

Internal jugular vein location and anatomy on ultrasound

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Abstract : *Introduction.* Anatomical variations of the internal jugular vein complicate central line placement in some cases. Our aim was to assess the diameter of this vein and its position relative to the internal carotid artery to investigate whether any correlation exists between these parameters on one hand, and patient subcategories and difficulty of cannulation and associated complications on the other hand.

Methods : In 48 patients, we measured the diameter of the internal jugular vein on ultrasound and assessed the position relative to the internal carotid artery, and performed cannulation under short-axis ultrasonographic view. Complications were noted and possible correlations investigated.

Results : Due to the relatively small sample population, statistical significance could not be met for any endpoint, though a general trend is clearly visible: there is no correlation between patient subpopulations and IJV diameter; the left IJV tends to overlap to a greater extent with the ICA than the right one does; the risk of complications is higher in left-sided cannulations, in smaller veins, and when significant overlap with the artery is present.

Conclusion : Ultrasound-guided cannulation yields better results than the landmark approach. If possible, the right IJV should always be preferred over the left one, and when the IJV is small or overlaps with the ICA to a great extent, a different vein should be selected.

Keywords : internal jugular vein (IJV) ; internal carotid artery (ICA) ; central line ; catheterization ; cannulation

INTRODUCTION

Vascular access is a very important aspect of the delivery of medical care in general, and is especially in the field of anesthesiology indispensable to guarantee an adequate and safe course of any surgical procedure. Access to the intravascular compartment through a peripheral vein is a quick and easy way to achieve this goal and is sufficient in most situations. There are, however, several settings – administration of fluids or medication as well as measurement of the central venous pressure (CVP) or introduction of a foreign body (e.g. a pulmonary artery or PA-catheter) – in which a peripheral vein

does not suffice and access through a central vein (jugular, subclavicular, or femoral) is preferred or necessary.

The internal jugular vein (IJV) – and more specifically the right one – is a popular vein for placement of a central venous catheter (CVC) due to its superficial location and thus its accessibility, a broader range of indications compared to other vessels (e.g. placement of a PA-catheter, something that cannot be achieved through the femoral vein) and benefits involving safety such as the possibility of manual compression to prevent the formation or the extent of a hematoma (which isn't possible with the subclavian vein). However, in the latter case the femoral vein is usually preferred.

Central venous catheterization was historically achieved without any technical devices, making use of some superficially located landmarks that grossly correlate with the course of the deeper vein. One can use the anterior, posterior, or central approach. With the increasing availability of ultrasound appliances – also in the OR – and the ever improving quality of screen resolution, the ultrasound-guided method is gaining more and more popularity.

The superiority of ultrasound-guided punctures with respect to the blind landmark technique – in the area of efficiency (amount of attempts until success and the time to successful cannulation), as well as the complication rate – has been extensively reported (1-3), and the cost-effectiveness has been shown as well (4, 5). The quite obvious explanation for this lies in the fact that the landmark technique assumes a uniform anatomical relationship between the local structures relative to each other – like an anterolateral location of the IJV relative to the internal carotid artery (ICA) – in the entire patient population; an assumption that isn't without any risks, knowing that the location of the IJV and the ICA has several possible variations, and

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that accidental arterial puncture could result in potentially serious complications, among which local bleeding resulting in hematoma or the ejection of an embolism out of a stenotic ICA into the cerebral circulation. Another reason is that the landmark technique will fail in a thrombosed vein, a problem that doesn't occur with ultrasound imaging because the patency of the vessel can be assessed prior to puncture, and a different vein can be selected.

To avoid these and other potentially serious complications (e.g. pneumothorax), it is important to localize the IJV in each patient to ensure a safe approach. The use of dynamic ultrasonography is the most ideal method, because it provides the possibility to detect anatomical variations and to anticipate possible problems. Parameters that can have an impact on the success of central venous catheter placement are the vein diameter, and the position relative to the internal carotid artery.

In this study, we systematically placed a central venous catheter in the internal jugular vein under ultrasound guidance in a population of 48 patients with the goal to map variations in anatomy, to detect differences between subpopulations, and to find a relationship between the measured parameters and the ease of catheterization and rate of complications.

METHODS

The included population of the study consisted of the entire inpatient population of the University Hospital of Gasthuisberg (Leuven, Belgium) for whom placement of a central line was deemed necessary for reasons other than monitoring of vital signs for safety reasons during surgery (e.g. TPN, plasmapheresis, or administration of chemotherapeutics, antibiotics or other medication for long-term parenteral usage). In total, 50 cannulations were performed in 48 patients over a period of 75 days. Approval of the ethical committee was obtained and an informed consent has been included.

Wherever possible, cannulation and ultrasound guidance were performed under standardized circumstances: right-sided cannulation with patient placed in Trendelenburg position with his/her head rotated contralaterally in an angle of approximately 45°, if tolerated. Vital signs were registered in this position prior to the procedure. Any necessary deviations from this setting was specifically noted. Since it's not standard of care, we renounced the performance of left-sided cannulation by default, and, therefore, did not match patients for left- and right-sided cannulation. The left IJV was only used

when a (relative) contraindication was present for the right-sided vein (e.g. central line-associated bloodstream infection or central line-associated bloodstream infection (CLABSI) due to a previously placed central line on the right side).

For real-time two-dimensional ultrasound (RTUS) guidance, we used the BK Medical Ultrasound with a high-frequency (6-10 MHz) linear transducer. The short axis approach (SAX) was used for direct out-of-plane puncture, after measurement of the diameter of the IJV and assessment of its position relative to the ICA (Fig. 1). Doppler mode visualization was not implemented in the study.

We measured the largest diameter of the IJV in each patient on the side of cannulation in two perpendicular axes (Fig.1). Measurement was always performed at the level of the cricoid cartilage, though not necessarily always by the same physician. Special care was taken as to not compress or displace the jugular vein. An estimate of the cross-sectional area was made based on the assumption that the vessel was minimally compressed, and could be simplified to an elliptical shape. The position of the IJV relative to the ICA was assessed at the same level and divided into subcategories (Fig. 2). We made note of any anatomical anomaly we encountered, this being bifurcation, fenestrations, and abnormal (posterior or lateral) branching of the vein.

The following outcome parameters were assessed: success of cannulation (by which we mean correct placement, which was verified by means of

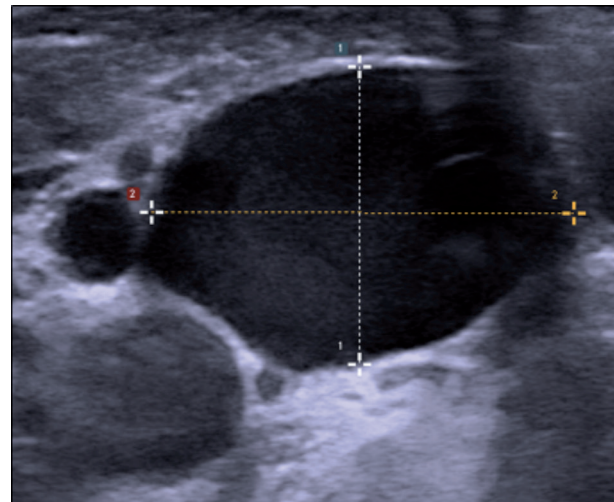


Fig. 1. — Ultrasonographic image of the neck vessels of one of the included patients on a short-axis view. The (right) internal jugular vein lies anterolateral to the internal carotid artery. The largest diameter is measured in two perpendicular axes, and, based on these measurements, an estimation of the cross-sectional area is made.

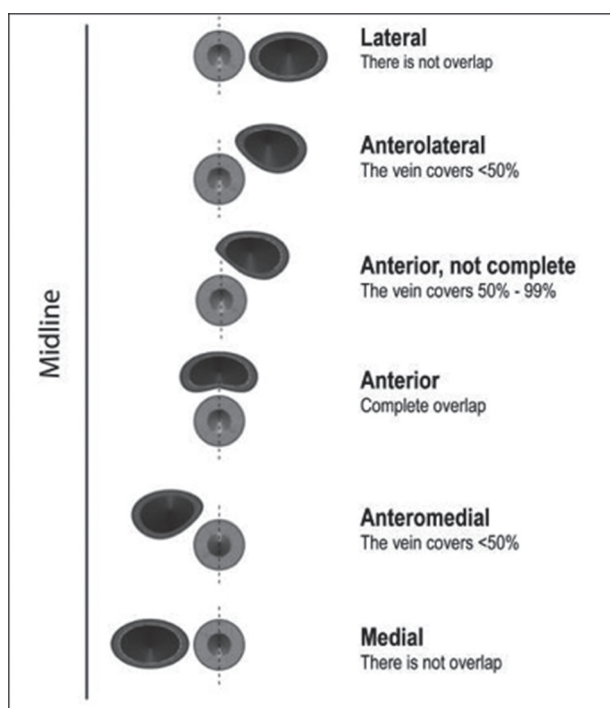


Fig. 2. — Schematic view of the position of the (right) internal jugular vein relative to the internal carotid artery, subdivided into the categories medial, anteromedial, anterior, anterior not complete, anterolateral, and lateral, defined by their degree of overlap (6).

chest X-ray and in-plane ultrasonography), number of attempts until success (in which successful cannulation after more than 3 attempts was categorized as being a 'difficult' cannulation), time until success (measured from the start of needling until insertion of the catheter and aspiration of venous blood from the lumen), and complications (accidental arterial puncture, pneumothorax, etc.).

Since the hospital where the study was held is a teaching hospital, it was possible for trainees/interns to aid in the process of cannulation. Therefore, the parameter 'time until success' could differ a significant deal unaccounted for by the actual difficulty level. If a trainee was present, this was noted and held into account.

A statistical analysis was made in order to define the relationships between patient subgroups (categorized by differences in age, gender, ethnicity, length, weight, puncture site), variables measured on ultrasound (diameter of the IJV and position relative to the ICA), and outcome parameters (success, time, difficulty of cannulation, and complication rate). Due to the relatively small patient population, we understand that statistical significance might not be met for our outcome measures. Because of this, we refrained from overly extensive analysis, but tried describing a general trend instead.

A small-scale literary review was performed for comparison of our own measured values and to provide the reader with a brief update of the current state of affairs. Articles along the lines of our study were searched for through online databases (PubMed, Cochrane library, and TRIP database). Relevant articles were selected based on title and abstract, and references and citations of these articles were examined in the same way.

RESULTS

In total 50 cannulations were performed in 48 patients, among whom 25 men and 23 women ranging from 20 to 87 years of age, and of which 41 right-sided and 9 left-sided.

Vein diameter

The mean diameter of the IJV was 13.09 mm, with a range of 4.25 to 25.50 mm. The mean cross-sectional area (CSA) was 138.20 mm² ranging from 30.64 mm² to 305.21 mm². A comparison between discrete variables (left vs. right and male vs. female) is schematically shown by means of box plots (Fig. 3). In order to determine the significance of the results, the measured values were submitted to Welch's t-test (two-tailed, using the Welch-Satterthwaite equation to estimate the degrees of freedom). Regarding the diameter of the IJV, we did not find a statistically relevant difference among different genders ($p = 0.91$) and side of cannulation (0.21). For analysis of the (semi)-continuous variables age, height, weight, and BMI, we plotted the CSA of the IJV in scatter diagrams (Fig. 4). Through simple linear regression – implementing the ordinary least squares method – the best-fitting

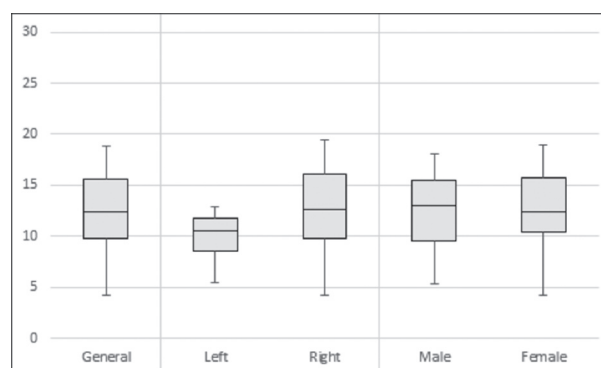


Fig. 3. — Comparison of the distribution of the measured diameters of the IJV in all patients. There is little difference between subpopulations, although – without reaching statistical significance – by average the left IJV tends to be smaller than the right one.

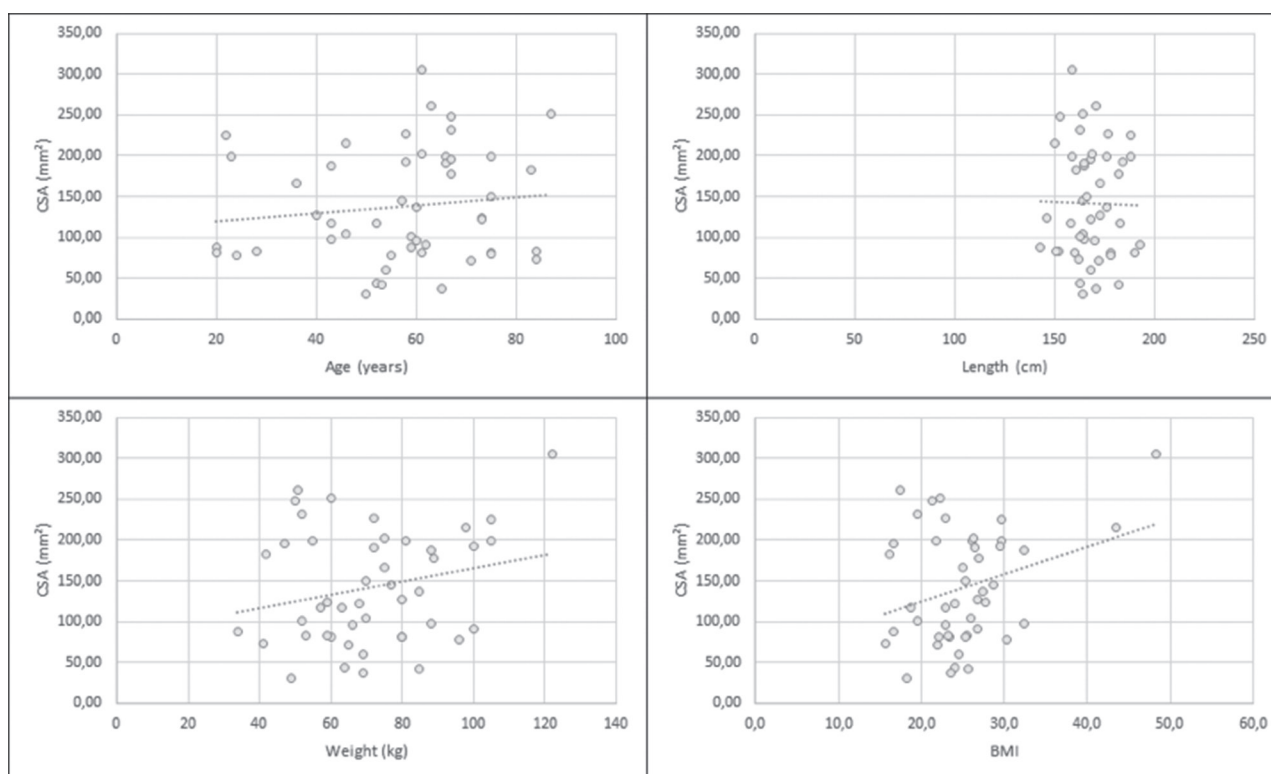


Fig. 4. — Scatter diagrams demonstrating the distribution of the cross-sectional area (CSA) of the IJV with increasing age, length, weight, and body mass index (BMI). Each dot represents the measurements of a single patient. No clear difference is shown.

Table 1a

Relative position of the IJV compared to the ICA in left-sided and right-sided cannulations. Further distinction is made between significant and non-significant overlap. Absolute numbers of the amount of cases in which overlap was seen. Percentages are shown between parentheses. The left IJV tends to overlap to a greater extent with the ICA than the right one does (statistical significance not met).

| Location | Left | Right | Total |
|-----------------------|---------|----------|----------|
| Medial | 0 | 0 | 0 |
| Anteromedial | 2 | 0 | 2 |
| Anterior | 2 | 11 | 13 |
| Anterior not complete | 2 | 4 | 6 |
| | 6 (67) | 15 (37) | 21 (42) |
| Anterolateral | 2 | 15 | 17 |
| Lateral | 1 | 11 | 12 |
| | 3 (33) | 26 (63) | 29 (58) |
| Total | 9 (100) | 41 (100) | 50 (100) |

Table 1b

Relative position of the IJV compared to the ICA in males and females both in left-sided, as well as in right-sided cannulation. Further distinction is made between significant and non-significant overlap. Absolute numbers of the amount of cases in which overlap was seen. Percentages are shown between parentheses. There is no clear difference in overlap between genders.

| Location | Male | | Female | |
|-----------------------|---------|----------|---------|----------|
| | Left | Right | Left | Right |
| Medial | 0 | 0 | 0 | 0 |
| Anteromedial | 1 | 0 | 1 | 0 |
| Anterior | 2 | 4 | 0 | 7 |
| Anterior not complete | 1 | 3 | 1 | 1 |
| | 4 (80) | 7 (25) | 2 (50) | 8 (40) |
| Anterolateral | 1 | 8 | 1 | 8 |
| Lateral | 0 | 6 | 1 | 4 |
| | 1 (20) | 14 (75) | 2 (50) | 12 (60) |
| Total | 5 (100) | 21 (100) | 4 (100) | 20 (100) |

minutes and 22 seconds in its absence. Insofar as the setting was a university hospital, ample time was reserved for teaching opportunities. Because of this, the duration of cannulation cannot be viewed as a reliable parameter, and we are unable to draw any conclusions. This is sustained by the fact that the average cannulation time was 2 minutes and 38 seconds in the absence of interns, and 5 minutes and 24 seconds in their presence.

DISCUSSION

Landmarks as compared to ultrasound

In the literature, the superiority of RTUS as compared to the classical landmark approach has been extensively reported. A systematic review (n = 5108) from 2015 (1) showed a success rate of 98.2%, as compared to 87.6% without use of US (RR 1.12 with 95% CI 1.08-1.17) and a shorter time and lower amount of attempts needed on average. The success rate on the first attempt was 78.7% and 50.1%, respectively (RR 1.57 ; 1.36-1.82). The general complication rate was significantly lower (3.9% as compared to 13.5% ; RR 0.29 ; 0.17-0.52), with accidental arterial puncture occurring in 2.6% and 9.4% of all studied cases (RR 0.28 ; 0.18-0.44), respectively. The quality of these findings was, however, very low to moderate at best.

A meta-analysis from Hind *et al.* (2) also reported a higher success rate under ultrasound guidance, with a shorter cannulation time and lower amount of attempts. There were less complications, though statistical significance was not met for this outcome parameter.

After a decade, several randomized controlled trials on this topic have been available, and Wu *et al.* published a new meta-analysis (n = 4185), in which the higher success rate was, once again, confirmed (98.0% and 87.1%, respectively ; RR 1.13). In that study, statistical significance was also met for the complication rate. They reported a risk reduction for accidental arterial puncture from 9.7% to 1.8% (RR 0.25 ; 0.15-0.42) and for the occurrence of pneumothorax from 3.0% to 0.11% (RR 0.21; 0.06-0.73). A few of their included studies focused exclusively on the subclavicular or femoral vein, but the measured results for the IJV alone correlate to a great extent with the general results, and they remain statistically significant (3).

Our results showed – without statistical significance – an increased frequency of complications when the procedure was left-sided, in smaller vessels, and when a higher degree of overlap

with the artery was present. Possible reasons for our higher complication rate compared to those described in other articles are, on one hand, a patient population with more severe comorbidities (since the study took place at a university hospital, to which more ‘difficult’ patients are often referred), and, on the other hand, the fact that it is also a teaching hospital, with less experienced staff (residents) performing cannulations. Cannulations were performed by several residents, among which also junior residents and trainees (under direct supervision), with very limited experience in central line placement, and with and without the use of ultrasound guidance. The complication rate is still non-inferior to the landmark technique described in the available literature, and thus we can assume that complications would be more common if the same performers would have implemented the landmark technique instead.

Because of a big divergence in skills and the time set aside for teaching, we won’t go deeper into the discussion of cannulation time.

Parameters measured on ultrasound

Factors that – even with ultrasound-guided puncture – contribute to the difficulty of catheterization are, according to the current available literature and among others, the diameter of the IJV, the position of the IJV relative to the ICA, and the occurrence of anatomical anomalies (vein bifurcations, fenestrations, and abnormal lateral/posterior branching), although the latter are rarities. For these anomalies, one can only rely on a few case reports (7-12).

Vein diameter

Mey *et al.* (13) found that a smaller diameter of the IJV yields a positive correlation with the failure rate, as well as the number of complications (however, the correlation with the latter was not found to be statistically significant). Out of 493 patients, they reported a failure rate of 14.9% with a vein diameter <0.7 cm, as compared to 3.9% with a diameter of 0.7-1 cm (and furthermore 2.8% with a diameter of 1-1.3 cm and 0% in veins larger than 1.3 cm in diameter). A study from Czyzewska *et al.* showed that, in a single patient, the diameter of the IJV to the left and the right could differ up to 850%, the left IJV being the smaller one in the majority of the cases (14). They did not report a significant difference in the average diameter between men and women. Their proposition following their study was to systematically measure the cross-sectional area of

the IJV prior to cannulation, to refrain from central line placement at that particular site, and choose a different vein when the IJV falls into the category of 'small veins'. Being larger on average, the right IJV should be preferred over the left as a first choice, or in an emergency setting (15).

We did not find any patient-specific parameters that correlate with the diameter of the IJV. We assume that the most determining factor in a patient is the fluid balance. As a result, the diameter of the same vein measured at different times can largely differ.

Several maneuvers to enlarge the diameter of the IJV and as such to increase the probability of successful cannulation have been tested and found effective, including the Trendelenburg position, Valsalva maneuver, compression of the IJV distal to the puncture site, and – in ventilated patients – positive pressure ventilation (16, 17). Applying hepatic pressure has not been proven effective (16).

Vein position

It has been postulated that an anterior position of the IJV relative to the ICA with a high degree of overlap yields a greater risk of accidental arterial puncture, as has been theoretically shown in an in vitro study by Bailey et al. Using ultrasonography, they looked at the proportion of vein and arteries where the exerted cannulations would result in, by determining the trajectory the needle would take if inserted according to the landmark technique (18). Umaña et al. found, in their study population, a lateral location of the IJV relative to the ICA in 24.3% of study subjects (95% CI 17.4-32.2), an anterolateral location in 33.8% (26.2-41.4), and an anterior (or more medially situated) location in 41.9% (33.9-49.8). An anterior location was found to be more frequent with increasing age, when the patient's head was rotated contralaterally (there was overlap between the vein and artery in 30.5% to 37.3% in neutral and rotated head position, and in 41.1% to 46.6% in neutral and rotated position on the right and left side, respectively), and, to a lesser degree, on the left side and in men (6).

Our results show a trend to a larger overlap on the left side, but we could not confirm these results in men and in the elderly. All of our measurements were performed while the patient's head was rotated contralaterally, we did not include images of the IJV with the patient's head in neutral position.

Left-sided versus right-sided cannulation

Sulek et al. reported that the left IJV is less prone to dilation when the patient is placed in the

Trendelenburg position, and that the left IJV more than its counterpart on the right exhibits an increasing tendency to assume a more anterior position relative to the ICA when the patient's head is rotated to the other side (19). Given all the information provided above, we can expect that a left-sided cannulation will pose a greater risk for complications.

A few years later, the same authors published a new study, in which they actually did report a higher complication rate in left-sided cannulations (20). Our findings support this presumption. We described more left-sided complications, and, also, longer cannulation times, though statistical significance was not met.

Other factors that contribute to the difficulty of a left-sided cannulation are the non-linear trajectory followed by the vein towards the superior vena cava, and the proximity of the thoracic duct.

We hold into account that, due to its compressibility, the diameter of the IJV can vary a lot, for example in Trendelenburg position, during a Valsalva-maneuver, due to compression by the ultrasound probe, and as a consequence of the patient's intravascular volume status. Furthermore, we realize that ultrasonography is always subject to interobserver and even intra-observer variability, and thus this should be held into account when interpreting the results.

Proper guidelines could help to further optimize the correct ultrasound technique, and, as such, contribute to a reduction of complications (21, 22).

CONCLUSION

Although statistical significance could not be met for our criteria – mostly due to a relatively small patient population – the general trend we describe very well matches the results found in the literature.

Although our additions did not meet statistical significance, an obvious trend can be described and could possibly be confirmed in larger trials.

Our general advice is to always use ultrasound guidance when placing a central line in non-

What we know

- *Real-time ultrasonographic guidance for central line placement increases success rate and decreases the risk of complications*
- *Smaller vessels are more difficult to cannulate*
- *On average, the left IJV is smaller than the right one*
- *The IJV often does not lie lateral to the ICA but more anteriorly with a varying degree of overlap*

What this article adds

- *On average, the left IJV tends to overlap with the ICA to a larger extent than the right one (not statistically significant)*
- *The hypothesis that an anteriorly located IJV yields to an increased risk of complications has been confirmed (not statistically significant)*

emergency settings, or when an ultrasound device is readily available. Furthermore, the right-sided IJV should be preferred over the left one. However, when the vein is found to be small or overlaps with the artery to a large extent, a different vessel should be selected or an alternative approach and/or needle path could be implemented.

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