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Ultrasound-guided anatomical evaluation and percutaneous cannulation of the right internal jugular vein in infants <4000 g

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Abstract

Background: The commonly preferred right internal jugular vein was investigated in terms of its dimensions, the relationship between its dimensions and anthropometric measures, and the outcomes of its cannulation in infants. Data regarding its position with respect to the carotid artery indicated anatomical variation.

Aim: The aim of this study was to share our observations pertaining to the anatomy and position of the right internal jugular vein with respect to carotid artery using ultrasound and our experience with ultrasound-guided right internal jugular vein access in neonates and small infants.

Materials and methods: A total of 25 neonates and small infants (<4000 g) undergoing ultrasound-guided central venous cannulation via right internal jugular vein within a 6-month period were included. Ultrasound-guided anatomical evaluation of the vein was used to obtain the transverse and anteroposterior diameters, the depth from skin and the position with respect to the carotid artery. Real-time ultrasound-guided central cannulation success rates and complication rates were also obtained. The patients were divided into two groups with respect to their weight in order to compare both the position and the dimensions of right internal jugular vein and cannulation performance in infants weighing <2500 g and ⩾2500 g.

Results: The position was lateral to the carotid artery in 84% of all infants and similar in both groups. The first-attempt success rates of cannulation were similar (70% vs 73.3%) in both groups, with an overall success rate of 88%.

Conclusion: Right internal jugular vein revealed a varying position with respect to carotid artery with a higher rate of lateral position. The presence of such anatomical variation requires ultrasonographic evaluation prior to interventions and real-time guidance during interventions involving right internal jugular vein.

Keywords

Central venous catheter, neonates, ultrasound

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Introduction

The placement of central venous catheters is frequently required in critically ill neonates and small infants, especially when the umbilical vein is not available and peripheral or other central venous access such as epicutaneo-caval catheter is impossible. The internal jugular vein (IJV) can be preferred over subclavian and femoral veins because of its wider diameter.[1,2] The complication rates, including pneumothorax and haemothorax, are also lower in IJV access.[1–3] In small infants, the anatomical landmarks recommended for IJV cannulation in adults may not be useful due to their immaturity; furthermore, the vein diameter is small and the access site is narrow. The IJV has been reported to be a safe and effective route of venous access, and ultrasonographic evaluation and guidance during cannulation have proven to be a useful approach to improve the success rates and to reduce the complication rates in

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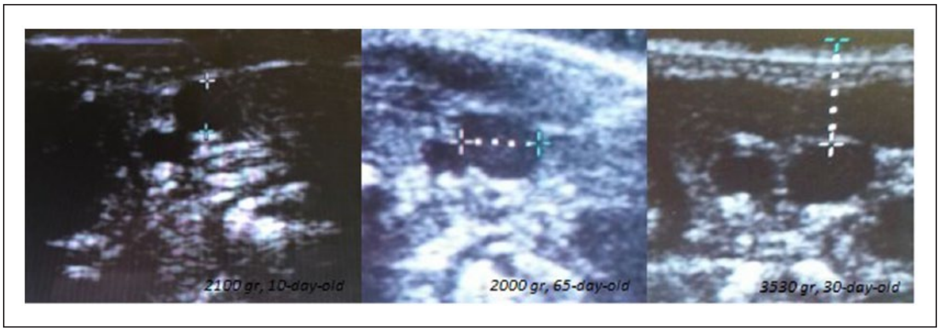

Figure 1. Frozen ultrasound images showing anterolateral and lateral position of RIJV with respect to carotid artery and measurement of diameters with depth from skin.

neonates and small infants.[1,2,4,5] In last years, ultrasound (US)-guided brachiocephalic vein (BCV) has gained interest especially in small infants due to its several advantages.[6–9] However, training in image acquisition and in-plane needle insertion technique with US dedicated to BCV access is required, although the learning curve was suggested to be shorter than the other vascular access techniques.[9] In our practice, our first choice has often been the right side for IJV cannulation, because of our higher experience on US-guided out-of-plane right internal jugular vein (RIJV) access due to its more straight forward path to the superior vena cava with similar dimensions compared to the left.[2]

The data pertaining to the position of the RIJV with respect to the carotid artery (CA) are not clear and may be related to either the position or the size of the infants. This retrospective study was designed to share our observations pertaining to the anatomy and position of the RIJV using US and to share our experience regarding outcomes of US-guided RIJV access in neonates and small infants.

Methods

After obtaining Institutional Ethical Committee approval (20 March 2018, GO 18/270-13), the neonates and infants <4000 g requiring central venous cannulation during 6 months between 1 September 2017 and 1 March 2018 were retrospectively assessed in terms of ultrasonographic evaluations of the RIJV and outcomes of the US-guided central venous cannulation procedures. None of the infants had prior interventions (surgery or catheterization) in the RIJV, and there were no vascular malformations; none of the patients was receiving any vasoactive drugs or active volume resuscitation. The indications for central venous cannulation were either for long-term use in intensive care unit (ICU) or after operations such as duodenal atresia or gastroschisis.

All the cannulations were performed in the operating room. All infants were under general anesthesia with muscle relaxation, endotracheally intubated and mechanically ventilated maintaining the peak airway pressure between 10 and 15 cm H_2O without positive end-expiratory pressure (PEEP). The patients from ICU were already endotracheally intubated and mechanically ventilated when scheduled for either central cannulation or surgery, whereas the others scheduled for surgery were endotracheally intubated and mechanically ventilated as indicated due to the surgical procedure. The infants were laid on gel pads to obtain a position aligning torso and lower extremities, and the head was rotated approximately 45°–60° to the contralateral side and lowered sufficiently to obtain a wide area of the neck for vascular access by placing a roll under the shoulders supporting the neck. Trendelenburg position was not used. Ten percent povidone iodine (PI) solution was used to provide an aseptic access site, and after sterile draping, the US transducer was covered with a sterile cardboard camera cover for surgery (Medbar®, İzmir, Turkey) with US gel inside on the transducer. The US machine (SonoSite, Titan, WA, USA) had the freeze and caliper features facilitating the measurements. The US transducer (40 mm linear probe, 10–5 MHz) was applied perpendicular onto the skin over the vascular structures in the neck between the cricoid cartilage and the clavicle. The transducer position was adjusted by slight movements proximally and distally with minimal pressure exerted on the skin to obtain the widest cross-sectional dimensions of the RIJV. The sonographic images were fixed using the freeze feature, and dimensions were measured using the caliper feature and were recorded. The position of the RIJV with respect to the CA was described as well as its dimensions (Figure 1). The 4 F catheters (DLR 4 F, double lumen 8 cm catheter, 0.018 in. 50 cm guidewire, Istanbul, Turkey) were placed according to the dimensions of the RIJV. The catheter diameter was chosen according to the diameter of RIJV to be approximately 1:3 of the transverse diameter of the vein: simply as 4 F when the RIJV transverse diameter was >4 mm (3 F when >3 mm and 5 F when >5 mm). US-guided needle insertion and blood withdrawal were used to confirm access to the IJV (Figure 2). The catheter was introduced using the Seldinger technique, and an ultrasonographic long-axis view (LAX) was taken to confirm the placement of catheter inside the RIJV

Figure 2. US-guided needle insertion and blood withdrawal to confirm access to RIJV (2000 g, 3-day-old).

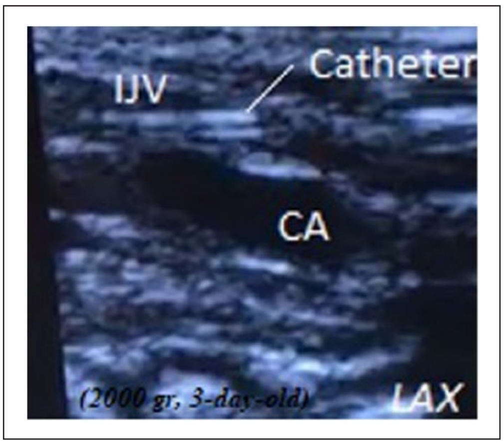

Figure 3. Location of catheter confirmed using ultrasound long-axis view (LAX).

(Figure 3). The catheter tip position was confirmed using portable radiography. The catheters were secured with sutures.

The ultrasonographic measurements and the cannulations were performed by the same anesthetist experienced in the US technique. More than three attempts (>3 skin punctures) were considered to be unsuccessful and indicated a change in vascular access site. The recommended maximum attempt number was suggested to be five; however, we preferred to attempt no more than three in order to avoid the risk of complications such as puncture of close structures.[4]

In order to compare the position and dimensions of RIJV and also the success rates of cannulation in infants weighing <2500 g and ⩾2500 g, the infants were grouped into two with respect to their weight.

Statistical analysis

Continuous numerical variables were assessed by the Shapiro–Wilk test to evaluate whether they were close to normal. Descriptive statistics for continuous numerical variables were defined using mean ± standard deviation (SD) or median (min–max), whereas the categoric variables were defined as numbers of patients and percentages (%). The significance of difference between groups in terms of age was analyzed by Mann–Whitney's U-test. The significance of difference between groups in terms of transverse, anteroposterior diameters and depth was analyzed using Student's t-test. The categorical variables were analyzed by Fisher's exact test. The data were analyzed using IBM SPSS Statistics (IBM Corporation, Armonk, NY, USA). Value of p less than 0.05 was accepted to be statistically significant.

Results

There were 25 neonates and infants <4000 g requiring central venous cannulation during 6 months between 1 September 2017 and 1 March 2018. The median body weight was 2800 (range: 1510–3890) g and the median age at the time of the procedure was 10 (range: 0.083–88) days. The patients were grouped according to their body weights; Group I was defined as those <2500 g and Group II ⩾2500 g (Table 1).

The position of the RIJV was lateral with respect to CA in 84% of all infants and similar in both groups (Table 2). The transverse and anteroposterior diameters, the depth from skin and the position of the RIJV with respect to CA are shown in Table 2. The transverse diameters were significantly smaller in patients <2500 g than in those ⩾2500 g, whereas the anteroposterior diameters were similar. The depth of the RIJV from the skin was also similar between groups.

Central venous access from the RIJV was successful in 22 patients. The first-attempt success rates were 70% and 73.3% in Groups I and II, respectively ($p = 0.999$) (Table 3). One of the three patients who had unsuccessful access via the RIJV had access from the right BCV and two had access from the left IJV. There were no complications pertaining to the procedures and no arterial punctures occurred.

Discussion

We observed that the RIJV had a varying position with respect to the CA with a higher rate of lateral position. Our first-attempt success rate of cannulation was 72%, with an

Table 1. Demographic data of the patients.

	Group I (<2500 g) ($n=10$)	Group II (⩾2500 g) ($n=15$)
Age (days), median (min–max)	4 (0.083–52)	28 (0.083–88)
Gestational age (week), median (min–max)	34.55 (28.6–39.0)	38 (28.3–40.7)
Postmenstrual age (week), median (min–max)	36 (29.8–39.40)	41.3 (36.3–49.3)
Preterm/term	3/7	5/10
Body weight (g), median (min–max)	2015 (1510–2475)	3400 (2600–3890)
Gender (F/M)	4/6	8/7

Table 2. Success rates of central venous access in groups.

	Group I (<2500 g) ($n=10$)	Group II (⩾2500 g) ($n=15$)	Total ($n=25$)
First attempt	70% ($n=7$)	73.3% ($n=11$)	72% ($n=18$)
⩾Second attempts	20% ($n=2$)	13.3 % ($n=2$)	16% ($n=4$)
Failure	10% ($n=1$)	13.3% ($n=2$)	12% ($n=3$)
Overall success rate	90% ($n=9$)	86.6% ($n=13$)	88% ($n=22$)

Table 3. Dimensions and position of RIJV of patients.

	Group I ($n=10$)	Group II ($n=15$)	p-value
Transverse diameter (mm), mean ± SD	4.64 ± 0.72	5.67 ± 0.70	0.002[a]
Anteroposterior diameter (mm), mean ± SD	3.86 ± 0.84	4.33 ± 0.49	0.089[a]
Depth (mm), mean ± SD	6.07 ± 1.20	6.23 ± 1.13	0.732[a]
Lateral position	8 (80%)	13 (86.7%)	0.999[b]

[a]Fisher's exact test.
[b]Student's t-test.

overall success rate of 88% in anesthetized, endotracheally intubated and mechanically ventilated newborns and infants <4000 g.

The position of RIJV with respect to CA varied in previous studies. In a study by Di Nardo et al.,[10] the RIJV was observed to be anterolateral, lateral, and anterior (complete overlap) with respect to CA in 66%, 28%, and 6% of infants weighing <5 kg, respectively. In a similar study by Montes-Tapia et al.,[11] the position was reported to be lateral in 69% of 100 neonates weighing between 540 and 2480 g. In another study investigating patients between 0 and 18 years of age including nine patients aged between 0 and 1 month, the IJV was reported to be mostly lateral or anterior to the CA with an overall variation rate of 7.7% in all age groups.[5] The position of IJV was also described by classifying the degree of its overlap with CA as major (>50%), minor (<50%), and no overlap.[2] The complete overlap was reported to be 50% and 72.9% in patients weighing 1.4 ± 0.2 kg and 2.8 ± 0.5 kg, respectively.[2] In our study, a complete overlap was not observed, and our results were closer to those of the study by Montes-Tapia et al.[11] These documented variations in anatomical position of IJV with respect to CA prove US to be crucial for both the evaluation prior to central venous cannulation and the real-time guidance for needle and guide advancement during the procedure to avoid adverse events and complications. Results from a larger sample size will provide a clearer data when the observational trial NCT03604094 is completed.

In the study by Montes-Tapia et al. conducted in 100 newborns weighing between 540 and 2480 g, the overall success rate and the first-attempt success rates of cannulation were 92.3% and 55.6%, respectively, in low-birth-weight (LBW; 1501–2480 g) infants.[4] Similar to that study, the overall success rate was 90% in our study. However, the first-attempt success rate was 70% in our patients weighing between 1510 and 2475 g. Montes-Tapia et al.[11] reported the dimensions with regard to the groups individually and reported the anteroposterior diameter of the RIJV in LBW (1800 (range: 1501–2480) g) infants to be 2.7 (range: 1.3–4.5) mm; therefore, the wider RIJV diameter in our patients may have led to our higher rate of first-attempt success rate. However, in the study by Montes-Tapia et al.,[11] midazolam and fentanyl sedation was provided for the infants, 73% of whom were mechanically ventilated; the remaining spontaneously breathing ones may have had insufficient sedation reducing the first-attempt success rate. Our anesthetic management including general anesthesia and muscle relaxation, providing immobility, and abolishing the generation of negative intrathoracic pressure for spontaneous breathing may have increased the first-attempt success rates.

In last years, the BCV access in small infants has been reported to have advantages over IJV access.[6–9] The BCV is suggested to be the largest vein accessible with US, incompressible with either transducer compression, needle advancement, or respiration, accessible with in-plane technique allowing observation of needle tip advanced in the vein. These advantages over IJV access result in higher success rates. Our experience on US-guided BCV access in small infants has been improving since last year. In our report, we performed a rescue BCV access in one infant. Our BCV access number is increasing as our experience improves.

Limitations

The dimensions of RIJV were reported to be affected by airway pressures and position of anesthetized patients.[12–14] In our study, all infants were examined under general anesthesia, with endotracheal intubation and mechanical ventilation, without application of Trendelenburg position. The anesthetic management was standardized, ensuring that all the dimensions were measured under general anesthesia in infants in supine position (head rotated the other side with a roll under the shoulders). The head rotation, which is the generally recommended technique for IJV access, may have affected the perception of the IJV being lateral or anterolateral with respect to CA. However, since it is the generally recommended technique, the position of the RIJV being lateral or anterolateral with respect to CA with head rotation may prove to be beneficial in order to avoid puncture of CA. The standardized anesthetic management provided us a standardized measurement of RIJV, but since general anesthesia is not mandatory for RIJV cannulation, the data of our study regarding the dimensions and success rates of cannulation should be considered in terms of these standardized circumstances. However, the intravascular volume has a true impact on dimensions of IJV.[15–17] In our study, all patients had a peripheral vascular access and receive fluid infusion to maintain their baseline hourly requirements, but in need of a central venous access for either long-term use in ICU or after surgery. We could not obtain a record of those fluid infusions pertaining to their duration and rate prior to the procedures due to the retrospective nature of our study. Among our patients, there were ones who had different diagnosis such as duodenal atresia or gastroschisis which may have caused a difference in volume status leading to an effect on vascular dimensions. These are to be addressed in our prospectively designed observational study (no. NCT03604094).

The ultrasonographic evaluations were performed by a single experienced anesthetist and no repetitions were performed to assess variability and reproducibility. The placement of the US transducer was adjusted in order to obtain the widest cross-sectional area; therefore, we cannot suggest an exact point for vascular access on the small area of the skin between the cricoid cartilage and the clavicle.

The time required for vascular access was not recorded, so we cannot compare with previously reported times. The tip location was confirmed using portable radiography. We used chest X-ray both to confirm the correct placement of the tip of the catheter and to ensure that no pneumothorax developed. However, using intracavitary electrocardiographic confirmation of catheter tip location can be considered as a safe and effective method to avoid exposing the infants to X-ray as was reported in a recent study addressing infants <5 kg.[18]

Another method to be discussed is the use of 10% PI solution for asepsis in our study. As our Pediatric Surgery Department policy, we do not prefer to use chlorhexidine in 70% isopropyl alcohol in newborns (CHX-IA) and small infants due to potential development of chemical burns and skin injuries.[19–21] Besides, there are insufficient safety data to recommend chlorhexidine in alcohol or aqueous solutions for infants at age <2 months.[18] Chlorhexidine was reported to be superior in preventing skin colonization, but there is no evidence of it being superior to PI in preventing septicemia.[22] However, PI has the potential to be absorbed leading to thyroid dysfunction.[22] In a recent paper by Kieran et al.,[23] PI and CHX-IA were compared in terms of catheter-related blood stream infection (CR-BSI) rates in preterm infants.[23] In this study, CR-BSI rates were not different between two agents. The skin damage rates were also not different and were reported to be very few, as the investigators minimized the amount of agent used avoiding the spread throughout the skin to reduce the potential risk of adverse skin reactions. However, PI caused a rise in thyroid stimulating hormone (TSH) requiring treatment with thyroxine in 5.1% of patients.[23] Previously, this thyroid dysfunction related to PI was also defined in infants exposed to PI repeatedly or for long periods.[24] This adverse effect should be considered in terms of risk–benefit ratio when a choice is to be made between PI and CHX-IA use in preterm infants. The risk of absorption can be minimized by washing the skin immediately after the procedure as recommended for any disinfectant.[21] As our hospital policy, the potential risk for skin damage hindered our CHX-IA use in newborns; however, as the adequately powered controlled trials especially designed for its safety increase, it will surely be considered as a true alternative to PI for infants. Since there is no official recommendation for antisepsis in infants regarding the use of any disinfectant, these agents must be used with caution anticipating any potential hazard.[21,22]

The security of the catheters was provided by sutures. Sutureless security may have been considered; however, we do not actually have such devices or tapes in our hospital.

Conclusion

The anatomical variations in the position of the RIJV with respect to the CA in neonates and small infants require real-time US guidance both prior to and during interventions concerning vascular structures in the neck.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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