Internal Jugular Vein and Carotid Artery Anatomic Relation as Determined by Ultrasonography

Christopher A. Troianos, M.D.,* Richard J. Kuwik, M.D.,† John R. Pasqual, B.S.,‡ Alexander J. Lim, M.D.,§
David P. Odasso, M.D.$

Background: Cannulation of the internal jugular vein (IJV) is associated with a 95% success rate when external landmarks are used. Anatomic variability has been implicated as the cause for difficulty in cannulation without ultrasound. In contrast to an IJV located lateral to the carotid artery (CA), an IJV overlying the CA may result in CA puncture. The authors' purpose in this study was to examine, using ultrasound, the anatomic relation of the IJV and CA as viewed from the perspective of a cannulating needle.

Methods: Ultrasound imaging was used in 1,136 patients to examine the relation between the IJV and CA. A 7.5-MHz transducer was placed in the direction of a cannulating needle on the right neck at the apex of the angle formed by the division of the sternocleidomastoid muscle. A Polaroid® photograph of the image was later scored by three blinded investigators according to the percentage of the CA overlaid by the IJV (0 to 4).

Results: Of the 1,136 Polaroid® photographs of the ultrasound images, 1,009 were suitable for scoring. Fifty-four percent of all patients received a score of 4, which indicated that the IJV overlies more than 75% of the CA in an imaging plane positioned in the direction of a cannulating needle. Patients older than 60 yr were more likely to have this anatomy than patients younger than 60 yr (P < 0.05). None of the other patient characteristics recorded were predictive of this anatomic relation.

Conclusions: In a majority of patients, the IJV is not lateral to the CA in an ultrasound imaging plane positioned in the direction of a cannulating needle. Instead, the IJV overlies the CA in 54% of patients overall, predisposing these patients to CA puncture if the cannulating needle traverses the IJV. (Key words: Anatomy, internal jugular vein. Anesthesia, techniques: internal jugular vein cannulation. Monitoring, ultrasound. Vein, internal jugular.)

THE internal jugular vein (IJV) is a route commonly used to access the central circulation because of its accessibility during surgery and predictable anatomic location. Although cannulation of the IJV, using anatomic landmarks, is associated with a 95% success rate,1 researchers in recent studies demonstrated improved success and fewer complications when ultrasound guidance is used to facilitate cannulation.2–4 Anatomic variation or unreliability of the external landmarks was implicated as the cause for difficulty in cannulation without ultrasound.5 An anatomic relation in which the IJV overlies the carotid artery (CA) has accounted for unintentional CA puncture.2–4 The purpose in this study was to identify the anatomic relation of the right IJV and CA in the direction of a cannulating needle using ultrasound imaging in 1,136 patients and to determine which patient characteristics are associated with an overlying (instead of laterally positioned) IJV.

Materials and Methods

With approval of the Research and Human Rights Committee of The Mercy Hospital of Pittsburgh, and written informed consent, 1,136 patients admitted for surgery were studied prospectively. Patients with prior neck surgery were excluded from the study.

The ultrasound device (Site Rite, Dymax, Pittsburgh, PA) consisted of a 7.5-MHz transducer, a two-dimensional image display, and a Polaroid® camera (Polaroid Corp., Cambridge, MA), modified for close-up photography. Awake patients were placed supine on a stretcher parallel to the floor without a pillow, and their heads were rotated as far to the left as was comfortable. Im-

* Vice Chairman for Research: Director, Intraoperative Transesophageal echocardiography.
† Staff Anesthesiologist.
‡ Research Assistant.
§ Anesthesiology Resident.

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Address reprint requests to Dr. Troianos. Department of Anesthesiology, The Mercy Hospital of Pittsburgh, 1400 Locust Street, Pittsburgh, Pennsylvania 15219.
aging of the right IJV was performed at the apex of the angle formed by the division of the sternocleidomastoid muscle. The needle guide attached to the transducer was positioned in the direction of a cannulating needle entering the skin at the apex of the angle and directed toward the ipsilateral nipple (fig. 1). The imaging plane of the probe was directed in the same plane as a cannulating needle, not in a coronal plane. A 7.6 × 7.6 cm photograph was taken of the ultrasound image of the CA and IJV.

Patient characteristics, including age, height, weight, body surface area, and history of chronic obstructive pulmonary disease, myocardial infarction, or congestive heart failure, were recorded.

All photographs were scored later independently by three investigators who were blinded to patient characteristics and the scoring by the other investigators. Scoring was defined as follows:

0 = the IJV was positioned completely lateral to the CA on the image display;
1 = the IJV overlapped up to and including 25% of the diameter of the CA;
2 = the IJV overlapped more than 25% and up to and including 50% of the diameter of the CA;
3 = the IJV overlapped more than 50% and up to and including 75% of the diameter of the CA;
4 = the IJV overlapped more than 75% of the diameter of the CA.

This scoring system was used to identify patient anatomy that allows for carotid puncture by a needle that traverses the IJV before entering the CA. An increased likelihood of carotid puncture in this manner would be expected with a greater score.

Patients were eliminated from statistical analysis if the image quality was poor or if scoring was disparate among the three scorers (2 or greater difference in score). If the three independent scores differed by one, the score of the two concurring investigators was used for statistical analysis.

Data were analyzed by chi-square analysis to compare incidence of score between different age groups. Both one-way analysis of variance and Kruskal-Wallis one-way analysis of variance by ranks were used to examine whether age, weight, height, vein size, artery size, and history of chronic obstructive pulmonary disease, myocardial infarction, or congestive heart failure were different by score category. Linear regression was used to test the relation between vein size and other continuous variables. A P value less than 0.05 was considered to be significant.

Results
The Polaroid® photographs of 1,136 patients were reviewed by three investigators (CAT, RJK, JRP). Poor image quality and disagreement in score by 2 or greater eliminated 127 patients from statistical analysis. Among the remaining 1,009 patients, 54% of these patients received a score of 4 (more than 75% of the CA is overlaid by the IJV; table 1). The only demographic data category predictive of a score of 4 was age (P < 0.05). Patients with more advanced age were more likely to have a score of 4. Sixty-four percent (64%) of patients aged 60 yr or older had a score of 4, whereas only 4% of patients younger than 60 yr had a score of 4 (P < 0.05). A greater percentage of the patients younger than 40 yr had scores less than 3 (46% of these younger patients compared with only 2% of patients aged 60 yr or older; P < 0.05).

Vein size (both width and anteroposterior diameter) was both positively related to score (P < 0.01). Patients with larger veins had a higher score. There was no correlation between weight, height, or age with vein size. There was no difference in vein size with respect to the patient’s gender or a history of myocardial infarction, congestive heart failure, or chronic obstructive pulmonary disease (table 2).

Discussion
Cannulation of the IJV is considered to be the standard of care for intubation of the airway and intravenous access. Anatomically, the CA lies cephalad to the IJV and is overlain by the sternocleidomastoid muscle. The CA pulse is best visualized at this point. The CA pulse is used as a landmark for guiding needle placement into the IJV. The ease of access to the IJV through the CA is dependent on several factors, including the angle of the needle, the thickness of the skin, and the patient’s body habitus. In this study, we assessed the anatomical relationship between the IJV and CA and determined the feasibility of using this approach to cannulate the IJV in a cohort of adult patients.
INTERNAL JUGULAR VEIN AND CAROTID ARTERY ANATOMY

Table 1. Anatomic Scoring Based on Age

<table>
<thead>
<tr>
<th>Score</th>
<th>&lt;40 yr</th>
<th>40–49 yr</th>
<th>50–59 yr</th>
<th>60–69 yr</th>
<th>≥70 yr</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>22 (8.7)*</td>
<td>13 (8.6)</td>
<td>10 (5.9)</td>
<td>2 (1.0)</td>
<td>18 (7.3)</td>
<td>65 (6.4)</td>
</tr>
<tr>
<td>1</td>
<td>36 (14.2)*</td>
<td>13 (8.6)</td>
<td>18 (10.7)</td>
<td>22 (11.5)</td>
<td>19 (7.8)</td>
<td>108 (10.7)</td>
</tr>
<tr>
<td>2</td>
<td>58 (23.0)*</td>
<td>28 (18.4)</td>
<td>18 (10.7)</td>
<td>17 (8.9)</td>
<td>27 (11.0)</td>
<td>148 (14.7)</td>
</tr>
<tr>
<td>3</td>
<td>42 (16.7)</td>
<td>23 (15.1)</td>
<td>23 (13.6)</td>
<td>29 (15.2)</td>
<td>23 (9.4)</td>
<td>140 (13.9)</td>
</tr>
<tr>
<td>4</td>
<td>94 (37.3)</td>
<td>75 (47.3)</td>
<td>100 (59.2)</td>
<td>121 (63.3)†</td>
<td>158 (64.5)†</td>
<td>548 (54.3)</td>
</tr>
</tbody>
</table>

Total: 252 | 152 | 169 | 191 | 245 | 1,009

Numerical values in table indicate the number of patients in that particular age group with that particular score. Values in parentheses are the percentage of patients in that age group with that particular score.

* P < 0.05, score < 3 versus patients ≥ 60 yr.
† P < 0.05 versus < 60 yr of age.

Discussion

Cannulation of the IJV is commonly performed using visual and palpable anatomic landmarks. A variety of techniques have been used to access the IJV, without demonstration of superiority of one technique over another. Anatomically, the CA is posterior and medial to the IJV, and techniques that incorporate palpation of the CA pulse result in a lower incidence of CA puncture.

Carotid artery puncture can occur either primarily (needle placement directly into CA lumen), or secondarily (after the cannulating needle transverses the IJV). The ease with which the IJV is compressed accounts for the initial undetected entry into the IJV. The anatomic position of the IJV is described classically as lateral to the CA. This anatomic relation describes the relation of these structures in the coronal plane, not in the directional plane of the cannulating needle with the head turned to the contralateral side (fig. 2). This may explain why our study revealed a greater proportion of patients than expected whose IJV was positioned anterior rather than lateral to the CA. If the IJV is anterior to the CA, undetected entry (and exit) through a compressed IJV may result in puncture of the CA, as reported previously.

In ultrasound-simulated cannulation techniques, Metz et al. noted the consistency of the anatomic relation between the IJV and CA (the IJV being anterior and lateral to the CA). They suggested that because the IJV was found consistently to be lateral to the CA, the CA pulse can be used as a primary or alternative landmark. Their study population, however, consisted of hospital employees, aged 24–38 yr. This is consistent with the current study, which demonstrated a more laterally positioned IJV in younger patients. The current study examined the anatomic relation in a variety of age groups and demonstrated that although the IJV position is more often overlying rather than lateral to the CA (54% of all patients), a greater proportion of patients older than 60 yr have this anatomic relation (table 1). If this anatomic relation is present, initial attempts of IJV cannulation would be unsuccessful if the CA was the sole landmark. Subsequent repositioning of the cannulating needle medially could result in CA puncture after undetected entry into a compressed IJV. The ease of vein compression with minimal external pressure or needle advancement is apparent when ultrasound is used to facilitate cannulation of the IJV.

In a recent study of 15 hospital workers, aged 18–60 yr, the effect of head position on the relative positions of the CA and IJV was examined. Sulek and colleagues showed greater overlap between the vessels when the head was rotated 80° compared with rotation of 0° and 40°. This is consistent with our study, in which we demonstrated overlap when patients were placed in a cannulating position with their head rotated to the opposite side. However, why did our study reveal more overlap between the two vessels in the older patients? One would expect that older patients would not be able to rotate their head to the same degree as younger patients. If head rotation alone determines the degree of overlap, less overlap would be expected in older patients. The Sulek et al. study, with its sample size of only 15, did not examine the effect of age on the degree of overlap. Unfortunately, we did not measure the degree of head rotation during our study to comment on whether head rotation affects the amount of overlap between the IJV and CA. In another study,
Table 2. Measured Variables

<table>
<thead>
<tr>
<th></th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td>No. of patients</td>
<td>65</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>71.9 ± 15.4</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>169.7 ± 9.9</td>
</tr>
<tr>
<td>Vein width (cm)*</td>
<td>1.1 ± 0.4</td>
</tr>
<tr>
<td>Vein A-P diameter (cm)*</td>
<td>0.8 ± 0.3</td>
</tr>
<tr>
<td>Artery width (cm)</td>
<td>0.7 ± 0.2</td>
</tr>
<tr>
<td>Artery A-P diameter (cm)</td>
<td>0.6 ± 0.2</td>
</tr>
<tr>
<td>COPD</td>
<td>10 (15%)</td>
</tr>
<tr>
<td>Hx MI</td>
<td>5 (8%)</td>
</tr>
<tr>
<td>CHF</td>
<td>4 (6%)</td>
</tr>
</tbody>
</table>

Values are mean ± SD. Values in parentheses are the percentage of patients with that particular score who had a history of COPD, MI, or CHF.

A-P diameter = diameter of the vessel in the anterior-posterior dimension of the cannulating view; COPD = number of patients with a history of chronic obstructive pulmonary disease; Hx MI = number of patients with a history of myocardial infarction; CHF = number of patients with a history of congestive heart failure.

*P < 0.01, vein size was positively related to score; all other variables were not related to score.

where ultrasound-simulated cannulation was used, Metz et al. found that head rotation did not affect the likelihood of cannulating the IJV. Their subjects, however, were all younger than 40 yr. Our observation of greater vessel overlap in older patients is likely due to the fact that the common CA becomes elongated and tortuous in older patients, presumably from arteriosclerosis.

The effect of the “cannulating” position on the anatomic relation of the vessels is demonstrated by the magnetic resonance image in Figure 3. The magnetic resonance image confirms what we observed with ultrasound. Namely, when patients are placed in a cannulating position with head turned to the contralateral side, there is often overlap between the IJV and CA.

If a score of 3 or 4 (>50% of the CA is overlaid by the IJV) is considered a more “dangerous” anatomic relation for CA puncture, the results are impressive for all age groups (68% of all patients had scores of 3 or 4). Although patients younger than aged 60 yr had a statistically lower incidence of CA overlap with older patients, the most likely patient also was 4. Why is the overlap predicted to be only 4% rather than 10%, there are possible explanations. First, patients had the IJV overlapped by the cross-sectional diameter of the CA. If large IJV may overlie the CA in addition, extend beyond the axillary vein, and result in overlap in the sampling. Second, the needle puncture at the center of the lumen of the vein produces fewer complications. A needle directed at the center of the vein that does not overlie the CA is less likely to puncture the CA than a needle directed at the center of the vein that overlies the CA. Entry into the CA may be made just cephalad of the puncture site. The head turned to the left, representing actual operating conditions, or “what the cannulating needle sees.”

Fig. 2. Cross-sectional illustration of the neck that depicts the anatomic relation of the carotid artery (A) and internal jugular vein (V). Quadrangles above the cross-sections illustrate the ultrasound images of the artery (A) and the vein (V). (A) Coronal approach, head facing anteriorly, representing conventional anatomic approach. (B) Cannulating needle approach, head turned to left, representing actual operating conditions, or what the cannulating needle sees.
Fig. 3. Nuclear magnetic resonance image of the neck at the apex of the division of the sternocleidomastoid muscle, demonstrating the anatomic relation of the right carotid artery (A) and right internal jugular vein (V). (A): Head facing anteriorly. (B): Head turned toward left.

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