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Comparison of ultrasound guided brachiocephalic and internal jugular vein cannulation in critically ill children☆,☆☆,★

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ABSTRACT

Purpose: To determine whether ultrasound (US)–guided longitudinal in-plane supraclavicular cannulation of the brachiocephalic vein (BCV) improves cannulation success rates compared to transverse out-of-plane internal jugular vein (IJV) cannulation in urgent insertion of temporary central venous catheters (CVC) in critically ill children.
Materials and methods: Prospective open pilot (non-randomized) comparative study carried out in a pediatric intensive care unit (PICU) of a university-affiliated hospital. Newborns and children aged 0 to 14 years admitted to the PICU in whom an urgent CVC was clinically indicated and was inserted in the IJV or BCV by US guidance were eligible. First-attempt success rate, overall success rate, number of puncture attempts, and cannulation time were compared between IJV and BCV techniques.
Results: Forty-six procedures (24 IJV and 22 BCV) in 38 patients were included. Full-sample median (range) age and weight were 13 (0.6-160) months and 9.5 (0.94-50) kg. No significant differences between IJV and BCV groups were observed for sex, age, weight, admission diagnosis, intra-procedural mechanical ventilation and sedation protocol. First attempt success rate was higher in the BCV than the IJV group (73 vs 37.5%, $P = .017$). Overall success rate was slightly higher in the BCV group (95 vs 83%, P = nonsignificant). Median (range) number of cannulation attempts [1 (1-3) vs 2 (1-4)] and cannulation time [66 (25-300) vs 170 (40-500) seconds] were significantly lower in the BCV group ($P < .05$). Patient's weight was inversely related to the number of cannulation attempts (Pearson coefficient −0.537, $P = .007$) and cannulation time (Pearson coefficient −0.495, $P = .014$) in the IJV but not in the BCV group. No major complications were observed.
Conclusions: Ultrasound-guided supraclavicular in-plane BCV cannulation improved first attempt CVC cannulation success rates and reduced puncture attempts and cannulation time compared to US-guided out-of-plane IJV in critically ill children. A large randomized clinical trial is warranted to confirm our results.

1. Introduction

Safe and effective central venous catheter (CVC) placement is an essential procedure in critically ill children. Traditionally, cannulation has been performed using the landmark technique, but more recently, ultrasound (US) guidance has become a standard of care in adults and children [1–3]. Ultrasound guidance increases cannulation success rates and reduces puncture attempts. Preprocedural US examination allows a detailed evaluation of the vascular anatomy, vein size, and patency, which may help to choose the most appropriate cannulation site [4]. Intraprocedural US guidance enables the practitioner the ability to advance the needle under direct visualization, thereby minimizing the risk of complications such as pneumothorax or arterial puncture. Finally, postprocedural US helps to detect, in a timely manner, complications such as catheter tip malposition and pneumothorax [5,6]. In children, when compared to adults, CVC placement is considered a more challenging procedure, especially in neonates and small infants. In such cases, anatomical references are not easily defined, vein size is small and puncture area is limited. As a consequence, failure rates using the landmark technique for cannulation range from 4 to 38% [7]. Insertion of CVC under US guidance would be expected to be particularly

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beneficial in critically Ill children who require a rapid and safe central line. However, there is currently no consensus regarding the optimal site and type of access for US-guided CVC insertion in critically ill children. Studies comparing different US-guided cannulation techniques in such patients are not available. In recent years, supraclavicular in-plane cannulation of the brachiocephalic vein (BCV) has emerged as an alternative approach which may offer advantages during difficult CVC insertion that may occur in neonates and small infants in the pediatric intensive care unit (PICU). However, reported experience about BCV cannulation in the PICU is very limited [8,9].

The objective of this pilot study was to determine whether ultrasound (US)–guided longitudinal in-plane supraclavicular cannulation of the brachiocephalic vein (BCV) improves cannulation success rates compared to transverse out-of-plane internal jugular vein (IJV) cannulation in urgent insertion of temporary central venous catheters (CVC) in critically ill children.

2. Material and methods

2.1. Design and setting

This was an open prospective nonrandomized comparative study including all consecutive urgent US-guided cannulation procedures of the BCV and IJV in children aged 0 to 14 years admitted to the PICU from January 2013 to November 2015. We considered urgent situations those CVC insertions indicated in patients with acute hemodynamic instability, respiratory failure or when the CVC was needed for therapy or monitoring without delay. No cannulation was attempted during resuscitation. Elective cannulations performed in outpatients transferred to the PICU for CVC insertion or as scheduled procedures were not eligible. Parents or guardians gave their consent for participation in this study and the protocol was approved by the local ethics committee.

2.2. Procedure

All cannulations were performed by 2 pediatric intensivists trained in US-guided CVC placement. Both operators have performed US-guided IJV cannulation for more than 4 years in clinical practice (more than 50 cannulations) before the study. Experience with BCV US-guided technique at the beginning of the study was less than 1 year for operator 1 (around 10 procedures) and around 2 years for operator 2 (between 10 and 20 procedures). Catheterization was performed using a standard Seldinger technique under sterile conditions. All the patients received sedation and analgesia with midazolam (0.1 mg/kg) plus ketamine (2 mg/kg) or propofol (2 mg/kg) plus fentanyl (1 μg/kg). Additional doses were given based on physician's criteria. Two portable US machines were used during the study period: Vivid I (General Electrics, Haifa, Israel) and M Turbo (Sonosite, Japan) equipped with a 12 MHz 10 cm footprint linear probe for older children and a 6- to 13-MHz 6 cm footprint linear probe for small children, respectively. Before the procedure, US was used to assess IJV and/or BCV vein size, patency, and collapse with transducer pressure or respiratory efforts. The final decision of which vein to cannulate was made at the practitioner's discretion according to the patient's characteristics and vein examination. No rigid rule or algorithm was used to choose the vein access. However, BCV was favored in case of spontaneously breathing small infants because it tends to collapse less than IJV with inspiration. Left BCV was chosen over right BCV in most instances because it has a less angulated entry into the superior vena cava which has been associated to easier guidewire advance. Also, for right-handed operators, left BCV can be cannulated from the side of the patient instead from the head which is advantageous in small infants with limited space for airway management. CVC caliber was selected according to patient's age and vein size. Commercial catheters kits with 21G and 22G introducing needles were used. During the procedure, the patient was positioned with the neck extended and rotated 45° opposite to the cannulation side. A towel roll was placed under the shoulders to achieve adequate neck extension. In patients under mechanical ventilation, ventilator settings were not manipulated during cannulation.

For IJV cannulation a standard transverse out-of-plane approach was used [10]. For BCV cannulation a supraclavicular approach with longitudinal in-plane insertion of the needle was used [11]. To locate the BCV, first a transverse plane of the IJV is obtained; transducer is then moved downwards following the course of IJV to the supraclavicular fossa and tilted anteriorly to image subclavian artery and finally subclavian vein-BCV junction (Figure 1, left). The needle attached to a syringe is inserted in-plane from the lateral aspect of the transducer directed to the BCV near to the subclavian vein-BCV junction (Figure 1, right). Complete visualization of the long-axis view of the needle (including bevel) during the procedure is essential. If the needle trajectory is lost, the needle should not be advanced further. When the needle enters into the BCV, blood is aspirated and the guidewire is advanced. In small infants we used a 0.018 inch straight floppy guidewire. Ultrasound should confirm the intravascular location of the guidewire before advancing the catheter. Cannulation is completed after a scalp skin incision, dilation and advancement of the catheter to the defined distance. Aspiration of blood from all of the CVC lumens is checked and the CVC is secured. Then CVC tip position is assessed by chest radiography and/or US [6].

2.3. Measurements

Patient's sex, age, weight and admission diagnosis were recorded. Intraprocedural variables and outcomes included sedation protocol, positive pressure ventilation (PPV), vein size (mm), CVC size (French), number of cannulation attempts, cannulation time (in seconds), success rate (first attempt and overall), immediate mechanical complications and CVC indwelling days. Vein size was measured as the maximal anterior-posterior diameter of the vein. Before the procedure, both inspiratory and expiratory vein diameters were measured and averaged over 3 respiratory cycles using a M-mode trace of the vein avoiding transducer compression. Cannulation attempt was defined as every skin puncture [11,12]. Cannulation time was recorded from the first skin puncture to the successful guidewire pass by an assistant [13]. If the cannulation failed, time from the initial puncture to the withdrawal of the needle after the last puncture attempt was considered as the cannulation time. The time from the guidewire pass to CVC placement was not considered as cannulation time for the purpose of this study because this time does not depend on the US technique used. Successful cannulation was defined as the correct placement of the CVC within the intended vein and aspiration of free blood flow. Change in the cannulation site was considered a cannulation failure. Immediate mechanical complications included pneumothorax, accidental arterial puncture, pericardial effusion and perivascular hematoma.

2.4. Statistical analysis

The main outcome of this study was successful cannulation on the first attempt because we believe it reflects the technical advantage of a vascular access technique better than other outcomes. We assumed a 55% first attempt success for US-guided IJV cannulation based on a previous study in the PICU [12]. With a power of 0.80, an alpha error of 0.05 and predicted losses of 20%, 22 procedures in each group would be needed to detect a 35% improve in first attempt success resulting in a 90% first attempt success rate that we considered an optimal result. Data are presented as number and percentage for categorical variables and median, range and interquartile range (IQR) for continuous variables. IJV and BCV groups were compared using chi square test, Fisher exact test and non-parametric Mann Whitney *U* test. A *P* value less than .05 was considered statistically significant. Pearson correlation coefficients were calculated to assess the correlation of patient's weight with number of cannulation attempts and cannulation time.