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Ultrasonographic anatomic variations of the major veins in paediatric patients

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Editors' key points

- This study investigated localization of the internal jugular (IJV), subclavian (SCV), and femoral (FV) vein sites.
- The relevant percentages of anatomic variations obtained for all these areas support the future systematic use of ultrasound guidance to facilitate central venous cannulation in paediatric patients.

Background. The aim of our study was to describe the anatomic relationships in internal jugular (IJV), subclavian (SCV), and femoral (FV) vein sites.

Methods. One hundred and forty-two children had a two-dimensional (2D) ultrasound (US) evaluation of IJV, SCV, and FV sites. They were enrolled according to their age: 0–1 month old (*n*=9), 1 month old to 2 yr old (*n*=61), 2–6 yr old (*n*=22), 6–12 yr old (*n*=32), and 12–18 yr old (*n*=18).

Results. We found about 7.7% variation for the IJV. The most common anatomic variations were a lateral (nine children) or anterior (nine children) position of the IJV to the carotid artery. Regardless of the age category, about 9.8% of the anatomic variations were found for the FV. The most common anatomic variation in our study was that the FV ran anteromedially to the femoral artery (17 children). Anatomic variation of the SCV, regardless of age category, was about 7.4%. The most common anatomic variation was the SCV, which ran medially (10 children) to the subclavian artery.

Conclusions. The relevant percentages of anatomic variations obtained for all these areas support at least a systematic US screening before attempting to obtain central venous access, ideally using a US-guided technique.

Keywords: central venous catheters; femoral vein; jugular veins; paediatrics; subclavian vein; ultrasonography

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The main sites for central venous catheter insertions are the internal jugular (IJV), subclavian (SCV), femoral (FV), and arm veins (cephalic and basilic). In most cases, the success rates of catheter insertion are higher when using two-dimensional ultrasound (US) techniques.[1–4] US guidance for central venous access is mandatory, especially when there is a risk of hypovolaemia or anterior cannulation failure, in morbidly obese patients and in young children.[1–4] Anatomic variations, occurring in up to 18% of patients, could explain the occurrence of catheterization failures or complications of this landmark technique.[5 6] US evaluations were able to confirm variations in the position of the IJV and highlight other malpositions of the FV and the SCV in a paediatric population. The aim of our study was to describe the anatomic relationships of the IJV, SCV, and FV sites.

Methods

Patients

This study was approved by the local ethics committee and was in accordance with the Declaration of Helsinki (2000). After explaining the experimental procedure, we obtained parental written informed consent.

We prospectively studied paediatric patients for elective neurosurgery who underwent general anaesthesia with mechanical ventilation in the supine position before fluid expansion.

Patients with previous ventriculoatrial shunt, regional surgery or irradiation, cannulation, or deep venous thrombosis were excluded.

Technique

Structures were analysed with a US device (Acuson X300 Ultrasound System, Siemens Medical Solutions USA, Malvern, PA, USA). The US images were performed by a team practising in the anaesthesiology and intensive care unit of the Hôpital Neurologique Pierre Wertheimer (F.Du., S.G. and E.P.S.N.).

All children fasted for 6 h, but were allowed clear fluids (10 ml kg^{-1}) up to 2 h before surgery. Anaesthesia management of all patients followed standard procedures. After anaesthesia induction, mechanical ventilation was started. No positive end-expiratory pressure (PEEP) was applied during the mechanical ventilation. No neuromuscular blocking agent was administered. Haemodynamic variables, including heart rate and systolic, diastolic, and mean arterial pressures, were continuously monitored and recorded before and after measurements.

After anaesthetic induction and 15 min before US measurements, the patient was placed in a reverse Trendelenburg position of 15°, a suitable posture according to the predefined central venous site: neutral position of the head (IJV); lower limb abduction (FV) and neutral head position with a transverse block placed under the shoulders (SCV). The US used for this study involved the acquisition of real-time two-dimensional (2D) images using a transducer at high frequencies (user selectable multi-hertz imaging with 2D beam steering and trapezoidal imaging capabilities, frequency bandwidth 5–13 MHz and a VF13-5SP transducer if the patient's weight was <10 kg). The vein was identified by its position relative to the artery and its absence of pulsatility and collapsibility were studied by applying gentle pressure. Normal vein locations were defined by their position relative to the satellite artery:[7 8]

- anterolateral for the IJV, the transducer was placed at the level of the cricoid cartilage (Fig. 1A);
- posteromedial or medial for the FV, the transducer was placed below the inguinal ligament over the pulsation of the femoral artery (Fig. 1C); and
- anteromedial for the SCV, the transducer was placed infraclavicularly (Fig. 1F).

The following parameters were measured: vein and artery diameter, the depth and distance between them, and the position of the vein compared with the artery (eight possible quadrants: anterior, posterior, medial, lateral, anteromedial, anterolateral, posteromedial, and posterolateral). To achieve accurate measurements, all images were obtained by the same investigator and were analysed later by two other investigators.

The internal diameters of the blood vessels were measured from the lateral to the medial wall using a calliper. The US device was calibrated so that the image projected was magnified at a 2:1 ratio. Measurement accuracy was on the order of 0.01 cm.

There were five age groups in this study: 0–1 month old (i.e. birth to 30 days old); 1 month old to 2 yr old (i.e. 31 days old to the day before the second birthday); 2–6 yr old (i.e. from the second birthday to the day before the sixth birthday); 6–12 yr old (i.e. from the sixth birthday to the day before the 12th birthday), and 12–18 yr old (i.e. from the 12th birthday to the day before the 19th birthday). The data collected included age, gender, weight, body surface area (BSA), diagnosis according to the neurosurgical procedure, cross-sectional vessel diameter and depth (from the skin surface), and the time required to measure the three bilateral vessels in the central sites using the US procedure. BSA was calculated based on height and weight using the Haycock method.[9]

Statistics

The Fisher exact test was performed to compare anatomic venous location variations between the right and left sides within each age category. All results are expressed as median [median absolute deviation (MAD)], except age, which is expressed as median and range. *P*-values less than the chosen level of 0.05 were regarded as statistically significant. All statistical analyses were performed using StatView for Windows (version 4.57; Abacus Concepts, Berkeley, CA, USA).

Results

A total of 142 children, ASA I or II, were enrolled in this prospective study. None of the patients had a history of previously attempted central venous cannulation. The patient characteristics of the study subjects are summarized in Table 1.

A total of 852 measurements (three central venous sites explored bilaterally in 142 patients) were performed with the US procedure, lasting 13 (4) min for each patient. Anatomic variations are presented in Table 2 and in Figure 1B, D, E, G, and H.

The cross-sectional internal diameters of the blood vessels studied are summarized in Table 3. There were no accidental arterial punctures in the children who underwent central venous cannulation.

Discussion

US is considered the gold standard for vascular access placement. Many authors have stated that direct US visualization of a central vein provides advantages over 'blind' techniques.[3–5 10–18] The main advantage of US-guided interventions lies in the fact that the needle position can be seen in real-time, which increases the number of successful central venous cannulations.[4 17]

Even though both the National Institute for Health and Care Excellence and new evidence-based guidelines recommend the use of US guidance when placing central venous catheters, this has not been universally accepted.[4 13 19–21] Critics have raised concerns about the small evidence base and have questioned the advantages of US for regular practitioners.[19–21] Furthermore, US has its limitations in vascular access: the need for special equipment, the high cost, and the time required to master the technique.[3 4]