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Safety and efficacy of ultrasound assistance during internal jugular vein cannulation in neurosurgical infants

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Abstract *Objective:* Ultrasound guidance (USG) for internal jugular cannulation is the best solution in difficult settings where paediatric patients are involved. This is an outcome study on efficacy and complications of the USG for the internal jugular vein (IJV) cannulation in neurosurgical infants as well as an ultrasound study of anatomical findings of the IJVs in infants. *Design and settings:* A prospective study conducted in two Academic Neurosurgical hospitals. *Participants:* In 191 babies (body weight <15 kg), anatomical findings were studied. We performed CVC echo guided placement in 135/191 infants (weighting <10 kg). *Results:* After a brief training period, both institutions adopted a common protocol and USG device. We obtained successful cannulation in all patients. Carotid puncture (1.5%) was the only main complication registered and minor complications were poor. Time required for cannulation was 12.5 ± 5.7 min. Anatomical findings (in 191 patients) were IJV laterality in 34.6% cases, IJV antero-lateral in 59.7% and anterior in 5.7%. A linear relation was found between weight and internal jugular vein diameter even if $R^2 = 0.43$ and the model cannot be used to predict the exact size of the vein. In 62/135 babies weighting <10 kg, anatomical measurements were done in supine and Trendelemburg position. Trendelemburg position increases significantly ($P < 0.001$) IJV diameter, but not IJV depth. *Conclusions:* We considered ultrasound guidance as the first choice in infants because it can enhance IJV cannulation success, safety, and allows one to measure relationships and diameter of the IJV and optimise the central line positioning.

Keywords Pediatrics · Cardiovascular monitoring · Peri-operative care

Background

The use of central venous catheters (CVC) is of main stem importance during neurosurgical procedures for both anaesthesiologists and intensive care physicians. The internal jugular vein (IJV) might be used for central venous catheterization for its low incidence of mechanical and infectious complication [1]. Given the different vein diameters in children, incorrect positioning of CVC can lead to serious complications, such as perforation of the heart or great vessels [2]. A different problem could rise using an incorrect CVC size: a large gauge catheter could impair cerebral venous return especially in patients with cerebral masses or hydrocephalus, possibly precipitating an existing intracranial hypertension [3, 4]. Strong evidence reports on the use of USG cannulation for central venous catheterization in both adult and paediatric patients [5–7] and the key benefits achieved from the use of ultrasound are the reduction of fatal complications, such as haemothorax, pneumothorax and carotid haematoma, as well as the increased success rate and reduced time in cannulation [8]. To our knowledge, vascular anatomy of infants was assessed in few studies, such as by small autopsy series [9] or by angiographic methods [10]. Seemingly, to our clinical experience only three authors used ultrasonography to evaluate right IJV anatomy in children [11–13]. The primary goal of our study was to evaluate the outcome in terms of success rate, complications and cannulation time. Secondarily, we performed a US evaluation of IJV in paediatric patients weighting less than 10 kg to find a correlation between body weight or age and IJV cross-sectional diameter. The efficacy of the Trendelemburg position (TP) to increase the IJV cross-sectional diameter as well as the assessment of the anatomical relationship between carotid artery (CA) and IJV were also analysed.

Methods

After receiving the approval of the institutional ethics committees of the two centres involved in the study (National Neurological Institute “C.Besta”, Milan and Catholic University Medical School, Policlinico “A. Gemelli”, Rome), all patients below 2 years of age, undergoing neurosurgical procedures, were consecutively enrolled in the study from September 2001 to January 2007. We obtained parental written informed consent for the ultrasound-guided cannulation of IJV. Exclusion criteria for the study analysis were: (1) patients weighting more than 15 kg, (2) refusal of informed consent or (3) any contraindication for central venous line placement. All patients were under general anaesthesia and controlled ventilation during the procedure. Infants were NPO from 6 h before the surgical procedure; they usually had no IV line before surgery. Most infants did not vomit before surgical intervention, and vital parameters and metabolic status was stabilised preoperatively. There were three investigators for each centre; each of them had a 3 years experience in ultrasound guided vascular cannulation of more than 20 paediatric cases. They underwent a common training period within the same facility, using a similar US device (Sonosite Titan, Sonosite Inc. Bothell, WA, USA). Both centres used a 7.5 MHz ultrasound linear probe for vessel imaging and cannulation.

We performed bilateral imaging of IJV prior to the procedure, measured the cross sectional IJV diameter and depth and identified the dominant IJV, its patency and collapsibility or presence of intraluminal thrombosis by standard compression manoeuvre. A subgroup of infants (62 patients) underwent ultrasound imaging in two positions: head turned at 45° with a silicon shoulder roll in supine position (SP) or head turned at 45° with a shoulder roll in TP (the 15° inclination from the horizontal plane was achieved with a measurable surgical bed). The degree of head rotation was established using an adjustable goniometer and by verifying the angle of the head turn. IJV cross-sectional diameter and relative position to the carotid artery were measured by labelling a marker on the skin surface, indicating the sagittal line. Images were frozen and a second operator not blinded, but expert in ultrasound cannulation did the measurement. In 69/135 patients, after the anatomical assessment, IJV cannulation was performed with the head rotated at 45°, whereas the remaining patients underwent CVC positioning with 90° head rotation (Figs. 1, 2). In all patients, ultrasound-guided cannulation was performed where the best IJV visualisation was obtained, anyway at the apex of the angle formed between the two heads of sternocleidomastoid muscle (anteroinferior access). The exploration angle of the transducer was at 25° and the focal length 15 mm from the cap (skin surface). This allows high-resolution real time images of structures up to 40 mm deep to the skin. A sterile technique was used by draping the neck area and covering the ultrasound probe with a sterile plastic sheath. A real-time visualisation of the IJV was performed with hand-free technique for the cannulation [14]. Collected data were age, sex, weight, diagnosis according to neurosurgical procedure, dominant IJV, cross-sectional diameter of the IJV in SP and TP, depth of the IJV from the skin surface in SP and TP, and success rate. IJV relationships with CA were measured when the head was at 45° of head rotation. Complications were defined as major (carotid puncture, pneumothorax, haemothorax) or as minor neck haematoma, difficulty with wire insertion and multiple attempts (defined as skin or vein punctures before successful placements). Cannulation time was measured in minutes by the physician attending to the procedure, from skin puncture to catheter in site. We created a customised database containing patients' characteristics, imaging measurements and procedure findings. We expressed data as mean ± standard deviation and used a paired sample t test to compare means. A Pearson correlation coefficient was used to establish continuous variables. The Spearman rank correlation was used for ordinal data. A P value (two-sided in all tests) of <0.05 was considered significant. SPSS software, version 11, uses (SPPS Inc., Chicago, IL, USA).

Results

One hundred ninety-nine patients were enrolled in the anatomical study: eight of them were subsequently excluded because their weight slightly exceeded 15 kg, 56 patients had imaging only without attempt at cannulation while in 135 babies an ultrasound-guided cannulation of the IJV was always performed successfully as shown in Fig. 5. Overall complication rate was 16.7% and carotid puncture was the only major complication (1.5%). Minor complications included multiple skin puncture (6.1%), multiple vein puncture (3.8%) and multiple skin and vein puncture (5.3%). We found no statistical differences when comparing the successful or complications rate of the 45° and 90° head rotation.

Time required for ultrasound cannulation was 12.5 ± 5.7 min. Time of permanence of the central venous access was 5.2 ± 6 days. The evaluation of CVC-related infections was not an endpoint of the study: in three patients with prolonged hyperthermia, the central line was withdrawn at 5, 6 and 9 days, respectively, but catheter tip cultures were negative.

No significant correlation was found between overall complications and age, weight, sex as well as IJV cross-sectional diameter/depth in both TP and SP.

CA and IJV anatomy relationships were studied in 191 patients, mean age 10.8 ± 8.09, mean body-weight 8.1 ± 2.9 kg. Laterality of IJV was detected in 66 patients (34.6%) while IJV was antero-lateral in 114 (59.7%) and anterior in 11 babies (5.7%). Relationships described in Fig. 3 were compared with other studies' series [11–13].

The IJV cross-sectional diameter and depth were assessed in SP in 135 infants (weight <10 kg), with an average of 7.2 ± 4.46 months. Mean body weight was 7.04 ± 2.03. Right IJV was found dominant in 90% of our population. Measurement in SP revealed an IJV cross-sectional diameter of 6.58 ± 1.89 mm; whereas IJV average depth in SP was 7.69 ± 1.65 mm. Patients and neurosurgical classification are depicted in Table 1.

A logistic regression model was performed in order to find a relation between age and weight with IJV cross-sectional diameter in SP. We found a linear regression only between weight and IJV cross-sectional diameter while there is no correlation between age and IJV cross-sectional diameter in SP. The formula applied to calculate the IJV cross-sectional diameter should be: IJV diameter = 2.165 + 0.63 × weight (kg.)

In this formula, 2.165 is the intercept of the linear regression model and 0.63 is the estimated parameter for weight variable with a P value <0.001. Even if there is a linear trend, there is also scattering of the values so $R^2 = 0.43$ (Fig. 4).

In 66/135 patients, with an age range from 2 days to 23 months (6.5 ± 5.3) and average weight of 6.9 ± 2.2 kg, IJV was measured in both SP and TP. In the patients, IJV cross-sectional diameter in SP was 6.9 ± 1.96 mm and depth was 7.8 ± 1.5 mm, IJV cross-sectional diameter in TP was 7.4 ± 2.05 mm and depth was 7.8 ± 1.74 mm. A significant difference ($P < 0.001$) was found between cross-sectional diameter in the TP and the SP, while there was no difference regarding SP- and TP-depth of the vein.

Discussion

Percutaneous venous cannulation in infants and small children can represent a challenging procedure. In our study, no major life-threatening complications, such as pneumothorax or haemothorax occurred. The incidence of CA puncture was low (1.5%) and the neck haematoma did not cause airway compression: in these two cases, jugular vein visualisation was normal and a lower approach was successfully performed.

Main complications were represented by multiple skin or venous attempts: sometimes causing difficulties during J-wire insertion resulting in repeated venous approaches.

The small IJV dimensions in infants can cause an over passing of the posterior wall of the vein and so, even with the ultrasound assistance, a slow progression of the needle is required in a quiet setting. Overall time for cannulation was similar as compared to other paediatric series [20], even if we consider the total time from skin puncture to catheter in site and blood aspired from a lumen of the catheter.

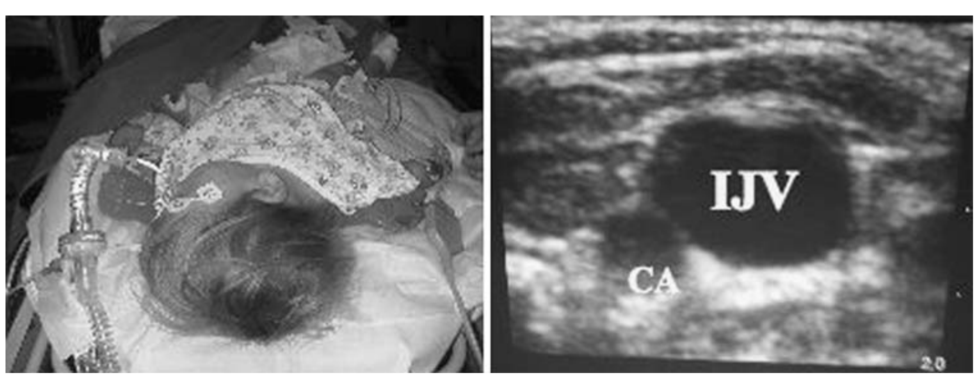
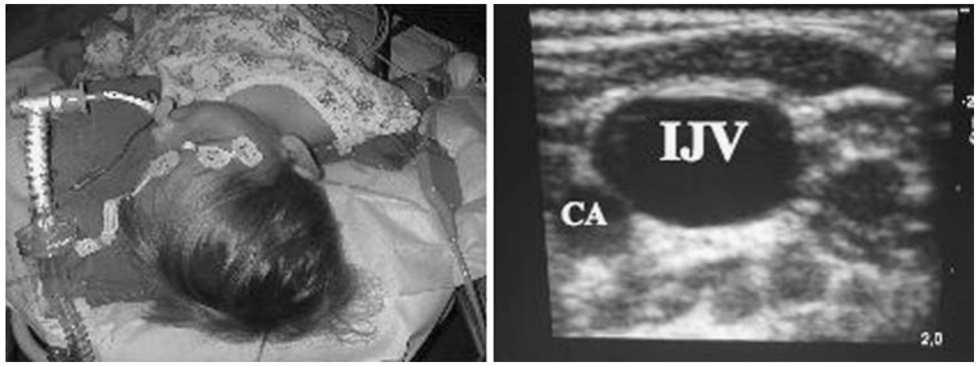


Fig. 1 Patient is positioned with head turned at 90°, Ultrasound image shows right IJV lateral to carotid artery

Fig. 2 Patient with head turned at 45°, Ultrasound image shows right IJV more ellipsoidal and lateral to carotid artery



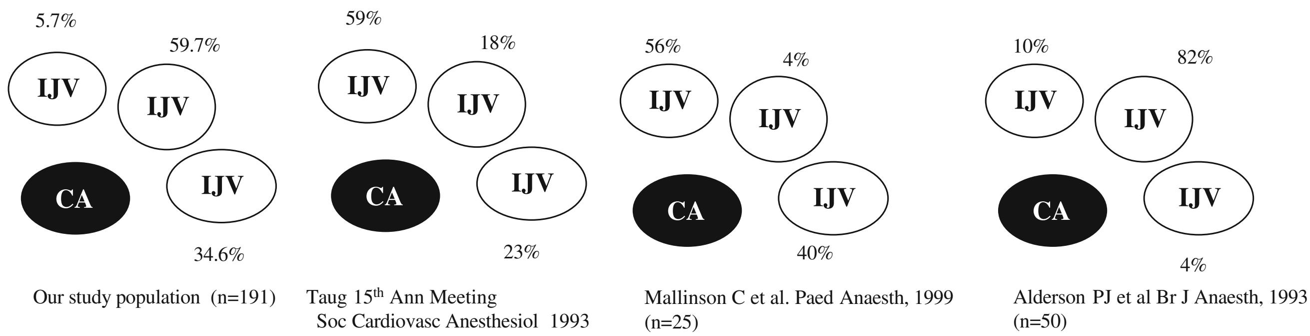


Fig. 3 Relationships between carotid artery (*CA*) and internal jugular vein (*IJV*) in our population of patients compared to similar studies

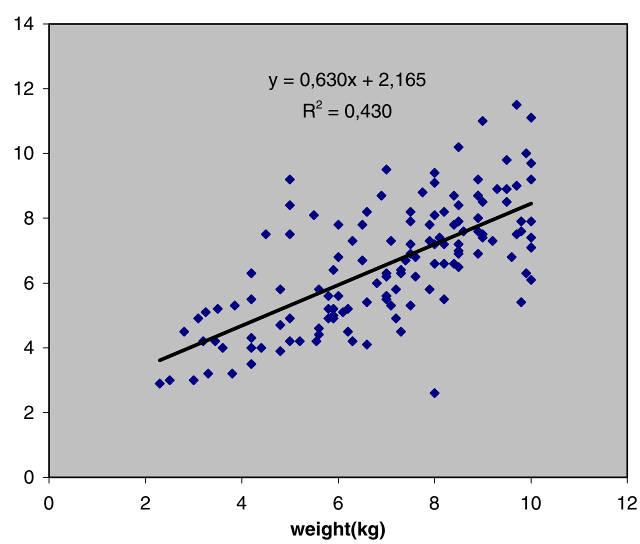


Fig. 4 Relationship between IJV cross-sectional diameter and weight of the study population ($n = 135$)

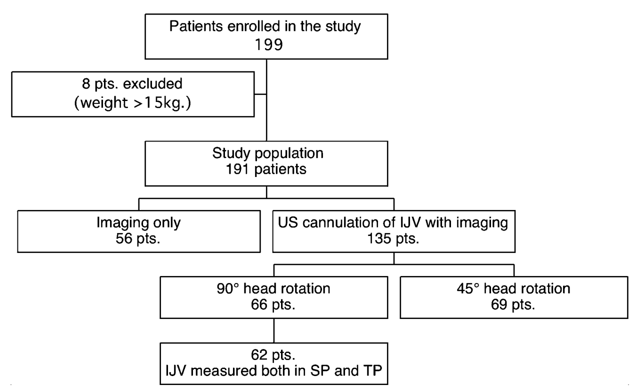


Fig. 5 Flow diagram of the population of patients studied

Since the introduction of ultrasound assistance for central venous cannulation, there was an important reduction in major complications [7], even if few authors [15, 16] did not find significant differences between the landmark and the ultrasound technique. These studies demonstrated a higher success rate when the ultrasound method was applied in the older children (86% in patients above 6 years of age) while cannulation rate was poor (50%) in infants below 3 months. Our first aim was to assess the IJV anatomy using ultrasound imaging. To our knowledge, only five studies were published on infants' vascular anatomy [9–13]: both relationship between IJV internal diameter and patient's age or weight, and IJV-CA relative positions are controversial.

Our findings are quite different from the classical anatomical description where IJV is normally lateral to CA [17]. At this regard, it is important to remember Mallinson statement: in children with cardiac disease, the relationship

Table 1 Patients' characteristics (135 patients)

	$n = 135$
Age (months)	7.2 ± 4.46
Sex (M/F)	82/53
Weight (kg)	7.04 ± 2.03
Surgical diagnosis	
Hydrocephalus	35
Cerebral tumours	40
Cranyostenosis correction	59
Epilepsy surgery	1
IJV cross-sectional diameter (mm)	6.58 ± 1.89
IJV depth (mm)	7.69 ± 1.65

Data are presented as mean ± standard deviation

between IJV and CA may not be in accordance with classical anatomical teaching [13]. Furthermore, the marked dispersion of the patient age must be taken into consideration: on the contrary, our patients' population were extremely homogenous in terms of age. Moreover, we focused our attention on the youngest children where difficulty and complication rate seems to be higher.

Another aim of our study was to measure the IJV cross-sectional diameter in order to find a correlation with age or weight. A linear regression between body weight and IJV cross-sectional diameter measured in SP has been illustrated (Fig. 4). The formula could aid in predicting the diameter of the vein in order to choose the correct gauge size of the CVC.

A 3.5-Gauge (French) catheter has an external diameter of 1.05 mm. This could be dangerous in the case of a baby with a predicted dominant IJV of 2 mm internal diameter, because this reduces to 50% the vein diameter and could impair cerebral venous drainage especially in children with cerebral masses or intracranial hypertension, where it is important to maintain a good jugular venous flow. The selected subgroup having the ultrasound measurements in both SP and TP revealed a significant difference between the IJV cross-sectional diameters, but not in the IJV depth. This demonstrates that the Trendelemburg position can facilitate the cannulation of the vein by increasing IJV diameter. The line insertion was performed when the IJV was best visualized in the TP or SP. Our recommendation is to visualise the IJV with the optimal head rotation and with a shoulder roll to find the best IJV cross-sectional diameter. While TP increases the IJV size and may help CVC placement, it may result as unbeneficial for patients with increased intracranial pressure. Our overall success rate was higher than that previously reported [18–21], but not different from Verghese paediatric experience [7] and Karakitsos' adult population [20]. As previously stated, no statistical difference was detected between 45° and 90° approaching position. In patients with the head rotated at 90°, it is possible, anyway, to obtain a favourable working position with the mastoid, the neck and the thorax of the infant lying on the same plane.

In our study, we could not perform all measurements in TP due to impending neurological problems; otherwise, the ultrasound study of the IJV allowed us to create a linear model that does not predict exactly the IJV diameter as in other studies [9, 10] with older children. For this reason, we suggest that one must always perform an ultrasound evaluation of the neck in infants at both the puncture site and the catheter size selection; this increases the safety of the procedure.

This is the first study focusing on a highly selected population of neurosurgical infants: in these patients, according to Himmelseher [22], the need for central line insertion is increasing, both for haemodynamic monitoring and fluid/vasopressors infusion. In our opinion, the use of ultrasound assistance must be considered as the first choice since it allows (1) a high success rate, (2) a correct selection of dominant IJV, (3) the best catheter size as compared to IJV cross-sectional diameter to avoid venous drainage impairment and (4) a low incidence of complications.

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