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Original article

CT evaluation of anatomical variations of the internal jugular veins in Thai adults

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Background: The internal jugular vein (IJV) is used to obtain central venous access for various reasons. Awareness of the expected location and anatomic variations of the IJV is very important to avoid inadvertent arterial puncture.
Objective: We evaluated anatomical variations of the IJVs, including diameter, depth from skin surface, relative distance from common carotid artery (CCA) and position in relation to CCA in Thai adults by using CT scan of the neck.
Material and Methods: A total of 77 patients who underwent CT scan of the neck (nasopharynx, larynx) at the Department of Radiology, King Chulalongkorn Memorial Hospital (KCMH) from May 1, 2009 to April 30, 2012 were retrospectively reviewed. The diameter of the IJVs, depth from skin surface and relative distance between the IJVs and CCAs were taken bilaterally. Bilateral CCAs were taken as reference points for measuring the location of the IJVs, recorded as lateral, anterior, medial or posterior position. These parameters were evaluated using the same axial slice at a level of cricoid cartilage, which was compatible with the recommended point for central venous catheter insertion via the IJV. Intra- and interobserver reliability between researcher and another radiologist was assessed by intraclass correlation coefficient (ICC).
Results: The right IJVs were usually larger than the left IJVs (57/77 or 74.0%) with significant difference in diameter (14.9 ± 4.0 mm vs. 11.6 ± 3.8 mm, $p < 0.0001$). The right IJVs were significantly located more superficial than the left IJVs (16.3 ± 4.2 mm vs. 17.0 ± 4.4 mm, $p = 0.049$). The right IJVs tended to have distance far from the CCAs more than the left IJVs (1.3 ± 0.6 mm vs. 1.2 ± 0.9 mm, $p = 0.372$). Most of the IJVs located laterally to the CCAs (145/154 or 94.2%). A total of 4/154 IJVs (2.6%) were located anteriorly and 5/154 IJVs (3.2%) were located posteriorly. There were two cases that the posterior position of the IJVs was seen bilaterally. No medially located IJV was found.
Conclusion: There were anatomical variations of the IJVs, including diameter, depth from skin surface, relative distance from the CCAs and position in relation to CCAs, which remained potential risk when jugular venous access was attempted. Awareness of these variations is very important.

Keywords: Central venous access, CT, internal jugular vein (IJV), Thai, variation

The internal jugular vein (IJV) drains most of the blood from the skull, brain, and superficial and deep parts of the face and neck. It originates at the jugular foramen at the cranial base, in continuation with the sigmoid sinus, descends along the neck in the carotid sheath, reaching the subclavian vein posteriorly to the sternal end of the clavicle, thereby forming the brachiocephalic vein [1]. The IJV is directly anterior and lateral to the carotid artery [1-3] as shown in **Figure 1**.

The IJV is used to obtain central venous access for various reasons, such as for parenteral nutrition, blood sampling, blood transfusions, plasmapheresis, giving antibiotics and long-term chemotherapy, hemodialysis vascular access, and monitoring right atrial pressure. The right IJV is also required for creation of transjugular intrahepatic portosystemic shunt, transjugular liver biopsy and inferior vena cava filter placement [4, 5].

Generally, a right-sided approach is recommended for insertion of a central venous catheter via the IJV, because the right IJV has a much wider diameter and runs more superficially. Moreover, the right-sided approach carries a shorter inserted catheter length and a lower risk of thoracic duct injury than a left-sided approach [6, 7].

The landmark-guided technique has been commonly used to obtain venous access. The preferred middle approach to the right IJV is shown in **Figure 2** [8].

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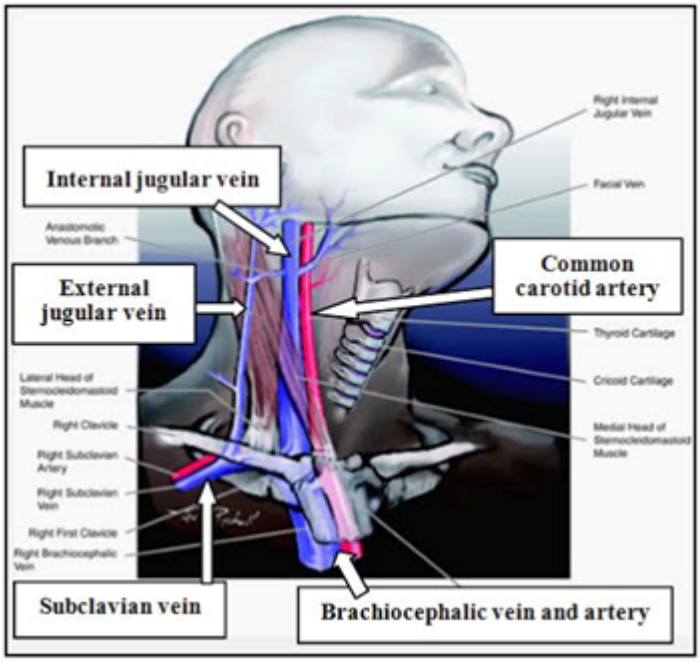

Figure 1. Internal jugular vein (IJV) and subclavian vein anatomy at the level of the neck. Anterolateral view. Note the triangle formed by the medial and lateral heads of the sternocleidomastoid muscle showing as a window for puncture and catheterization of the IJV. The IJV is lateral and anterior to the common carotid artery [1].

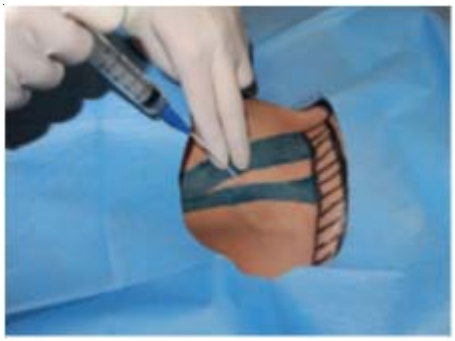

Figure 2. Preferred middle approach to the right internal jugular vein. The needle enters the skin at the apex of the triangle formed by the sternal and clavicular heads of the sternocleidomastoid muscle. The needle is held at a 30- to 45-degree angle to the skin and directed toward the ipsilateral nipple [8].

Although the general anatomy, landmarks and relationship of the IJV with the common carotid artery (CCA) are known and have been described in anatomy texts [1-3], there are variations in the position and relationship with the artery that may lead to unsuccessful IJV cannulations or inadvertent carotid artery punctures that range from 2% to 17% [9, 10]. Failure rates of internal jugular vein cannulation range between 5% and 18%, and complications may occur in up to 14% of cases [10-12].

Ultrasound can be used to locate the IJV and provide guidance of IJV cannulation. However, portable ultrasound is not widely used, especially in emergency settings and for bedside venous access needs. Awareness of the expected location and anatomic variations of the IJV is very important. Also limiting information was documented in Thai people.

The radiological anatomy of the IJVs has been studied using ultrasonography, accounting for position, size, depth from the skin surface or variations of IJVs in relation to their carotid arteries [13-22], but the ultrasonography has some limitations with respect to delineating the anatomy of the jugular veins, in being operator dependent with technique variability [17, 21].

Computed tomography (CT) has distinct advantages over ultrasonography in order to evaluate anatomical variations of the IJV because it is more objective.

The purpose of this study is to evaluate anatomical variations of the IJVs, including diameter, depth from skin surface, relative distance from the CCA and position in relation to CCA in Thai adults by using a CT scan of the neck.

Materials and methods

Patient population

Consecutive patients who underwent CT scan of the neck (nasopharynx, larynx) at the Department of Radiology, King Chulalongkorn Memorial Hospital (KCMH) from May 1, 2009 to April 30, 2012 were included and retrospectively reviewed. Each patient was included only once.

Patients of less than 18 years of age, history of head and neck masses or cancer, presence of neck pathology or history of neck trauma, previous neck surgery or invasive procedure, previous radiotherapy, superior vena cava syndrome, alteration of hydration or cardiac status were excluded from the study.

Image acquisition

All CT examinations were performed on a 4-MDCT scanner (Somatom sensation 4, Siemens Medical Solution, Germany), a 16-MDCT scanner (Somatom sensation 16, Siemens Medical Solution, Germany) or 320-MDCT scanner (Aquilion ONE, Toshiba Medical Systems Corporation) using KCMH CT neck (nasopharynx or larynx) protocol (**Table 1**). The patients were in supine position with neutral head position and quiet respiration. Caudocranial scan was performed from SVC to suprasellar region. Image postprocessing techniques were also acquired in all patients using multiplanar projection reconstruction (MPR) in the three spatial planes (axial, coronal, and sagittal).

Image analysis

All CT images of the neck (nasopharynx, larynx) were reviewed retrospectively using a Picture Archiving and Communication System (PACS). Anatomical variations of the IJVs were measured by using computer-generated scales and recorded.

Intra- and interobserver reliability between researcher and another radiologist was assessed by intraclass correlation coefficient (ICC).

All images were privately reviewed in the film-reading room by the researcher and the advisor. The patients' data were kept secret. The research proposal has been reviewed and approved by the Ethics Committee of Faculty of Medicine, Chulalongkorn University.

Data collection

The demographic data including age, sex, clinical history, and underlying disease of all patients were collected.

The diameter of the IJVs, depth from skin surface and relative distance between the IJVs and CCAs were taken bilaterally (**Figure 3**). Bilateral CCAs were taken as reference points for measuring the location of the IJVs, recorded as lateral, anterior, medial or posterior position as indicated in **Figure 4**.

These parameters were evaluated using the same axial slice at a level of cricoid cartilage. This slice level is compatible with the recommended point for central venous catheter insertion via the IJVs [14, 17, 19, 20, 23].

Table 1. Protocol for CT of the neck (nasopharynx, larynx) at the Department of Radiology, King Chulalongkorn Memorial Hospital (KCMH).

	Somatom sensation 4	Somatom sensation 16	Aquilion ONE
kV	120 kV	120 kV	120 kV
mAs	180 mAs	260 mAs	120 mAs
Slice collimation	4×1.0 mm	16×0.75 mm	0.5×64 mm
Slice width	4.0 mm	3.0 mm	3.0 mm
Overlapping	20%	50%	50%
Gantry rotation time	0.5 s	0.75 s	0.6 s
Pitch	1	0.75	1
IV contrast (Nonionic)	70 ml, flow rate 1.5 ml/s 70 s-delayed	70 ml, flow rate 2 ml/s 40 s-delayed	60 ml, flow rate 2 ml/s 40 s-delayed

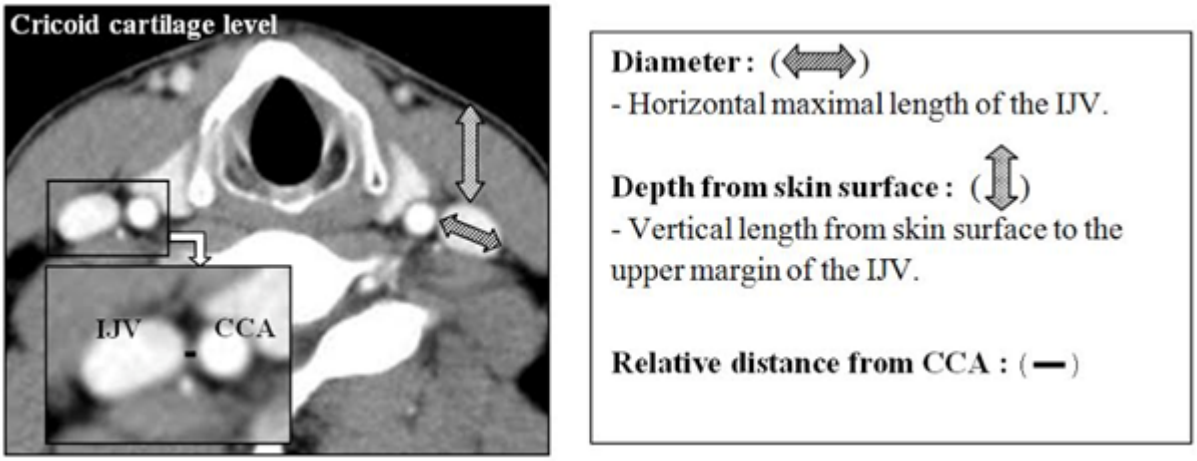

Figure 3. Definitions for diameter of the internal jugular vein (IJV), depth from skin surface of the IJV and relative distance from common carotid artery (CCA).

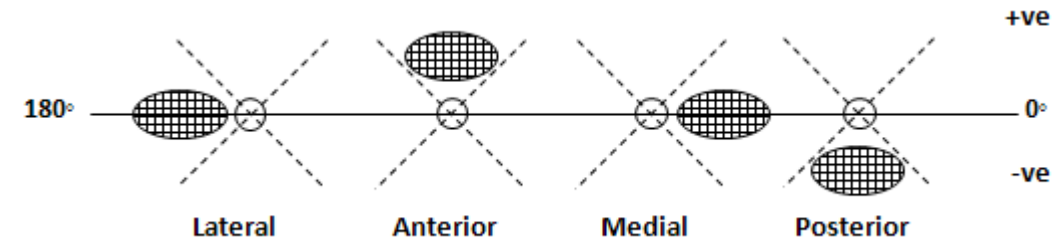

Figure 4. Definition of the right internal jugular vein (IJV) in relation to the right common carotid artery (CCA) showing the anatomical positioning. A mirror image applies for the left IJV. ◯, CCA ▭ IJV; ✕, perpendicular dotted axes rotated 45□ from horizontal axes are used to demarcate the IJV positions

Data analysis

The diameter, depth from skin surface and relative distance from CCAs of the IJVs are presented as mean and standard deviation (SD). The difference in these parameters between the right and the left IJVs were analyzed by paired *t* test. Statistical analyses were computed with a statistical software package (SPSS, version 16.0.0; IBM Corporation, Armonk, NY). A $p < 0.05$ was considered statistically significant. Measurement of the IJV diameter less than two SD below the mean of each side were termed "hypoplastic". Position of the IJVs in relation to CCAs was presented as percentage.

Results

A total number of 1,376 patients underwent CT scan of the neck during the study period. One thousand, two hundred and ninety-nine patients (94.4%) were excluded from the study because of the presence of any condition of the following, age less than 18 years (2.8%), history of head and neck masses or cancer (87.5%), presence of neck pathology (infection, inflammation, thrombus) (4.8%), history of neck trauma (0.8%), previous neck surgery or invasive procedure (3.1%), previous radiotherapy (0.8%) or alteration of cardiac status (0.2%) as shown in **Table 2**.

The remaining 77 patients, 34 (44.2%) men and 43 (55.8%) women, with their age range between 22 years and 92 years and mean age of 54.8 years were included in this study.

Diameter of the IJVs

The right IJVs were usually larger than the left IJVs (57/77 or 74.0%) with significant difference in diameter (14.9 ± 4.0 mm vs. 11.6 ± 3.8 mm, $p < .0001$). The largest diameter of the right IJV was 30.0 mm and the left IJV was 20.8 mm. One of the right IJVs was found to be hypoplastic, measured 6.7 mm in diameter. The smallest diameter of the left IJV was 4.1 mm (**Table 3**).

Table 2. Conditions for exclusion in 1,299 patients

Conditions	Number of patients	Percent (%)
Age < 18 y	37	2.8
History of head and neck mass or cancer	1,137	87.5
Neck pathology (infection, inflammation, thrombus)	62	4.8
History of neck trauma	10	0.8
Previous neck surgery or invasive procedure	40	3.1
Previous radiotherapy	10	0.8
Cardiac status	3	0.2

Table 3. Details of bilateral internal jugular veins

Parameters	Right (n = 77)	Left (n = 77)	*p*
Diameter (mean ± SD)	14.9 ± 4.0 mm (range 6.7-30.0 mm)	11.6 ± 3.8 mm (range 4.1-20.8 mm)	<.0001
Number of the right IJV larger than the left (%)	57/77 (74.0%)	20/77 (26.0%)	–
Hypoplastic IJV	1	0	–
Depth from skin surface (mean ± SD)	16.3 ± 4.2 mm (range 7.2–35.0 mm)	17.0 ± 4.4 mm (range 4.4–30.7 mm)	0.049
Relative distance from CCAs (mean ± SD)	1.3 ± 0.6 mm (range 0.6–3.8 mm)	1.2 ± 0.9 mm (range 0.6–8.0 mm)	0.372
Distance >5 mm away from CCAs	0	1	–
Distance ≤1 mm away from CCAs	27/77 (35.1%)	40/77 (51.9%)	–

Depth from skin surface

There was significant difference in depth from skin surface (p = .049) between the right and the left IJVs. The right IJVs located more superficial than the left IJVs (16.3±4.2 mm vs. 17.0±4.4 mm) (**Table 3**).

Relative distance between the IJVs and CCAs

There was no significant difference in relative distance between the right and the left IJVs and CCAs (1.3 ± 0.6 mm vs. 1.2 ± 0.9 mm, p = .372). One of the left IJV was found to be more than 5 mm from the adjacent CCA (8.0 mm). In 27 (35.1%) right IJVs and 40 (51.9%) left IJVs were found within <1 mm distance of the CCAs (**Table 3**).

Position of the IJVs in relation to CCAs

Most of the IJVs located laterally to the CCAs (145/154 or 94.2%). A total of 4/154 IJVs (2.6%, 4 left IJVs) were located anteriorly (**Figure 5**) and 5/154 IJVs (3.2%, 3 right IJVs and 2 left IJVs) were located posteriorly (**Figure 6**). There were two cases that the posterior position of the IJVs was seen bilaterally. No medially located IJV was found (**Table 4**).

Intra- and interobserver reliability between researcher and another radiologist was almost perfect agreement (ICC = 0.981 and 0.959, respectively).

Discussion

The IJV approach for central venous access is widely used by physicians, surgeons and anesthesiologists. Common complications of central venous access are laceration of neck vessels, inadvertent arterial puncture, hematoma, arteriovenous fistula, catheter malposition, air embolism, venous thrombosis, and infection. Accidental CCA puncture could be disastrous and life threatening when it results in accidental intraarterial cannulation, cerebrovascular accident, hemothorax, IJV-carotid artery fistula, or airway compromise secondary to hematoma [9, 24-26].

Ultrasonographic guidance is not yet the standard of care for IJV cannulation. The availability of ultrasound equipment and the associated costs of required hardware and training have been raised as reasons for lack of universal adoption of this technique [8].

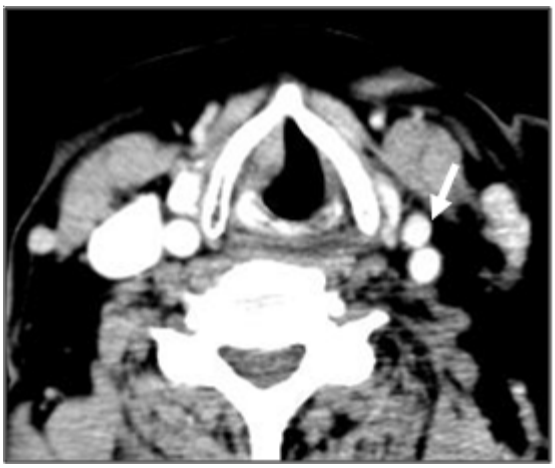

Figure 5. Left anterior internal jugular vein (arrow)

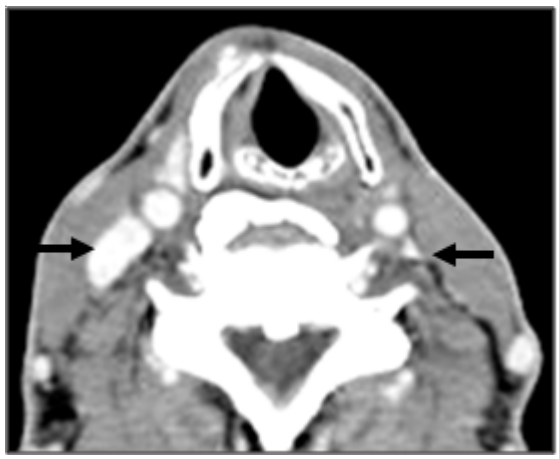

Figure 6. Bilateral posterior internal jugular veins (arrow)

Table 4. Percentages of internal jugular vein position in relation to the common carotid artery

Position of IJVs	Right	Left	Total (%)
Lateral	74/77	71/77	94.2
Anterior	0/77	4/77	2.6
Medial	0/77	0/77	0.0
Posterior	3/77	2/77	3.2

Knowledge of the anatomical variations of the IJVs will urge awareness when obtaining central venous access. Most of previous studies used ultrasonography to evaluate anatomical variations of the IJVs before performing central venous access. However, ultrasound observation has many limitations. External compression of the veins during the procedure may result in an inaccurate view of the diameter of the vein. Neck positioning and angulation of the ultrasound transducer can affect vein positioning relative to the carotid arteries [27]. Occlusions of the brachiocephalic vein and superior vena cava cannot be evaluated [28]. Moreover, other masses or structures in the mediastinum, which could alter the vascular anatomy cannot be evaluated. These limitations could lead to inaccurate measurements and could be a potential cause of the varying results in these studies.

In this study, we used CT of the neck to evaluate variations of the IJVs as superior to that using ultrasound. The CT imaging can exclude pathology affecting the vessel anatomy more efficiently. Moreover, it was not operator dependent, with no external pressure on the veins and minimal variations on neck position or respiration. Furthermore, CT can evaluate the bilateral IJVs simultaneously, and correctly evaluate the relationship between the IJVs and CCAs in the same axial slice simultaneously [5, 6]. There have been only three previous descriptive studies using CT evaluation [5, 6, 23].

To our knowledge, there have been two studies in Thailand, using ultrasound evaluated anatomical landmark of the IJVs, but their results did not give much information about the IJV variations [10, 29].

Four parameters of the IJVs had been evaluated, included diameter, position in relation to their carotid arteries, depth from skin surface and relative distance from carotid arteries.

In our study, the right IJVs had a much wider diameter than the left IJVs and also ran more superficially from the skin. These results were consistent with two previous CT studies and also two previous ultrasound studies [5, 6, 14, 16].

Tartiere et al. [23] also showed that the diameter and cross-sectional area of the right IJVs were significantly greater than those of the left IJVs by using CT. In Lim CT study [5], there were 7 hypoplastic IJVs (4.0%, 3 right IJVs and 4 left IJVs) out of 176 IJVs. Contrarily, in our study found only 1 hypoplastic right IJV (0.6%) out of 154 IJVs. There was a term "small size" [17], which meant the diameters of the IJVs were smaller than 5 mm, found in 24 (11.5%) out of 208 IJVs (14 right IJVs and 10 left IJVs). Although it was a small number of the hypoplastic or small size IJVs, it might represent potentially difficult cases for cannulation with external landmark-guided technique. With each 1 mm decrease in IJV size, there was a 37% significant increase in the risk of difficult cases [19]. Repeated attempts would also increase the risk of carotid puncture [16].

Tartiere et al. [23] showed that diameter and cross-sectional area of the right and the left IJVs were not significantly different according to age and sex. Troianos et al. [21] also showed no correlation between weight, height, or age with vein size and 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.

In an ultrasound study by Lin et al. [17], the right IJV diameters were wider than the left, but the left IJVs were more superficially from the skin. However, no statistical analysis was performed.

Our results showed that the distance between IJV and CCA was longer at the right side than the left side, but there was no significant difference. This result was consistent with two previous ultrasound studies [14, 17]. The previous three CT studies [5, 6, 23] did not mentioned much about this parameter. Lim [5] noticed that more than a half of the IJVs were within 1 mm of their CCAs. In our study, we found that 67 (43.5%) out of 154 IJVs were within 1 mm of their CCAs. In this group of the IJVs, the potential risk of traversing the veins and inadvertent puncturing the CCAs might be increased.

The majority of the IJVs in this study were in a lateral position (94.2%). This finding was consistent with the previous ultrasound studies [5, 13, 14, 17, 19]. The heterogeneity of the terms used for evaluating the position of the IJVs in relation to CCAs in the previous studies made the interpretation and comparison of data difficult. Some studies included the term anterolateral [15, 16, 18], overriding [17], overlapping [6, 21], contacting, and separating type [6]. The terms of overriding and overlapping could be comparable to the anterior position in our study (2.6%), which was considered riskier than the other types for puncture of the CCAs [21]. Moreover, we also found the posterior position of the IJVs (3.2%) were anatomical variations that could be missed without imaging guidance and potentiating inadvertent puncture of the CCAs. No medially located IJV was found in our study. By contrast, in a CT study by Lim et al. [5], there were 2 left IJVs (1.1%) out of 176 IJVs in the medial position, 2 right IJVs (1.1%) out of 176 IJVs in the posterior position, and 22 IJVs (12.5%) out of 176 IJVs in the anterior position. The reason for this variation may be the smaller sample of our study or some limitations of the study by Lim et al. [5] that most of the cases reviewed had a history of cancer and prolonged chemotherapy, which could alter the venous structure. In other ultrasound studies [13-19], there were also variations in the position of the IJVs. However, it was quite difficult to compare the results with our study because of the wide variations in ultrasound transducer position and direction across studies.

Our results clearly demonstrate that the right IJVs had a much wider diameter and ran more superficially than the left IJVs. Although there was no significant difference in the distance between IJVs and CCAs, the right side tended to have more separation distance than the left side (1.3 ± 0.6 mm vs. 1.2 ± 0.9 mm). Furthermore, variations in position in relation to the CCAs were found more frequently at the left side (6/77, 7.8% vs. 3/77, 3.9%). We may imply that, it is relatively safer to cannulate at the right side of the neck than the left side. This result for Thai people is consistent with other studies [6, 7, 14].

Conclusion

There were anatomical variations of the IJVs, including diameter, depth from skin surface, relative distance from the CCAs and position in relation to CCAs, which remained potential risk when jugular venous access is attempted. We have reported these results to make practitioners aware of the potential problems in common procedures and to reveal the expected location and anatomic variations of the IJVs in the proximity of the CCAs. We recommend that ultrasound-guided access to the IJVs be routinely applied to increase the chance of successful cannulation and minimizing the risk to the patients.

The authors have no conflict of interest to declare.

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