Ultrasound in Emergency Medicine

COMPARATIVE SONOANATOMY OF CLASSIC "SHORT AXIS" PROBE POSITION WITH A NOVEL "MEDIAL-OBLIQUE" PROBE POSITION FOR ULTRASOUND-GUIDED INTERNAL JUGULAR VEIN CANNULATION: A CROSSOVER STUDY

Dalim Kumar Baidya, MD, Chandralekha, MD, Vanlal Darlong, MD, Ravindra Pandey, MD, Devalina Goswami, MD, and Souvik Maitra, MD

Department of Anaesthesiology and Intensive Care, All India Institute of Medical Sciences, New Delhi, India

Abstract—Background: Ultrasound (US)-guided short-axis approach for internal jugular vein (IJV) cannulation does not fully protect patients from inadvertent carotid artery (CA) puncture. Carotid puncture is not rare (occurring in up to 4% of all IJV cannulations) despite the use of US. Objectives: Compare the sonoanatomy of the "medial-oblique approach" probe position with the classic US-guided "short-axis" probe position, specifically: relation of internal CA and IJV; vertical and horizontal diameter of IJV; and degree of overlapping of IJV with CA. Methods: One hundred consecutive patients between the ages of 18 and 50 years, both male and female, and American Society of Anesthesiologists Physical Status classification system (ASA PS) I–II undergoing elective surgery under general anesthesia were recruited in this prospective, randomized, crossover, parallel-group study. Results: The transverse diameter of the IJV was found to be significantly higher in the medial-oblique probe position ($p = 0.000$, mean difference $0.43$ cm; 95% confidence interval [CI] $0.34–0.52$). The percentage of overlap was also significantly lower in the medial-oblique probe position ($48.7 \pm 10.7\%$ in short-axis vs. $36.3 \pm 13.2\%$ in medial-oblique probe position; $p = 0.000$; mean difference $12.4\%$, 95% CI $9.1–15.8$). However, there was no statistically significant difference in the anteroposterior diameter of the IJV between the two probe positions ($1.11 \pm 0.26$ cm in short axis vs $1.07 \pm 0.25$ cm in medial oblique; $p = 0.631$). Conclusion: The medial-oblique probe position for IJV cannulation provides sonoanatomic superiority over the classic short-axis probe position. Further randomized, controlled trials may confirm the medial-oblique view's clinical benefit in the future. © 2015 Elsevier Inc.

Keywords—ultrasound; internal jugular vein; IJV; cannulation; ultrasound short-axis probe view; ultrasound medial-oblique view

INTRODUCTION

Internal jugular vein (IJV) cannulation is one of the most commonly performed procedures, in both the perioperative period and in intensive care. IJV cannulation is associated with various complications, for example, inadvertent carotid artery (CA) puncture, thrombosis, hemorrhage, and hematoma formation. The complication rate may be as high as 19% and gives rise to significant morbidity (1). CA puncture is the most devastating acute complication and may be associated with stroke and death (2). Ultrasound (US) guidance is considered to be standard-of-care technique in IJV cannulation in the operating room. In fact, the American Society of
Anesthesiologists’ practice guidelines for central venous access recommend that real-time US guidance be used for IJV access (3). However, at present, the US-guided short-axis approach does not fully protect a patient from inadvertent CA puncture. Although meta-analyses have shown that the use of US is associated with a higher success rate on the first attempt and fewer attempts overall, carotid puncture still is not rare despite the use of US, and in some series may occur in up to 4% of IJV cannulation attempts (4,5). The short-axis view in US has been found to be superior to the long-axis view in terms of success rate (6). Dilisio and Mittnacht in 2012 described a new “medial oblique technique” for US-guided IJV cannulation (7). The authors reported that this approach allows for optimal imaging of the IJV and the Ca side by side, following the needle throughout from the insertion of skin to vessel penetration in a medial-cephalad to lateral-caudal direction. This technique combines the advantages of the short-axis and long-axis approaches with a medial-to-lateral needle direction and minimizes the risk of carotid puncture.

The present study was designed to compare the sonoanatomy of the “medial-oblique approach” probe position with the classic US-guided “short-axis” probe position, specifically: relation of internal carotid artery (ICA) and IJV; vertical and horizontal diameter of IJV; and degree of overlapping of IJV with CA.

MATERIALS AND METHODS

After obtaining permission from our Institutional Ethics Committee, a total of 100 consecutive patients between the ages of 18 and 50 years, both male and female, and American Society of Anesthesiologists Physical Status classification system (ASA PS) I–II undergoing elective surgery under general anesthesia were recruited and gave written informed consent to this prospective, randomized, crossover, parallel-group study. Unwilling patients, patients with ASA PS III or higher, pregnant patients, patients with a history of previous neck surgery or previous IJV cannulation were also excluded.

A computer-generated random number list was used to prepare serially numbered opaque envelopes that contained the details of one or the other probe position to be followed first. The sealed envelopes were handed over to the anesthesia team (not part of the investigating team) who then opened and followed the specified technique. Data obtained from the US-generated image were analyzed by an anesthesiologist who was unaware of the group to which the images belonged.

The sonoanatomy of IJV cannulation in the 100 subjects was assessed as per randomized sequence for both the medial-oblique probe position and short-axis probe position.

Group M = Sonoanatomy of IJV in the neck in the “medial-oblique approach” probe position.

Group S = Sonoanatomy of IJV in the neck in the “short-axis” probe position.

Eligible patients underwent thorough preoperative evaluation and were checked against the exclusion criteria of the study. In the operating room, venous cannulation was done in a large peripheral vein of the subject’s hand using an 18-G polyurethane intravenous cannula. All patients received intravenous fentanyl 2 μg/kg 5 min prior to induction of anesthesia. After preoxygenation, anesthesia was infused with 2 mg/kg propofol intravenously, and tracheal intubation was facilitated by 0.5 mg/kg intravenous atracurium after confirmation of adequate mask ventilation. Anesthesia was maintained with 50% nitrous oxide-50% oxygen with a dial setting of isoflurane vaporizer of 1–3%, targeting an end tidal concentration of anesthetic agent around 0.8–1.0 of minimum alveolar concentration (MAC). Muscle relaxation was maintained with an initial dose of intravenous atracurium 0.5 mg/kg followed by 0.1 mg/kg at 30-min intervals or as clinically judged. The analgesic regimen was decided by the consultant anesthesiologist.

After induction of anesthesia, patients were draped in the usual sterile fashion and placed in the 15° Trendelenburg position with the patient’s head turned 30° to the left side. The US device and screen were positioned on the same side as the probe. A linear US probe was covered in a sterile sleeve and placed between the heads of the sternocleidomastoid muscle to capture an image of the CA and IJV in the short axis. Once the short-axis view was obtained, the US screen was frozen. The US screen was kept away from the anesthesiologist who was placing the probe, and it was only seen by another anesthesiologist who was unaware of the actual probe position. Then, the anteroposterior and transverse diameter of the IJV was measured, and amount of overlapping of the IJV over the CA was calculated. Overlapping was calculated using the following formula:

\[
\text{Overlapping} = \frac{(\text{length of IJV overlapping CA in transverse axis})}{\text{transverse diameter of IJV}} \times 100
\]

A sample screen view of the calculation of these views is shown in Figure 1.

The probe was then rotated approximately 30° counterclockwise, in a medial-cephalad to lateral-caudal direction. This positioning allowed visualization of the IJV in a long-axis view, and imaging of the CA at the medial aspect of the image displayed in its short-axis.
Then, again, the screen view was frozen and similar analysis was done. Probe position for both short axis and medial oblique view has been depicted in Figure 2. Either “short-axis” view or “medial oblique” view was obtained first according to the randomization sequence.

The following data were collected from each group of images:

- Relative position of the ICA in relation to the IJV (medial, posterior or posteromedial). The definition of medial is <10% overlap, posterior >66% overlap, and the rest are defined as posteromedial.
- Length of overlapping of IJV over ICA.
- Transverse and anteroposterior diameter of the IJV.

**Statistical Analysis**

Demographic data are expressed as mean ± SD (age, weight, height) or proportion (gender and ASA physical
status). The relative position of the ICA with the IJV is expressed as a proportion. Continuous variables were analyzed by two-tailed unpaired t-test. Qualitative data were compared using chi-squared test. If required, log transformation was applied to normalize skewed data. A p-value of <0.05 was considered significant.

RESULTS

One hundred patients were enrolled in this study, and data from 100 patients were analyzed. Mean (SD) age and body weight of the patients was 44.6 years (9.0) and 57.1 kgs (7.9) (Table 1).

The transverse diameter of the IJV was found to be significantly higher in the medial-oblique probe position (p = 0.000, mean difference 0.43 cm; 95% confidence interval [CI] 0.34–0.52). Percentage of overlap was also significantly lower in the medial-oblique probe position (48.7 ± 10.7% in short axis vs. 36.3 ± 13.2% in medial-oblique probe position; p = 0.000; mean difference 12.4%, 95% CI 9.1–15.8). However, there was no statistically significant difference in anteroposterior diameter of the IJV between the two probe positions (1.11 ± 0.26 cm in short axis vs. 1.07 ± 0.25 cm in medial-oblique; p = 0.631). These results are shown in Table 2.

The classic “medial” position of the CA in relation to the IJV was obtained in only 21% of patients in the short-axis probe position. In 14% of patients the CA was posterior, and in the remaining 65% of patients it was posteromedial to the IJV in the short-axis probe position. In contrast, the classic medial position of the CA was obtained in 34% of patients in the medial-oblique probe position; in 6% of patients, only a posterior position, and in the remaining 60% of patients, a posteromedial position was obtained in the medial-oblique probe position.

DISCUSSION

The principle finding of our study is the significant reduction in overlap (mean reduction 12.4%) of the internal jugular vein and the CA when a medial-oblique US probe position is used. Apart from this, in the medial-oblique probe position, the CA was placed medial to the IJV in 34% of cases, and the transverse diameter of the IJV was also increased, adding to the safety margin. Our finding may be clinically translated to be a reduction in the incidence of CA puncture when the medial-oblique US probe position is used.

Traditional anatomic landmark-guided IJV cannulation poses the risk of accidental CA puncture, hematoma formation, pneumothorax, hemothorax, and other complications. Ultrasonography provides “real time” imaging, that is, the needle can be visualized entering the vein, thus reducing the incidence of complications and increasing the success rate. Inadvertent CA puncture can be avoided because the needle can be guided in real time. There is enough evidence in the current literature to recommend US guidance as “standard of care” in

Table 1. Patients’ Characteristics

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age in years (mean ± SD)</td>
<td>44.6 ± 9.0</td>
</tr>
<tr>
<td>Body weight in kg (mean ± SD)</td>
<td>57.1 ± 7.9</td>
</tr>
<tr>
<td>Sex (male/female)</td>
<td>49/51</td>
</tr>
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IJV cannulation (8,9). However, despite these advantages, the incidence of CA puncture even with US guidance is reported to be around 4%. This may be due to two reasons: in the short-axis view, the CA is most often found in a posterior or posteromedial position to the IJV and is found to be partially or even completely overlapped by the IJV; and the course of the needle during advancement is not well visualized by the out-of-plane approach used in the short-axis view. Obviously, overlapping of the two vessels is a significant risk factor for CA puncture through the IJV. Troianos et al. found that IJV overlaps the CA in 54% of patients in an US imaging plane positioned in the direction of a cannulating needle (10). In <10% of patients, the classic IJV was found lateral to the CA. Wang et al. found that the mean percentage overlap of the CA by the IJV when the head was in the neutral position was 29% at the apex of the neck in a transverse US imaging plane (11).

CA puncture can occur either by direct needle placement in the CA lumen or by a needle entering the artery after traversing through the IJV (transjugular carotid puncture). Significant overlap of the IJV over the CA in addition to the out-of-plane needle advancement used in the short-axis view predispose patients to arterial puncture, in contrast to the medial-oblique view where the mean overlap is reduced to only 36%. By using medial-oblique probe placement, one can use an in-plane approach to needle placement, from medial-cephalad to lateral-caudad direction, further reducing the chance of arterial puncture. Moreover, in the medial-oblique approach, a larger transverse IJV diameter is obtained and there will be a significant portion of IJV that will not overlap the artery. If the cannulating needle is directed to this portion of the IJV, arterial puncture can be minimized.

During needle insertion, compression of the low-pressure IJV by the US probe may increase the possibility of transjugular puncture. In the medial-oblique view, the anteroposterior diameter of the IJV is not reduced, in comparison to the short-axis view, thereby negating any advantage of the latter view.

### Limitations

The aim of our study was to find out the sonoanatomical relations of the internal jugular vein and CA in two different US probe positions. IJV cannulation was not attempted; hence, despite the anatomical advantages of medial-oblique probe position, its technical superiority cannot be established at this time. Further randomized, controlled trials are needed to prove its superiority in decreasing the incidence of CA puncture. Another limitation is that we studied anatomy only in 30° head rotation and at the apex of the triangle formed by the two heads of the sternocleidomastoid muscle. Whether this result is reproducible with probe placement in a different location and with various degrees of head rotation needs to be established.

### CONCLUSION

Medial-oblique probe position for IJV cannulation provides sonoanatomic superiority over classic short-axis probe position. Further randomized, controlled trials may confirm its clinical benefit in the future.

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### REFERENCES


ARTICLE SUMMARY

1. Why is this topic important?
   Carotid artery (CA) puncture during internal jugular vein cannulation may occur despite ultrasound guidance, and overlapping of the internal jugular vein and CA is the most important factor that determines the risk of carotid puncture. The medial-oblique view may decrease the amount of overlap, and also may potentially decrease the incidence of CA puncture.

2. What does this study attempt to show?
   A decrease in the amount of overlap between the internal jugular vein and CA, and an increase in the transverse diameter of the internal jugular vein.

3. What are the key findings?
   A decrease in the percentage of overlap between the internal jugular vein and CA. Transverse diameter is also increased in the medial-oblique view.

4. How is patient care impacted?
   Cannulation of the internal jugular vein is one of the most important procedures in emergency medicine and critical care. CA puncture, the single most important complication of internal jugular vein cannulation, at times gives rise to significant morbidity and even mortality. The medial-oblique view, discussed in this article, may reduce the chance of CA puncture.