The Optimal Angle of Head Rotation for Internal Jugular Cannulation as Determined by Ultrasound Evaluation

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Objectives: **The aim of this study was to determine the degree of head rotation that creates the maximal anatomic separation between the right internal jugular vein and the carotid artery.**

Design: **Single-center prospective, observational cohort study.**

Setting: **University medical center.**

Participants: **Fifty patients aged >21 years and undergoing cardiac surgery.**

Interventions: **An ultrasound machine equipped with a digital caliper was used to determine the relational anatomy of the internal jugular vein and the carotid artery, with patients in the Trendelenburg position at head angles of −15°, 0°, +15°, +30°, +45°, +60°, +75°, and +90°.**

Measurements and Main Results: **When examining the percentage of the internal jugular vein vertical diameter that is not overlapped by the carotid artery (vertically unencumbered), there was a difference between the head angle groups ($p < 0.01$). Unencumbered vertical distance was different between +75° versus 0°, and +75° versus +15°. At +75°, 60.3% ± 5.3% of the internal jugular vein was unencumbered vertically, whereas at 0°, it was 37.2% ± 3.9%, and at +15° it was 40.3% ± 3.8%. Only 72% of the patients were able to position their head at +75°, and 54% of the subjects were able to position their head at +90°.**

Conclusion: **The authors found the internal jugular vein becomes more vertically separated from the carotid artery at more extreme angles of contralateral head rotation.**

KEY WORDS: central line, central line complications, ultrasound, internal jugular vein, carotid artery injury, internal jugular cannulation

ULTRASOUND-GUIDED TECHNIQUES have improved the efficiency and safety of internal jugular vein (IJV) cannulation.[1] The relationship between head rotation and the relative anatomy of the right IJV and the carotid artery (CA), as it pertains to the safety of IJV cannulation, has not been elucidated unequivocally;[2–4] thus, optimal positioning of the head remains controversial.[5] The aim of this study was to determine the degree of head rotation that creates the maximal anatomic separation between the right IJV and the CA. Although not empirically validated, it is intuitive that maximizing this separation would reduce the incidence of inadvertent CA puncture or cannulation.

Complications of IJ lines reported in the literature include injury to the thoracic duct,[6] hematoma,[7] carotid dissection,[8] cerebrovascular accident,[9] delayed tension pneumothorax,[10] and death.[11] The landmark-guided technique has been associated with a 3% to 9% incidence of carotid puncture.[12] Domino et al studied IJ complications by analyzing closed malpractice claims for central line catheter injuries in the American Society of Anesthesiologists database. The database had 110 claims for injuries related to central catheters (1.7% of 6,449 claims). Database claims for central catheter injuries had a higher severity of injury, with an increased proportion of death (47%) compared with other claims in the database.[13]

Previous studies have attempted to define the anatomic relationship between the right IJV and the CA. Troianos et al found that the IJ overlaid the CA in 54% of their patients with their head turned "as far left as was comfortable."[2] Wang et al also studied anatomic effects of head rotation in emergency room patients.[3] Specifically, this study defined how much the right IJV (RIJV) horizontally overlapped the CA (percentage overlap = CA overlap by RIJ/CA diameter) at 0°, 45°, and 90° of head rotation. They found that the average overlap of the CA by the IJ was 29% at the apex of the triangle created by the sternal and clavicular heads of the sternocleidomastoid muscle and the clavicle with the neck in the neutral position. As the head rotation increased to 45%, the overlap of the carotid by the IJ increased to 42%; rotating to 90° gave 72% overlap.[3] They found similar results at the base of the neck: with the neck neutral, overlap of the CA was 44%; at 45°, overlap increased to 52%; at 90°, the overlap was 69%.

Riopelle et al studied circumferential adjustment of the ultrasound probe to minimize venoarterial overlap and maximizing the width of the IJ target.[5] They reported an advantage in using circumferential cervical adjustment of the position of the two-dimensional ultrasound probe. They further recommended using individualized adjustment of the degree of head rotation. Sulek et al studied overlap of the IJ and carotid in 12 healthy volunteers with head rotation of 0°, 40°, and 80° from the midline at 2 and 4 cm above the clavicle. They reported significant increase in percentage overlap of the carotid and IJ at both 40° and 80° of rotation on both the right and left. They concluded that the head should be kept as neutral as possible, less than 40°, during IJ cannulation.[4]

The present study differed from previous work in that the focus was on elucidating the anatomic relationship between the CA and the RIJV in the horizontal and vertical planes. The amount of lateral and vertical distance of IJV that was free from overlap by the CA at various degrees of head rotation was determined. The unencumbered vertical distance is of great importance, because the CA may be violated after the introducer needle has passed through the IJV.

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METHODS

After internal review board approval, informed consent was obtained from patients. Patients were evaluated for participation in the study if they were scheduled for cardiac surgery the following day. Because the authors' institution only performed adult cardiothoracic surgery, all patients were aged >21 years. The exclusion criteria were patient refusal for participation, current pre-existing right internal jugular central line, inability to maintain a Trendelenburg position of 15°, and previous neck surgery or carotid endarterectomy. Fifty patients from the authors' institution qualified during the study period.

All subjects were placed supine in the Trendelenburg position at 15°. All subjects were nonsedated and spontaneously breathing in the preoperative holding area during ultrasound evaluation. A Sonosite S-Cath Ultrasound System with L25×/13-6 MHz Transducer with a 0.8×3.0 cm footprint was used (Sonosite, Bothell, WA). With the patient's neck in neutral position, the ultrasound probe was placed lightly on the right side of the patient's neck (to avoid compression of the underlying vasculature). The transducer was located 6 cm above the clavicle, on the line bisecting Sedillot's triangle (Fig 1), so as to place the interrogated vessels in short axis. The ultrasound sector was adjusted to fully visualize both the RIJV and the CA, and the two-dimensional image was captured. Using the measuring tool included in the ultrasound software, the required measurements were performed.

The measurement of each vessel was determined with the vessel in short axis (Fig 2). The centers of both the CA and the RIJV were determined by using the midpoints of the major (along the widest dimension, usually lengthwise, or from left to right) and minor axes (along the narrowest dimension, usually from top to bottom) of the vessels. The distance between the vessel centers was measured and recorded. The closest distance between the CA and the RIJV also was determined. If the vessels contacted each other, this value was 0.

Two other measurements that reflect the proximity of the CA to the path of the RIJV needle puncture were performed, and they were designated as the unencumbered lateral distance and the unencumbered vertical distance. The unencumbered lateral distance is the lateral width of the RIJV that does not overlap the CA. This value then was divided by the diameter of the IJV to calculate the percentage of the vein that was unencumbered laterally. The unencumbered vertical distance is defined as the length of the line drawn from the most superficial point on the IJV to the plane created by the most superficial point of the CA. This value was then divided by the diameter of the IJV to calculate percentage of vein that was unencumbered vertically.

Fig 1. Orientation of the ultrasound probe. A photograph depicting the placement and orientation of the ultrasound transducer as it was used to determine anatomic distances.

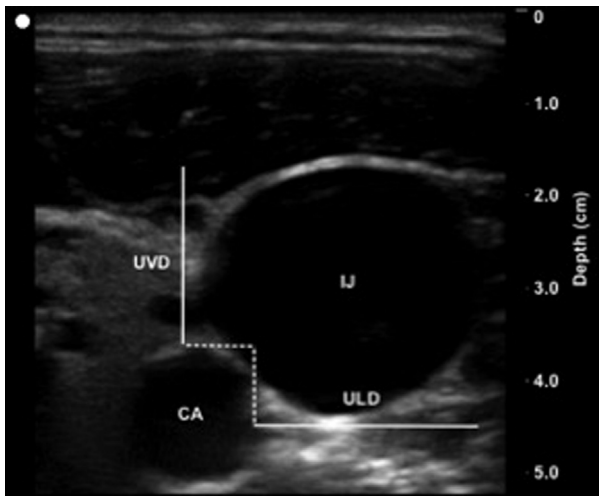

Fig 2. Anatomic distances. A photograph depicting the unencumbered lateral and vertical distances between the internal jugular vein and the carotid artery.

All of the measurements were performed with the patient supine in 15° of Trendelenburg, first with the patient with no neck rotation (0°), and then with +15°, +30°, +45°, +60°, +75°, and +90° of neck rotation to the left with the right internal jugular vein cannulation site increasingly exposed, as well as with the neck rotated to the right by 15°, which is defined as –15° in the present study. Neck rotation was determined with the use of a digital protractor.

RESULTS

After analyzing the collected data for all 50 patients, the average age was 67.9 ± 3.9 years, and 62.0% of them were male. The average weight was 82.9 ± 3.3 kg, and the average height was 167.4 ± 1.5 centimeters. Measurements were averaged at every head angle and are tabulated in Table 1. With the patient head at 0°, the distance between the centers of the RIJV and the CA was 1.19 ± 0.04 cm. The distance between the edges of the IV and the CA at 0° was 0.16 ± 0.03 cm. The IJ diameter and the CA diameter at 0° were 1.31 ± 0.07 cm and 0.76 ± 0.02 cm, respectively. All of the above were not statistically different among different head angles. At 0°, 87.2% ± 2.9% of the IJ was unencumbered laterally and 37.2% ± 3.9% of the IJ was unencumbered vertically. There was no statistical difference between the different head angles laterally, but there was a difference between the groups vertically ($p < 0.01$). Unencumbered vertical distance was different between +75° versus 0°