Original Article

Anatomical relationship between the internal jugular vein and the vertebral artery: An observational study in pre-school children using ultrasound imaging

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Abstract

Background and Aims: Central venous cannulation is performed in children requiring vasopressor use, long-term antibiotics, chemotherapy or parenteral nutrition. The internal jugular vein is the preferred site for cannulation. Though, there are several studies describing the relation of the common carotid artery (CCA) and internal jugular vein (IJV) in the neck, there is a paucity of data regarding the anatomical relationship between the vertebral artery (VA) and the IJV. This study aims to describe the anatomical relationship between the IJV and the VA using ultrasound imaging in pre-school children in India.

Material and Methods: Prospective observational cross-sectional study of 67 randomly selected children (age <5 years) who underwent an ultrasound examination of the right side of the neck, in a position mimicking central venous cannulation, to identify the relationship between the IJV and VA. The skin to the vertebral artery depth (D), width of the VA (W), distance between the IJV and the VA (DIV) was measured. Based on these, children were classified into high risk, moderate risk and low risk category for VA puncture.

Results: Of the 67 children, 15 (22.4%) patients belonged to the high-risk group, 25 (37.3%) belonged to the moderate-risk group and 27 (40.23%) belonged to the low-risk group.

Conclusion: In addition to localizing the carotid artery, pre-procedural scanning or real-time ultrasound examination to establish the anatomical relation of the IJV to the VA is imperative to alert the clinician of the possible risk of VA puncture.

Keywords: Internal jugular vein, pediatric, ultrasound-guided cannulation, vertebral artery

Introduction

Central venous cannulation is performed in children requiring vasopressor use, long-term antibiotics, chemotherapy or parenteral nutrition. The commonly used vascular access sites are the internal jugular vein, subclavian vein and the femoral vein.[1] Internal jugular vein (IJV) is preferred in the pediatric population due to its superficial position as well as technical ease of cannulation. Accidental arterial puncture and hematoma formation during IJV cannulation in children can increase morbidity and decrease success rates. The use of real-time ultrasound guidance has significantly decreased complications and improved rates of successful cannulation.[2]

Central venous cannulation in children is technically more challenging than in adults due to the anatomically short neck, small caliber of neck vessels and collapsible nature of the low

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Access this article online	
Quick Response Code:	Website: https://journals.lww.com/joacp
	DOI: 10.4103/joacp.JOACP_684_20

How to cite this article: Ganesh A, Paarel JP, Punnen GE, Siddarth R, Prakash KS, Sahajanandan R. Anatomical relationship between the internal jugular vein and the vertebral artery: An observational study in pre-school children using ultrasound imaging. J Anaesthesiol Clin Pharmacol 2022;38:544-7.

Submitted: 26-Dec-2020 **Revised:** 23-Mar-2021
Accepted: 03-Apr-2021 **Published:** 17-Nov-2022

pressure veins compared to adults.[3] During this procedure, inadvertent arterial puncture is a feared complication due to the proximity of the common carotid artery (CCA) and the vertebral artery (VA) to the IJV. There is a postulated higher risk of unintentional puncture of the vertebral artery in children than in adults as the relative size of the VA to the IJV is larger and the distance between the IJV and the VA is smaller.[4] Accidental puncture of the vertebral artery during IJV cannulation can result in VA pseudoaneurysms, arteriovenous fistula formation, dissection and thrombosis that can produce sequelae such as neurological deficits due to ischemia.[5]

The knowledge of the varying anatomical relationship between the VA and IJV will prevent inadvertent complications during cannulation.[6,7] As the needle approaches the IJV, there is compression of the anterior wall toward the posterior wall, often resulting in a through and through puncture of the IJV, without aspiration of blood. This can result in the needle approaching the VA, which usually lies posterior to the IJV. There are case reports of VA puncture during IJV cannulation in adults, even with the use of real-time ultrasound imaging especially with "out of plane" technique. Therefore, in this study, we analyze the anatomical relationship between VA and IJV in pre-school children in India using ultrasound imaging.

Material and Methods

This was an Institutional Review Board approved, prospective cross-sectional observational study performed in a tertiary care center in South India. Over a period of 2 months (September-October, 2014), 67 children were randomly selected from the Child Health and Pediatric Surgery wards of our center after obtaining informed consent from their parents.

Pre-school children of 0-5 years were included in the study. We excluded syndromic children, ex-premature children, children with neck mass or swellings and abnormal anatomy.

The sample size was based on the study by Kayashima *et al*.[8] which showed that 72.7% of cases had moderate to high risk. Using the equation $n = \alpha \times p \times (100-p)/d^2$, where α is the standard normal ordinate, p is the proportion of interest and d is the precision or allowable error. In our study, with α 1.96 (rounded to 2), p = 72.7, precision (d) of 11%, sample size was calculated as 67.

Ultrasound examination of the right IJV was done in supine with the neck in extension with 15-30° rotation to the left to mimic the common position adopted during central venous cannulation. Extension was achieved by placing a small rolled-up towel with a diameter of 5 cm below the child's shoulder. Ultrasound examination was done by an anesthesiologist with an experience of more than 30 cases of pediatric central venous cannulation and a consultant radiologist with an experience of more than 200 adult and pediatric neck ultrasound examination. A high-frequency linear probe (L10-5 MHz, GE Venue 40) in vascular mode was placed perpendicular to the skin at the midpoint between the suprasternal notch and mastoid process. Using B mode (2D) and color Doppler, the right IJV, CCA and VA were identified. The existence of the VA was confirmed by its branching from the proximal subclavian artery and its disappearance near the fifth or sixth vertebral transverse process in all cases [Figure 1].

The skin to the vertebral artery depth (D), width of the VA (W), and its distance from the internal jugular vein to vertebral artery (DIV) were measured using electronic calipers rounded off to the near 0.1 mm on an optimized, frozen transverse image. The skin to vessel measurements were made from the skin surface of the anterior neck to the anterior vessel wall. The extent of overlapping between the VA and IJV was classified into overlapping, partially overlapping and non-overlapping, as described by Kayashima *et al*.[8] Based on the measured D, W, DIV and degree of overlap of IJV and VA, children were classified into three groups [Figures 2 and 3].

Data was entered using the EPIDATA software. Summary statistics were reported on demographic and clinical characteristics. All categorical variables were reported using frequencies and percentages and continuous variables were expressed in terms of mean ± standard deviation (SD). Differences were considered significant at $P < 0.05$. Statistical analyses were performed using SPSS 25.0 software (Statistical Product and Service Solutions). One-way ANOVA (Analysis of Variance) and Bonferroni post-hoc tests were done between the three groups to compare the distance between the IJV and VA.

Results

Among the 67 children, 37 (55) % were males and 30 (45%) were females. The mean age (SD) was 32.03 (16.75)

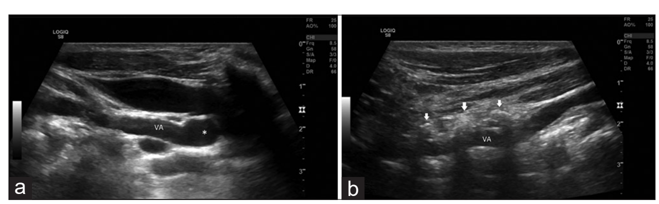

Figure 1: Longitudinal ultrasound images showing (a) origin of the vertebral artery (VA) from the proximal subclavian artery (*) and (b) course of the vertebral artery (VA) through the foramen transversarium (arrows indicating transverse process of cervical vertebrae) as it ascends in the neck

months. The mean D, W and DIV were 15 (14.3), 3.1 (0.6) and 2.1 (1.6) mm, respectively. VA was identified in all children (100%) with the help of color Doppler in addition to B-mode imaging.

In our study, 15 (22.4%) children belonged to high-risk group, 25 (37.3%) belonged to moderate-risk group and 27 (40.2%) belonged to low-risk group. The mean distance between IJV and VA was 2.1 mm (SD 1.598) for the high-risk group; 3.5 mm (SD 1.262) for the moderate-risk group and 3.8 mm (SD 0.949) for the low-risk group which was statistically significant ($P < 0.001$), implying that the risk of VA puncture is significantly high in patients with the overlapping of IJV and VA. The mean depth of the IJV from the skin was 6.57 mm (SD 2.069). The mean depth varied from 6.1 mm at 2 years of age to 7.8 mm for a 5-year-old child [Table 1].

Discussion

Though, there are several studies describing the relation of the CCA and IJV in the neck, there is a paucity of data regarding the anatomical relationship between the VA and the IJV.[9-11] While there are several studies describing the risk for accidental carotid artery puncture during IJV cannulation, there is paucity of studies regarding the risk of accidental VA puncture, except for a few case reports.[5]

Vertebral artery can be easily identified in children due to its larger size, tracing its origin from the subclavian artery. We identified the VA in all 67 children and our results are comparable to Kayashima *et al.*[8] who could identify the VA in 54 out of 55 study patients.

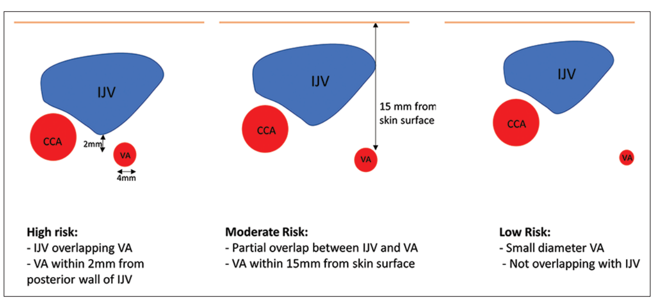

Figure 2: Risk stratification based on anatomical relationship of vertebral artery to IJV, depth of VA from skin and diameter of VA (adapted from Kayashima *et al.*[8])

Kayashima *et al.*[8] described the high-risk anatomy based on the relation between the IJV and VA. These high-risk features include (a) percentage of overlap between IJV and VA (b) VA located less than 2 mm from the posterior wall of IJV (c) distance of VA <15 mm from the skin surface (d) diameter of VA >4 mm. Of these, the degree of overlap and proximity of VA to the IJV may be a more important risk factor for accidental VA puncture during IJV cannulation, particularly in smaller children, where, very often, the IJV walls collapse toward each other as the needle approaches, especially if the child is breathing spontaneously or is hypovolemic. This can result in the needle piercing the posterior wall of the IJV and inadvertent VA puncture.

About 22.4% of our study patients belonged to the high-risk group which was significantly higher compared to the 12.7% high-risk anatomy observed by Kayashima *et al.*[8] Our results were comparable to Matsushita *et al.* who found that in 67% of children, the IJV was either fully or partly overlapping the VA.[7] Only 41% of our patients had non-overlapping IJV and VA, which is significantly different from Kai-Ming Yuan *et al.* who observed that in 97.14% cases, the VA was lying lateral to IJV.[12]

The mean distance between the IJV and VA below 2 years and at 5 years was 3.3 and 3.25 mm, respectively, which implies that the risk of puncture of the VA does not change with an increase in age. In the high-risk group, the mean distance between the IJV and VA was 2.1 mm implying there exists a very small average margin of error for accidental vertebral artery puncture.

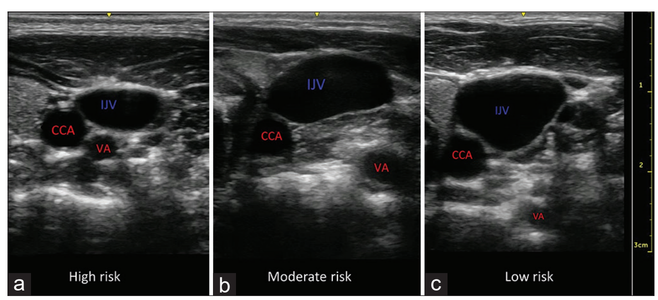

Figure 3: Transverse ultrasound images showing high-risk (a), moderate-risk (b) and low-risk (c) anatomical relation between VA, IJV and CCA. IJV: internal jugular vein, CCA: common carotid artery, VA: vertebral artery

Table 1: Observed measurements across different risk categories

	Low Risk (Non-Overlapping)	Moderate Risk (Partial Overlapping)	High Risk (Complete Overlapping)	*P*
DIJV	7.07 (SD 2.319)	6.36 (SD 1.846)	6.00 (SD 1.852	0.226
DVA	13.22 (2.006)	14.44 (SD 3.267)	14.33 (SD 2.498)	0.209
W	3.19 (SD 0.681)	3.08 (SD 0.702)	3.13 (SD 0.640)	0.857
DIV	3.85 (SD 0.945)	3.48 (SD 1.262)	2.13 (SD 1.598)	<0.001

DIJV: Distance of IJV from skin, DVA: Distance of vertebral artery from skin, W: Width of vertebral artery, DIV: Distance between IJV and vertebral artery

Further, in our study, the mean depth of VA from the skin (DVA) was less than 15 mm across all three risk groups. Kayashima *et al*. in their study observed mean DVA of less than 16 mm across all three groups. This is a significant finding as the introducer needles provided with standard central venous cannulation sets are 25 mm (4.5F, Vygon) and 38 mm (5.5F, Arrow) long. Hence, even if the needle is angled at 45-60° to the skin during puncture, there is risk of accidental puncture of the VA.

None of our patients had VA >4 mm. Across all the three groups, there was no significant difference in the VA diameters (mean range of 3.08-3.19 mm) similar to the observations made by Kayashima *et al*.[8] As the VA diameter was small across all the three groups, we did not look at the ratio of the cross-sectional area of IJV with CCA and VA.

The study had certain limitations. As this study was performed on non-anesthetized children, we did not consider the effects of preoperative fasting, anesthetic agents, positive pressure ventilation and Peak end expiratory pressure (PEEP) on venous caliber and tone unlike other studies done on anesthetized children.[13] Since children in this study did not undergo insertion of a central line, the actual risk of VA puncture and whether the use of ultrasound aided successful cannulation were not calculated. We looked only at the anatomy of the neck on the right side and did not consider other factors other than age like gender and body mass index which can vary the depth of the vascular structures. The scoring system used to calculate the risk adapted from Kayashima *et al*.[8] is not a validated tool.

Conclusion

In our study, 59.7% belonged to the moderate- to high-risk group for VA puncture during IJV cannulation due to IJV overlapping VA either partially or completely and close proximity of IJV and VA. Therefore, in addition to localizing the carotid artery, pre-procedural scanning or real-time ultrasound examination to establish the anatomical relation of the IJV to the VA is imperative to alert the clinician of the possible risk of VA puncture. Efforts should be made to adjust the direction and depth of needle to avoid VA puncture.

Acknowledgments

1. Dr. Sajan Philip George, former Head of the Department of Anaesthesia, Christian Medical College Vellore for constant support and guidance.
2. The Department of Anaesthesia technical staff for helping with the cases.
3. The Research Office and Institutional Review Board for guidance and access to the internal fluid research fund.

Financial support and sponsorship

Internal Research Fund, Christian Medical College, Vellore.

Conflicts of interest

There are no conflicts of interest.

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