface ultrasonography, some researchers have reported that the IJV distends during the Valsalva maneuver and in the Trendelenburg position, which may improve the chances of achieving successful cannulation.^{8,9} Moreover, the probability of this puncture complication decreases through diminution of the overlap between the IJV and CCA. In addition, the flattening of the IJV should also be considered in order to safely perform cannulations for CV access using the IJV approach. The aim of this study was to evaluate the effects of head rotation on the anatomic relationship between the CCA and IJV and on changes in IJV shape using portable ultrasonography.

Materials and methods

The subjects in this study included 30 volunteers (14 women and 16 men) who had never undergone cannulation of the IJV. Participant age ranged from 24 to 58 years (mean 35.3 years). Each subject was placed in the supine position during the examination. An ultrasonographic study was

performed using a Prosound $\alpha 7$ (ALOKA, Hitachi Aloka Medical, Tokyo, Japan) using a linear (7.5MHz) probe. Images of the right side of the neck were obtained 2 and 4 cm from the clavicle, along the lateral border of the sternal head of the sternocleidomastoid muscle. The distances from the clavicle were selected based on the common sites for CV port placement and CV catheter cannulation, respectively. Each subject's head was rotated leftward to 0°, 15°, 30°, 45°, 60°, and 75°, as verified using an adjustable protractor (Figure 1). Ultrasonography images were obtained in a transverse orientation to provide a cross-sectional view of the vessels, as previously described.^{2,7} In all studies, the transducer was held perpendicular to the bed using an adjustable protractor. Ultrasound was applied gently to avoid distorting the underlying low-pressure venous structures. Measurements were obtained using hard copies of the ultrasonography images. The study was approved by the Ethics Committee of our university.

Measurement of overlap and flattening

The outcome measurements included (1) the percentage of overlap between the CCA and IJV, and (2) flattening of the IJV. The percentage of overlap was defined as the overlap of the cross-sectional diameter of the CCA by the IJV (Figure 2(a)), calculated as follows

$$\text{overlap} = \text{overlap distance (mm)} / \text{CCA diameter (mm)}$$

Flattening of the IJV was defined as the difference between the vessel's transverse and longitudinal diameters, divided by the transverse diameter (Figure 2(b)), calculated as follows

$$\text{Flattening} = (\text{transverse diameter} - \text{longitudinal diameter}) / \text{transverse diameter}$$

All data are expressed as means $\pm$ standard deviation (SD). Microsoft Excel, version 14.0 (Microsoft, Redmond, WA, USA), was used for data collection and manipulation. All statistical analyses were performed using a statistical software package (SPSS/PC+; SPSS, Chicago, IL, USA). A repeated measures analysis of variance and Bonferroni correction were used to evaluate the effects of head rotation on the position and shape of the right IJV, the degree of overlap with the CCA and the extent of its flattening. In all comparisons, results of statistical analyses were considered significant at a P-value < 0.05 .

Results

Percentage overlap

The percentage overlap of the CCA by the IJV gradually increased as the head was rotated to the left, at both 2 and 4 cm above the clavicle (Figure 3). In the neutral position, the mean percentage overlap of the CCA by the IJV was 23.6% at 2 cm above the clavicle and 30.2% at 4 cm above the clavicle. The percentage overlap at 2 and 4 cm above the clavicle was significantly higher when the head was rotated $\geq 45^\circ$ ($P < 0.01$) and $\geq 30^\circ$ ($P < 0.01$), respectively (Table 1), compared with that observed in the neutral position.

Flattening

IVJ flattening gradually decreased (approximately to a perfect circle) as the head was rotated to the left at both 2 and 4 cm above the clavicle (Figure 3). In the neutral position, the mean flattening of the IJV was 0.34 at 2 cm above the clavicle and 0.49 at 4 cm above the clavicle. The flattening of the vessel was significantly less at $\geq 45^\circ$, 2 cm above the clavicle ($P < 0.01$), and at $\geq 30^\circ$, 4 cm above the clavicle ($P < 0.01$) (Table 2), compared with that observed in the neutral position. These results are presented in graphical format in Figures 4 and 5.

Figure 1 Ultrasonographic study of vessel overlap using an adjustable protractor to verify the angle of head rotation. A high-frequency linear probe was placed 2 and 4 cm above the clavicle while the head was turned 0°, 15°, 30°, 45°, 60°, and 75°. An adjustable protractor was used to verify the angle of head turn

Discussion

Our study was an anatomic survey of the position and shape of the IJV in the neutral position, as well as with increasing degrees of leftward head rotation. The major findings involved the determination of the extent of overlap of the CCA by the IJV and the flattening of the IJV at each

position. As the subjects' heads were rotated, the overlap significantly increased and the flattening significantly decreased.

The findings regarding the degree of overlap observed in this survey corroborate the results of two prior studies. Troianos et al. recorded images of 1100 patients in a far

Figure 2 Ultrasonographic imaging of the right internal jugular vein (IJV) and common carotid artery (CCA). a: %overlap = overlap distance (B)/CCA diameter (A) b: Flattening = {horizontal diameter (C) – vertical diameter (D)}/horizontal diameter (C)

Table 1 The effect of head rotation on percentage overlap. The percentage overlap at 2 and 4 cm above the clavicle was significantly higher when the head was rotated $\geq 45^\circ$ ($P < 0.01$) and $\geq 30^\circ$ ($P < 0.01$), respectively, compared with that observed in the neutral position

Distance above the clavicle (cm)	0°	15°	30°	45°	60°	75°
2	18.7 ± 19.9	19.4 ± 18.6	23.6 ± 22.4	30.9 ± 23.3*	37.9 ± 26.2*	48.9 ± 26.4*
4	21.1 ± 22.8	25.6 ± 26.1	32.6 ± 24.0*	41.2 ± 25.3*	53.1 ± 26.3*	62.0 ± 22.9*

Values are presented as mean (%) ± SD
* $P < 0.01$ compared with the neutral position

Figure 3 Correlation of the right internal jugular vein (IJV) and common carotid artery (CCA) using ultrasonography, 4 cm above the clavicle. As the subject's head was rotated to the left, the percentage overlap of the CCA by the IJV increased and the flattening of the IJV gradually decreased, to approximate a perfect circle. (a) 0°, (b) 15°, (c) 30°, (d) 45°, (e) 60°, (f) 75°

Table 2 The effect of head rotation on flattening of the IJV. The flattening of the vessel was significantly less at $\geq 45^\circ$, 2 cm above the clavicle ($P < 0.01$) and at $\geq 30^\circ$, 4 cm above the clavicle ($P < 0.01$), compared with that observed in the neutral position

Distance above the clavicle (cm)	0°	15°	30°	45°	60°	75°
2	0.36 $\pm$ 0.13	0.34 $\pm$ 0.13	0.34 $\pm$ 0.13	0.28 $\pm$ 0.12*	0.26 $\pm$ 0.12*	0.23 $\pm$ 0.11*
4	0.51 $\pm$ 0.16	0.48 $\pm$ 0.17	0.42 $\pm$ 0.18*	0.39 $\pm$ 0.14*	0.37 $\pm$ 0.13*	0.36 $\pm$ 0.12*

Values are presented as mean $\pm$ SD

* $P < 0.01$ compared with the neutral position

Figure 4 Line graph of the effect of head rotation on percentage overlap. The percentage overlap was significantly higher with a head rotation of 45° , 2 cm above the clavicle and with a head rotation of 30° , 4 cm above the clavicle, compared with that observed in the neutral position. As the head was rotated further to the left, the percentage overlap increased further

Figure 5 Line graph of the effect of head rotation on the shape of the internal jugular vein. The flattening was significantly lower with a head rotation of 45° , 2 cm above the clavicle and with a head rotation of 30° , 4 cm above the clavicle, compared with that observed in the neutral position. As the head was rotated further to the left, the flattening decreased further

lateral head rotation position and found that 54% of these patients exhibited $>75\%$ overlap of the CCA⁶; $<10\%$ of their study population had the classic “IJV lateral to CCA” anatomy. Their study found that 53% of the patients exhibited $>75\%$ overlap of the CCA at 90° of head rotation. A pilot study involving 12 volunteers, where the CCA overlap was

measured at 0° , 40° , and 80° of head rotation, found a trend of increasing overlap with increased head rotation.² These findings may also explain the mechanisms underlying CCA puncture. One proposed mechanism of arterial puncture relates to the overlap of the CCA by the IJV. During IJV puncture, venous blood return may not be achieved until

the needle is withdrawn because the pressure of the advancing needle can cause the IJV to collapse, the incidence of which is reported to be 50%.^{2,10} This, in turn, causes the needle to puncture the posterior wall of the IJV and the CCA, if it is lying behind the IJV. Although the neutral position is associated with the smallest amount of overlap, clearing the chin may prove difficult without the use of some head rotation. Our study provided greater details regarding the relationship between head rotation and the extent of overlap of the CCA by the IJV. To decrease the risk of accidental puncture of the CCA during an IJV puncture, head rotation should be limited to $<45^\circ$ for procedures occurring 2 cm above the clavicle and $<30^\circ$ for procedures occurring 4 cm above the clavicle.

The relationship between head rotation and flattening of the IJV has not been previously documented. A reduction in the flattening of the IJV, to where it approximates a perfect circle, may be desirable during attempts to safely cannulate the IJV. Our data demonstrated that flattening of the right IJV was significantly reduced as the head was turned to the left. Previously, the patient's head was rotated to the right for right subclavian vein catheterization. This prevented cannulation of the IJV because of a reduction in the right IJV volume induced by rotation of the head to the right.¹¹ Reducing the right IJV volume resulted in increased blood flow in the left IJV and decreased the flattening of the left IJV, thereby approximating a perfect circle. This phenomenon can also be observed during head rotation to the left.

The present study had some limitations. We only evaluated the anatomic data of healthy volunteers who had never undergone IJV cannulation. Moreover, the number of subjects in our study was small; therefore, further studies are necessary to confirm our findings. To overcome these limitations, more studies including data on both healthy volunteers and patients with different illnesses should be conducted.

Currently, ultrasonographic guidance is usually used in hospitals when performing IJV puncture. Ultrasonography is important for locating the IJV and guiding single-wall puncture of the IJV. However, ultrasonography is occasionally unavailable, such as in emergency settings and for bedside venous access needs. In these situations, the traditional blind technique is used. In such situations, we believe that having knowledge of the anatomic location and shape of the IJV is important in order to perform cannulations for CV access using the IJV approach. We have reported these anatomic data in order to alert practitioners to the potential problems associated with fairly common procedures and to inform them of the expected location and shape of the IJV associated with various degrees of head rotation.

Conclusion

In conclusion, leftward head rotation should be kept to $<45^\circ$ for procedures occurring 2 cm above the clavicle and

to $<30^\circ$ for procedures occurring 4 cm above the clavicle, when puncturing the right IJV. Moreover, the flattening of the IJV gradually decreases (until it approximates a perfect circle) as the head is rotated to the side, improving the chances of achieving successful cannulation.

DECLARATIONS

Competing interests: None

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Guarantor: S Murata

Contributorship: SM and IM researched literature and conceived the study. IM, MT, and DY analyzed and interpreted the data. IM with TM and TU collected and assembled the data. IM and SO made the draft of the article. SM revised the article for important intellectual content. SK made the final approval of the article. All authors reviewed and approved the final version of the manuscript.

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