Anatomical relationship of the internal jugular vein and the common carotid artery in Korean: A computed tomographic evaluation

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Background: It is important to understand the anatomical relationship of the internal jugular vein (IJV) to the common carotid arteries (CCAs) to avoid inadvertent arterial injury. This study used computed tomography (CT) to evaluate this relationship and the changes associated with simulated 30° body rotation (SR30) in Korean subjects.

Methods: A retrospective analysis of 81 healthy adult subjects was performed using CT during physical checkups between November 2012 and September 2013. Data on both the left and right side IJV and CCA were recorded at the level of the cricoid cartilage and analyzed. The CCA was used as a reference for estimating the IJV location; this was recorded as lateral, anterior, medial, or posterior, using a segmented grid. The degree of overlap was calculated as a percentage, and changes to the anatomical relationship and overlap percentage caused by SR30 were derived.

Results: Prior to simulating rotation, the IJV was lateral (54.3%), posterolateral (27.2%), anterolateral (17.9%), or anterior (0.6%) to the CCA. After SR30, their position moved significantly in the anterolateral direction (P = 0.000). The degree of overlap significantly increased from 42.0 to 91.4% after SR30 (P = 0.000). No significant difference was observed between results obtained on the right and left sides before or after SR30.

Conclusions: Special attention should be paid to possible CCA puncture during IJV catheterization because head or body rotation may induce anterior shifting of the IJV location relative to the CCA as well as an increased degree of overlap. (Anesth Pain Med 2015; 10: 118-123)

Key Words: Anatomical relationship, Common carotid artery, Computed tomography, Internal jugular vein, Korean.

INTRODUCTION

Catheterization of the internal jugular vein (IJV) is a technique widely used by physicians, surgeons, and anesthesiologists in many different fields within clinical medicine. The classic Sedillot triangle, which is formed by external landmarks (the clavicle and both heads of the sternocleidomastoid), has been commonly used for IJV punctures for decades. Both this triangle and the relationship of the IJV to the common carotid artery (CCA) are well known, and this landmark-guided technique is performed on the assumption that the IJV is usually situated laterally to the CCA [1,2]. Although there is a high success rate (95%) when these landmarks are used [3], unexpected positional or anatomic variations of the CCA could result in inadvertent puncture of the CCA; this occurs in 3 to 10.6% of cases [4,5]. CCA punctures may result from an increased degree of overlap between the IJV and the CCA, and previous studies have shown variation in this overlap [3,6-8].

It has recently been recommended that real-time ultrasonography should be used when possible to improve success rates and reduce the rate of complications [9]. However, portable ultrasound machines are not still widely used, especially in emergencies and in cases where bedside central venous access is required. Thus, it is important that the physician has a clear understanding of the anatomical relationship of the IJV to the CCA to avoid inadvertent arterial puncture.

The aim of this study was to evaluate the anatomical
relationships and the degree of overlap by using computed tomography (CT) in Korean subjects as well as the changes that occur in these elements after simulating 30° body rotation (SR30) to the contralateral side.

**MATERIALS AND METHODS**

This study was approved by the Institutional Review Board. Healthy adult subjects were retrospectively analyzed as part of a physical checkup between November 2012 and September 2013. Subjects were examined by CT imaging while in the supine position with a neutral head position and without a supportive pillow. Patients presenting with neck masses, goiters, lymphadenopathy, previous neck dissections or those undergoing radiotherapy were excluded.

The INFINITT PACS Version 3.0.113 BN 103 (INFINITT Healthcare Co., Seoul, Korea) was used to view and evaluate CT images at the level of the cricoid cartilage, which corresponds to the central approach (the apex of the triangle formed by the medial and lateral portions of the sternocleidomastoid muscle and clavicle), or the anterior approach (at the level of the cricoid cartilage along the medial edge of the sternocleidomastoid muscle) for venous puncture. Measurements were taken by using computer-generated scales, and the values were recorded. The centers of the IJV and CCA were defined as the intersection of the transverse and vertical diameters of each vessel. The center of the CCA was taken as a reference point for defining the location of the IJV, and an imaginary line was drawn from this point towards the center of the IJV. The location of each IJV was estimated using a clockwise or counter-clockwise rotation relative to the CCA at the center. Angles were measured and recorded as medial, anteromedial, anterior, anterolateral, lateral, posterolateral, posterior, or posteromedial by using a segmented grid as presented in Fig. 1 [10]. Thereafter, the degree of overlap (%)

![Diagram of anatomical positions of the right internal jugular vein](https://via.placeholder.com/150)

Fig. 1. Definition of anatomical positions of the right internal jugular vein (IJV) relative to the right common carotid artery (CCA), given in a counter-clock disposition using the CCA as the center of the dial. A mirror image applies for the left IJV. Anterior: 0° < Anterolateral < 15° and 345° ≤ Anteromedial < 165°, 165° ≤ Anterior < 195°, 195° ≤ Posteromedial < 225°, 225° ≤ Medial < 285°, 285° ≤ Anteromedial < 345°.

![Diagram of simplified cross-sectional diagram of the right neck](https://via.placeholder.com/150)

Fig. 2. Simplified cross-sectional diagram of the right neck shown by CT image at the level of the cricoid cartilage. The percent overlap is an overlap diameter (B) of the internal jugular vein (IJV) divided by the transvers diameter (C) of the common carotid artery (CCA). A: transverse diameter of IJV, B: The overlap distance from the lateral wall of CCA to the medial wall of IJV, C: transverse diameter of the common carotid artery. Degree of overlap expressed as B/C × 100.
between the IJV and the CCA was calculated as shown in Fig. 2. In addition, the locational changes of the IJV and degree of overlap were calculated according to the SR30 (Fig. 3) in order to assess the influence of simulating body rotation on the position of the IJV.

The software package SPSS for Windows 21.0 was used for statistical analysis (SPSS Inc., Chicago, USA). Results are expressed as mean ± standard deviation, number of cases and/or percentage. Collected data were tested for normal distribution and homogeneity of variances. Statistical analyses between the right and left sides of the neck were carried out with a chi-square test for analysis of variable frequency by including recorded locations and incidences according to the degree of overlap observed. A paired t-test was performed for statistical analysis of the mean values of degree of overlap on each side both before and after the SR30. A P value < 0.05 was considered statistically significant.

**RESULTS**

The demographic data and CT images 81 healthy subjects were reviewed in this study, and 162 IJVs were evaluated in terms of their anatomic relationship to the CCA. Demographic data is presented in Table 1.

Before SR30, the IJV was most commonly located in a position lateral to the CCA (88/162 or 54.3%). In 44 of 162 cases (27.2%), the IJV was located in a posterolateral position; in 29 cases (17.9%), it was anterolaterally positioned; and in 1 case (0.6%), it was in the anterior position, as shown in Table 2. There was no significant difference between locations on the right and left sides, and lateral positioning was most common in both. However, after SR30 to the contralateral side, the position of the IJV in relation to the CCA changed significantly compared to the supine position on both sides (P = 0.000, presented in Table 2). The greatest change in position of the IJV occurred in the lateral location; it shifted anterolaterally. The SR30 caused the left IJV to shift from the anterolateral position to the anterior position and from the anterior to the anteromedial position in 2 cases. The right IJV shifted from the anterolateral to the anterior position in 1 case (Table 3).

The overall incidence of overlap before the SR30 was 42%, and was not significantly different between the right and the left side (Table 3). However, overlap was significantly increased to 91.4% after the SR30 (P = 0.000 within the right or the left side, Table 3). Most of this increase involved overlaps of less than 50% (84% and 85.2% incidence on the right and left side, respectively). After SR30, the mean percentage overlap increased from −1.33% ± 22.39% and −1.33% ± 22.39% to 20.93% ± 19.40% and 19.88% ± 23.84% on the right and left side, respectively (P = 0.000).

**DISCUSSION**

This study found that the IJVs are located lateral to the center of the CCA in greater than half (54.3%) of Korean subjects in the supine position with a neutral head position. SR30 to the contralateral side resulted in anterior venal shift
Table 2. Anatomic Relation of Each Internal Jugular Vein Relative to Their Common Carotid Artery before and after Simulating 30° Body Rotation (SR30) to the Contralateral Side on Each Side

| Position | Before SR30 (P = 0.400) | After SR30 (P = 0.410) |
|----------|--------------------------|------------------------|
|          | Right | Left | Total | Right | Left | Total |
| AM       | 0 (0) | 1 (1.2) | 1 (0.6) | 0 (0) | 1 (1.2) | 1 (0.6) |
| A        | 13 (16) | 16 (19.8) | 29 (17.9) | 54 (66.7) | 61 (75.3) | 115 (71) |
| AL       | 42 (51.9) | 46 (56.8) | 88 (54.3) | 26 (32.1) | 18 (22.2) | 44 (27.2) |
| L        | 26 (32.1) | 18 (22.2) | 44 (27.2) | 0 (0) | 0 (0) | 0 (0) |
| Total    | 81 (100) | 81 (100) | 162 (100) | 81 (100) | 81 (100) | 162 (100) |

Data are expressed as number of cases and percentage. AM: anteromedial to the carotid artery, A: Anterior to the carotid artery, AL: anterolateral to the carotid artery, L: Lateral to the carotid artery. * P < 0.05 compared with the results before the SR30 on the right, left, and total, respectively.

Table 3. The Incidence of Overlap and the Mean Overlap Percentage before and after Simulating 30° Body Rotation (SR30) on Each Side

| Overlap (%) | Before SR30 (P = 0.071) | After SR30 (P = 0.209) |
|-------------|--------------------------|------------------------|
|             | Right | Left | Total | Right | Left | Total |
| 0           | 45 (55.6) | 49 (60.5) | 94 (58.0) | 7 (8.6) | 7 (8.6) | 14 (8.6) |
| < 25        | 27 (33.3) | 26 (32.1) | 53 (32.7) | 45 (55.6) | 52 (64.2) | 97 (59.9) |
| ≥ 25 and < 50 | 8 (9.9) | 1 (1.2) | 9 (5.6) | 23 (28.4) | 17 (21.0) | 40 (24.7) |
| ≥ 50 and < 75 | 1 (1.2) | 3 (3.7) | 4 (2.5) | 5 (6.2) | 1 (1.2) | 6 (3.7) |
| ≥ 75        | 0 (0) | 2 (2.5) | 2 (1.2) | 1 (1.2) | 4 (4.9) | 5 (3.1) |
| Total       | 81 (100) | 81 (100) | 162 (100) | 81 (100) | 81 (100) | 162 (100) |

Data are expressed as number of cases and percentage. * P < 0.05 compared with the results before the SR30 on the right, left, and total, respectively.

predominantly to the anterolateral position (71%) and the incidence of patients with the CCA overlapped by the IJV was significantly increased from 42.0 to 91.4%.

Extensive knowledge of the anatomic relationships and degrees of overlap between the IJV and the CCA is imperative to avoid unintentional arterial injury. The majority of clinical studies have evaluated the anatomic locations of the IJV and the degree of overlap between the IJV and the CCA with either ultrasonography or CT imaging [2,3,6,8,11-16]. These studies have shown that the IJV is commonly positioned lateral or anterolateral to the CCA, and the incidence of overlap was reported to be between 6 and 95%, depending on the method of calculation.

In a retrospective CT imaging study similar to that presented here, the IJV was reported to be generally located in the lateral position [11,12]. Lim et al. [11] reported that the position of the IJV in relation to the CCA was lateral in 85.2% of the cases (right; 88.6%, left; 81.8%), anterior in 12.5%, medial in 1.1%, and posterior in 1.1%. Another study examining 80 Korean patients in the supine position with neutral positioning of the head and neck conducted CT imaging at the level of the cricoid cartilage. This study showed that the IJV was located laterally to the CCA in the majority of cases (right; 81.3%, left; 72.5%; both sides 76.9%), while anterolateral and posterolateral positioning was observed in only 20.6 and 2.5% of patients respectively [12]. Our results were similar to the previous results involving the use of CT images: Positioning of the IJV in relation to the CCA was reported as lateral (54.3%), anterolateral (17.9%), and posterolateral (27.2%), when assessed in patients in the supine position with neutral head positioning; anterior positioning of the left IJV was found in a small percentage of cases (0.6%). In addition, when our results were re-calculated according to the definitions provided by Lim et al. [11], the location of the IJV was defined as lateral in 98.1% of cases and anterior in 1.9% of cases.
In contrast to the above findings, studies with ultrasonography-guided imaging have reported positioning of the IJV to be anterolateral, with contralateral head rotation, in the majority of cases [2,3,13-16]. Turba et al. [2] reported that the most common location of the IJV was anterolateral (87.8% on the right, 84.5% on the left) by using portable ultrasonography in 180 patients with approximately 30° contralateral head rotation. Maecken et al. [10] demonstrated anterolateral (45%), anterior (28%), and anteromedial (23.8%) IJV positioning when scanning at 45° at the level of the cricoid with 30° rotation to the contralateral side. Anterolateral positioning occurred more frequently on the right side than on the left (54.3 vs. 35.7%), while anteromedial positioning was more commonly observed on the left side (18.3 vs. 29.3%). In a study of 35 Korean patients, Lee and Lee [16] described anterolateral positioning in 42.9% of cases and lateral positioning in 51.4% of cases scanning perpendicularly to the spinal axis at the cricoid cartilage level in the neutral head position. They also reported that the incidence of patients with the CCA overlapped by the IJV (mean overlap percentage) was 48.5% (18.8 ± 25.7%) and 38.5% (10.8 ± 17.0%) in the right and left sides respectively. In the present study, contralateral SR30 was used to reproduce conditions in ultrasonography studies where contralateral head rotation was investigated. The location of the IJV in relation to the CCA was altered significantly in anterolateral (71%) cases. Following the re-calculation of results according to formulas described by Lim et al. [11], changes in lateral (81.5%) and anterior (18.5%) positioning were the most significant. In addition, the incidence of patients with the CCA overlapped by the IJV after simulated rotation significantly increased from 42.0 to 91.4%. This increase was concentrated in the area of < 50% overlap, wherein it resulted in the incidence of 84.0 and 85.2% in the right and left side, respectively.

There are discrepancies regarding the reported incidence of anatomic locations and the degree of overlap between previous studies and the present study. This may be attributed to a lack of uniformity in terms of objective measurements of the anatomic relationship of the IJV to the CCA, including variations in the degree of head rotation, probe direction, and the classification of the location of the IJV [6-8,10,17,18]. First, variations in the degree of head rotation may influence the reported findings regarding positioning of the IJV relative to the CCA, and degrees of overlap reported by [8,10,17,19], who showed that increasing head rotation significantly increased the incidence of overlap up to 85% as degrees of rotation increased at > 30° contralateral head rotation. Second, unlike CT, ultrasonography is not an easy technique to perform strictly from the anterior to posterior position, as the probe must be placed perpendicular to the skin to obtain high-quality images. Thus, scans may be performed from different angles (0° to 45°) lateral to the neck. Sibai et al. [6] demonstrated that the majority of patients showed lateral (51%) and anterolateral (33%) positioning of the IJV relative to the CCA with the ultrasound probe directed perpendicular to the floor following contralateral head rotation, while directing the probe perpendicular to the skin resulted in a higher number of anterolateral positions (77%). For this reason, they recommended that the ultrasound probe be directed perpendicular to the floor for a patient in the supine position with the head tilted to the contralateral side of the cannulation. Finally, many reports used different classification schemes for the location of the IJV such as a segmented grid, clock-dial terminology, or 4 segments of 90° each [2,10,11].

Our study was limited by the fact that we cannot provide evidence for a direct correlation between the simulations method using the CT image and actual head rotation in clinical situations because we could not find the supporting references. As mentioned in previous reports, many clinicians perform IJV cannulation in the supine or Trendelenburg position with the head in a neutral or rotated position. However, researchers usually perform it in the semilateral position with the aid of an ipsilateral pad, or in the Trendelenburg position with minimized head rotation in the same sagittal plane of the body. Therefore, we conducted this study using simulated rotation of the CT image, assuming that the effect on the relationship of the IJV and CCA using our body rotation method would be similar to that using a 30° head rotation.

In conclusion, the present study found that in Korean subjects, the location of the IJV was usually anterolateral with contralateral body rotation and lateral with a neutral head position. Furthermore, even though it is well known that the application of ultrasonography is a useful tool to improve success rates and reduce the incidence of complications, there are situations in which the use of ultrasonography may not be possible, particularly in emergency cases and when bedside central venous access is required. In these situations, central venous catheterization is generally performed by using conventional methods with external landmarks and palpation of the CCA. Based on this study as well as previous studies, it must be noted that head or body rotation may induce anterior
shifting of the IJV location relative to the CCA as well as an increased degree of overlap, which increases the risk of complications during IJV catheterization in the absence of ultrasonography.

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