

# The Effect of Head Rotation on the Relative Vascular Anatomy of the Neck: Implications for Central Venous Access

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## Abstract

**Context:** Previous studies have shown that safe venous cannulation is difficult when the internal jugular vein (IJV) overlies the carotid artery (CA) as the probability of inadvertent arterial penetration is greatly increased. **Aims:** The goal of this study was to examine the anatomical relationships of the IJV and CA as a function of the degree of head rotation in order to minimize the risk for CA puncture. **Settings and Design:** Our study was a prospective study using a sample of 496 Emergency Department patients. **Methods and Material:** The anatomic relationships of the right and left IJVs and CAs were recorded with head rotation at three different positions. Patients who had the IJV in a 45 to 135 degree relationship to the CA were deemed to be in the high-risk zone for arterial puncture. **Statistical Analysis:** Chi square, ANOVA. **Results:** Right IJVs were in the high risk zone for 39.5%, 47.8% and 60.9% of cases at 0, 45 and 80 degrees of head rotation, respectively ( $P < 0.001$ ). Left IJVs were in the high risk zone for 59.1%, 69.2% and 80.0% at 0, 45 and 80 degrees of head rotation, respectively ( $P < 0.001$ ). **Conclusions:** Head rotation should be minimized during IJV cannulation to decrease the overlap of CA by IJV. Cannulation of the left IJV appears to carry a higher degree of risk as compared to the right IJV. Placing the head in neutral position, avoiding rotation, and using ultrasound guidance are recommended to minimize complications during central venous access.

**Keywords:** Cannulation, catheterization, central, ultrasound, venous

## INTRODUCTION

Internal jugular vein (IJV) catheterization is a common procedure with complications such as carotid artery (CA) puncture, hematoma, and pneumothorax.<sup>[1]</sup> Conventionally, physicians have relied on the use of anatomic landmarks for the placement of central lines; however, past studies have demonstrated that significant anatomic variation exists.<sup>[2-6]</sup> Previous studies have found that the degree of head rotation is an important factor leading to varying anatomy and therefore has the potential to increase complications.<sup>[5-9]</sup> To the best of our knowledge, no study has examined the anatomic positions of both the right and left neck vasculature as a function of head rotation.

## METHODS

This was a prospective study conducted in the emergency department (ED) of an urban Level I Trauma Center and teaching hospital with annual census of 90,000. This ultrasound study was designed to determine the functional

relationship of the IJVs and carotid arteries as measured in degrees based on head rotation. No actual venous cannulations were performed as part of this research study. The study sample consisted of 505 participants enrolled from July 2009 to May 2013 and analyzed from February 2016 to October 2017.

### Study setting and population

Patients were randomly enrolled on a convenience basis when one of our researchers was available. Researchers were present during both day and night shifts.

The study included adult patients (18 years or older). All patients possessed intact right and left IJVs and carotid arteries,

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with the absence of trauma to or current catheter cannulation of these structures. Participants were included regardless of their chief complaints and whether or not central venous access was anticipated or necessary during their ED visit. This was an IRB approved study, and informed consent was obtained for each study participant in English and/or Spanish.

Patients who had pathologies that would interfere with the ultrasound examination (overlying epidermal infection, epidermal mass, surgical site staples, etc.) were excluded from the study as were pregnant women, participants with acute changes in mental status, and patients in acute distress.

Ultrasound measurements were obtained using a Sonosite Micromaxx (Bothel, WA) linear array probe (10–5 MHz). The probe was applied in the transverse orientation for all measurements. Patients were placed in 15° of Trendelenburg position as per established central venous access technique. The degree of Trendelenburg was determined using a goniometer. The neck vasculature was imaged at the midpoint (caudal to cranial) of the traditional sternocleidomastoid/clavicle triangle, which has its lateral borders formed by the sternal and clavicular heads of the sternocleidomastoid and its inferior border formed by the clavicle. Ultrasound images were archived digitally. Degree (angle) measurements were recorded after obtaining the ultrasound image at each measured degree of head rotation (0°, 45°, and 80°). The ultrasound probe was applied with light pressure to minimize distortion of the vasculature secondary to probe-induced compression.

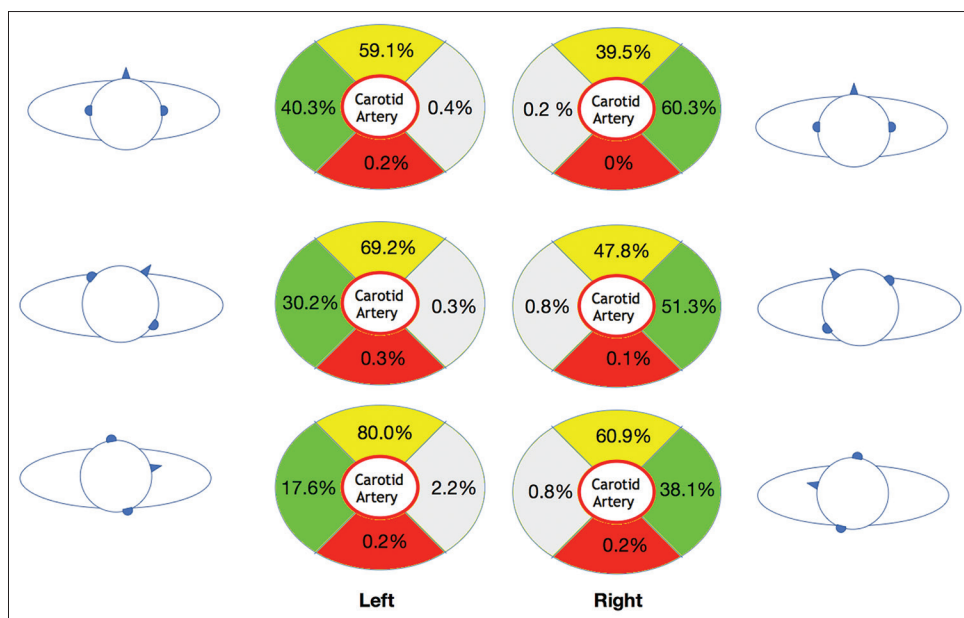
## RESULTS

A total of 505 participants were enrolled in this study. Of those enrolled, nine either opted out after enrollment, or had an acute

change in status that excluded them for being a candidate for the study. In total, 496 patients were evaluated for this study. For the right IJV, there were four, three, and seven images that were not available for 0°, 45°, and 80° of head rotation, respectively. For the left IJV, there were five, eight, and seven images that were not available for 0°, 45°, and 80° of head rotation, respectively.

The IJV was classified as being in the “high-risk zone” when it was in the range of 45–135° in relationship to the CA, thus increasing the chance of inadvertent arterial puncture resulting from through-and-through puncture of the vein. For the right IJV location in relation to the right CA, 39.5% of patients were high risk at 0° of head rotation, 47.8% were high risk at 45° of head rotation, and 60.9% were high risk at 80° of head rotation ( $P < 0.001$ ). A similar yet more striking trend was noted for the left IJV. For the left IJV location in relation to the left CA, 59.1% of patients were high risk at 0° of head rotation, 69.2% were high risk at 45°, and 80.0% of patients were high risk at 80° of head rotation ( $P < 0.001$ ). Three participants were noted to have aberrant anatomy in which the right or left IJV was deep to the respective CA, thereby making safe venous cannulation nearly impossible [Figure 1].

One-way ANOVA analysis was used to compare mean IJV rotation relative to the CA for each position of head rotation for both the left and right sides. The mean position for the IJV relative to the CA on the right side was 135° at 0° of head rotation, 131° at 45° of head rotation, and 121° at 80° head rotation ( $P < 0.001$ ). The mean position for the IJV relative to the CA on the left side was 128° at 0° of head rotation, 121° at 45° of head rotation, and 108° at 80° head rotation ( $P < 0.001$ ) [Figure 2].



**Figure 1:** A graphic representation of the distribution of internal jugular vein location relative to the carotid artery for each corresponding position of contralateral head rotation ( $P < 0.001$ )

## DISCUSSION

Central venous cannulation of the IJV has been taught using the landmark technique for many years. In this method, the anatomic triangle formed by the medial and clavicular heads of the sternocleidomastoid muscles is identified and used for guiding cannulation. In 2015, Umaña *et al.* demonstrated in a small study of 78 patients that a large portion of their study patients possessed significant anatomic variations; most notably, 31.1% of their patients had more than 50% overlap of the IJV over the diameter of the CA thereby predisposing these patients to arterial puncture.<sup>[6]</sup> In a study by Sibai, the majority of patients showed lateral (51%) and posterolateral (14%) positions of the IJV relative to the CA.<sup>[4]</sup> Another study demonstrated that the majority of their patients possessed significant anatomic variations; most notably, 54% of patients had at least 75% overlap of the IJV over the diameter of the CA thereby predisposing these patients to arterial puncture.<sup>[3]</sup> These studies all demonstrate the variability of the anatomical relationship of the IJV to the CA in patients. However, this anatomic variation would not have been realized without the aid of ultrasound. Further studies have shown that ultrasound guidance provides a safe alternative to the landmark technique and is now considered the standard of care for central venous cannulation. Ultrasound may be used preprocedure to identify and mark the location of the vascular anatomy using a surgical pen. However, real-time imaging with needle visualization during cannulation is preferred.

One study of 49 patients looked at the vascular anatomy of the right neck as a function of leftward head rotation and found that the degree of head rotation is a significant parameter for IJV overlap onto the CA.<sup>[8,9]</sup> Similarly, other studies have shown overlap of the left CA by the left IJV to be a function of rightward head rotation.<sup>[9]</sup> It appears that the overlap is more common on the left side than the right, for both neutral and rotated head positions.<sup>[5-7]</sup> To the best of our knowledge, no study to date has determined the anatomic relationship of the

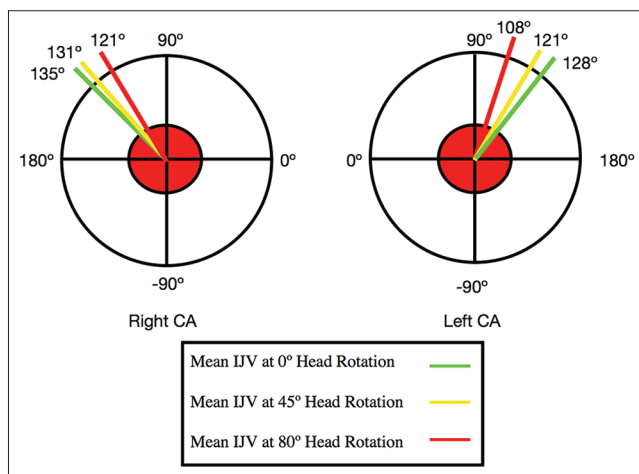
internal jugular and carotid arteries as a function of the degree of head rotation for both the right and left neck vasculature.

When placing a central venous catheter in the IJV, the temptation is great to rotate the head as far as possible to “open” the neck and better visualize the anatomic landmarks as has been the teaching in textbooks. In these instances, the possibility of arterial puncture resulting from through-and-through venous puncture is increased. When attempting central venous cannulation blindly using the landmark technique, the user relies on blood flow pulsations being present in the finder needle to indicate arterial puncture. Unfortunately, many of the patients in whom central venous access is needed are hypotensive, and therefore, pulsations may not be present. In addition, the easy compressibility of the IJV is well appreciated by those who routinely place central lines using ultrasound. A large percentage of patients in whom central venous access is needed are volume depleted, thus greatly increasing central venous compressibility.

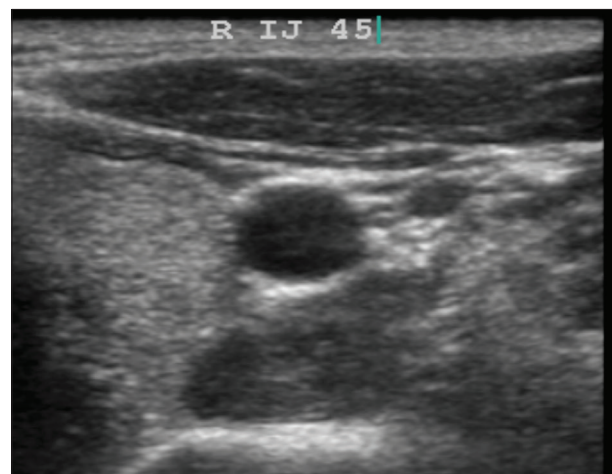
Surprisingly, three patients in our study had aberrant anatomy in which the IJV was deep to the CA. In this case, the accidental dilation and cannulation of the more superficial artery in a patient with this anatomic variation could lead to vascular complications, especially if a 9-French or dialysis catheter is used for access [Figure 3].

Our results support the findings from other studies.<sup>[6-9]</sup> To the best of our knowledge, however, our study is the first to determine the anatomic relationships of the internal jugular and carotid arteries as a function of the degree of head rotation for both the right and left neck vasculature.

These results suggest that the use of ultrasound for real-time guidance should be employed for all central vein cannulations, especially those with poor anatomical landmarks or hypotension. In addition, the angle of head rotation should be minimized, and in the absence of contraindications, the right IJV should be prioritized over the left IJV when central access is being obtained. By following these recommendations,



**Figure 2:** Each line above represents the mean internal jugular vein to carotid artery relationship in rotational degrees for the corresponding amount of contralateral head rotation ( $P < 0.0001$ )



**Figure 3:** Reversal of anatomy leading to the carotid artery being located superficially to the internal jugular vein is an uncommon anatomical condition that is a risk for arterial puncture

the incidence of complications can be minimized. Finally, ultrasound proficiency takes practice. Even though ultrasound guidance is employed, arterial puncture can still occur.<sup>[10,11]</sup>

### Limitations

The primary limitation of the study was image acquisition. First, the ultrasound image obtained is dependent on the location of the ultrasound transducer on the neck which, in turn, is influenced by the ability of the operator to locate and correctly position the transducer on the midpoint of the sternocleidomastoid muscle triangle which may have been influenced by patient body habitus. Locating landmarks in obese patients can be more challenging, causing any two operators to not place the probe in exactly the same location.

Second, the amount of overlap of the IJV relative to the CA may be affected by probe pressure. Using a light scanning technique prevents compression of the IJV, and therefore, one would expect the degree of overlap to be less. Operators with less experience tend to use more probe pressure, and this may have affected the degree of overlap that the IJV had relative to the CA.

Third, these results may not reproduce clinical procedures exactly because before placing a central venous catheter clinically, the operator generally scans along the pathway of the IJV to determine the best position for cannulation. As a result, the degree of overlap with the CA may change along the course of the IJV. Our study did not include different levels because we were most interested in looking at the relationship of the vessels at the location where the procedure would be performed using the landmark technique.

Finally, this was a convenience sample and may not be representative. A small number of patients were excluded from the study because of incomplete data sets. Each of these things may have affected the results of this study in small ways.

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### Conflicts of interest

There are no conflicts of interest.

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