Comparison between ultrasound-guided supraclavicular and infraclavicular approaches for subclavian venous catheterization in children—a randomized trial


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Editor’s key points

- Central venous catheterization is challenging in small children.
- Ultrasound (US) guidance may reduce risks such as carotid puncture, haematoma, and pneumothorax.
- The authors compared insertion times and complications during US guided supraclavicular and infraclavicular catheterization techniques.

Background. Ultrasound (US)-guided subclavian vein (SCV) catheterization via the supraclavicular (SC) or infraclavicular (IC) approaches can be useful in children. The purpose of this study was to compare the efficacy of these approaches.

Methods. This prospective, randomized study included 98 children who were < 3 years old, and who were divided into two groups: the SC group (n = 49) and the IC group (n = 49). All SCV catheterizations were guided by US and performed by a single experienced anaesthesiologist. Data regarding puncture time, number of attempts, successful guidewire insertion, catheter insertion time, and complications were analysed.

Results. The median puncture time was longer in the IC group than the SC group (48 vs 36 s, P = 0.02). Multiple attempts (number of attempts > 3) were more frequently required in the IC group than the SC group (24.5 vs 6.1%, P = 0.01). The incidence of guidewire misplacement was higher in the IC group than that of the SC group [10 (20.4%) vs 0 (0%), P = 0.001]. Catheterization was successfully performed in all patients. No pneumothoraces or arterial punctures occurred in either group.

Conclusion. During SCV catheterization under US guidance in paediatric patients, the SC approach yielded a shorter puncture time and decreased the incidence of guidewire misplacement when compared with the IC approach.

Clinical trial registration. ClinicalTrials.gov, NCT01527175.

Keywords: subclavian vein; ultrasonography

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Central venous catheter (CVC) insertion is an important technique, as CVCs are commonly used in critically ill patients, and those undergoing major surgery. The subclavian vein (SCV) is the preferred site for CVC insertion because of its lower risk for infection and its ability to provide patient comfort in long-term use.1 However, because of the close proximity of the SCV and vulnerable anatomic structures (subclavian artery or lungs), SCV catheterization can result in complications such as subclavian artery puncture causing a haematoma or haemothorax, and pneumothorax.1–3 CVC placement is also challenging in small children because of their small vein size. Therefore, CVC placement under ultrasound (US) guidance is recommended, particularly for small children.4–7 Recently, US-guided IC and the SC approaches for SCV were introduced for infants and children.8–10

US-guided IC and SC approaches yield higher success rates and lower complication rates in children. However, to date, no studies have compared their efficacy. The purpose of this study was to compare the efficacy of the US-guided IC and SC approaches for SCV catheterization in paediatric patients.

Methods

This study was approved by our Institutional Review Board, and written informed consent was obtained from the parents. The eligibility was assessed for patients who were <3 yr in age, and who were undergoing general anaesthesia for elective congenital cardiac or neurosurgery requiring CVC insertion. Patients with severe lung disease, vascular malformations, prior CVC insertions, increased intracranial pressure...
symptoms, or previous lung or chest surgeries were excluded.
Children were then randomized into either the SC or IC approach group for SCV catheterization according to a computer-generated randomization table with an allocation ratio of 1:1. The allocations were concealed in sequentially numbered, sealed, opaque envelopes.

**Study protocol**

After the placement of routine monitors, general anaesthesia was induced. The trachea was intubated with a tracheal tube and the lungs were mechanically ventilated. All procedures were performed on the right SCV by the same paediatric anaesthesiologist. The operator had 5 yr of experience in paediatric anaesthesia and had been involved in at least 50 previous successful US-guided SCV catheterizations using both IC and SC approaches in children.

**Position**

All patients were placed in a 10° head-down position with a rolled towel placed under their shoulders. The head was turned 30° away from the side of the venipuncture, and the ipsilateral arm was gently pulled towards the knee.

**US scanning**

We used a LOGIQe US unit (GE Medical Systems Co., WA, USA) with its linear ‘Hockey-Stick’ Probe (i12L-RS probe, 8–10 MHz). The US unit was set for optimal imaging at a depth of 1.9 cm for infants and 2.2 cm for children. The operator was positioned at the child’s right side in order to perform the right SCV catheterization, with the display of the US unit positioned at the left side of the child to allow the operator to view both the US image and the patient’s landmarks. US guidance was performed using the procedures described in previous studies. After reaching the IJV-SCV junction by tracing the IJV, the US probe was turned laterally and caudally to obtain the longitudinal images of the SCV and the brachiocephalic vein for the SC approach (Fig. 1). For small neonates, the probe was tilted to expose the needle entry site on the skin. For the IC approach, the US probe was positioned over the clavicle to view the distal part of the SCV in the IC area. The US probe was adjusted to obtain the best longitudinal image of the distal SCV at the IC level, the clavicle, and the proximal SCV (Fig. 2). The best longitudinal view of the SCV was confirmed by a well-defined SCV, in addition to confirming the largest SCV diameter.

**Central venous catheterization**

Paediatric CVC sets (4 Fr or 5 Fr) (Blue FlexTip® ARROWgard Blue® Catheter Arrow International, Inc., PA, USA) were used. A 21-gauge 4-cm needle, attached to a syringe, was used to puncture the SCV. While carefully maintaining the best longitudinal view of the SCV, the needle was advanced, using an in-plane approach, under the guidance of US (Figs 1 and 2). When the needle tip was visible in the SCV and successful blood aspiration was confirmed, the guidewire was then introduced into the SCV through the needle while keeping the J-tip directed in the caudal direction. US was used to confirm the correct insertion of the guidewire into the SCV. Successful catheter insertion was confirmed by aspiration of blood through the catheter and examination of a subsequent chest X-ray.

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**Fig 1** Ultrasonographic longitudinal view of the right SCV and the illustration of the probe application for the SC approach. Arrow indicates the SCV puncture site and the direction of the needle’s advancement in the US image. US probe placed in the SC region in order to obtain a US image for the SC approach and the needle adjusted for the in-plane approach. SCV, subclavian vein; BCV, brachiocephalic vein.
Data analyses
Another anaesthesiologist recorded the puncture times, number of attempts, successful guidewire insertion rates, catheter insertion times, and complications. The puncture time, as a primary outcome, was defined as the time from the initial skin puncture to the aspiration of blood from the SCV through the needle. The number of attempts was defined as the number required for each needle advance to puncture the vein; multiple attempts were defined as more than three attempts. The catheter insertion time was defined as the time from blood aspiration through the needle to free aspiration through the catheter. If the guidewire was not verified in the brachiocephalic vein or identified in the IJV, this was recorded as guidewire misplacement, and the patient was excluded from the catheter insertion time measurements. All times were measured in seconds. Complications, including arterial puncture and pneumothorax, were also recorded.

Statistical analyses
Sample size estimations were performed in accordance with data from a pilot study performed in 20 patients, in which the mean puncture times [standard deviation (s)] were 54 (60) s and 102 (88.2) s in the SC and IC groups, respectively. We estimated that a random assignment of 98 subjects was required to provide a 0.6 effect size, with 80% power at the 5% significance level, which takes into consideration the usual 10% loss of study participants. Statistical analyses were performed using SPSS 19.0 (SPSS, Inc., Chicago, IL, USA). Normality tests were performed using the Kolmogorov–Smirnov test. All data are expressed as the mean (s) [range], number (%), or median [interquartile range (IQR)] as indicated. Data between the groups were compared using the χ² test, the Mann–Whitney U-test, and Student’s t-test as appropriate. Statistical significance was defined as P < 0.05.

Results
The enrolment, randomization, and analysis process are summarized in Figure 3. No significant differences were observed in patient characteristics between the two groups (Table 1). The median (IQR) puncture time was significantly shorter in the SC group [36 (24–60) s] when compared with the IC group [48 (30–114) s, P = 0.02] (Table 2). The incidences of multiple attempts were significantly higher in the IC group compared with the SC group (24.5 vs 6.1%, P = 0.01). However, successful guidewire insertion rates for the first attempt and the catheter insertion times did not differ significantly between the two groups. CVCs were inserted into the SCV of all patients within 20 min.

The incidences of guidewire misplacement into the ipsilateral IJV were significantly higher in the IC group (20.4%) when compared with the SC group (0%) (P = 0.001). All guidewire misplacements were verified in the ipsilateral IJV. No pneumothorax or arterial punctures occurred.

Discussion
This prospective randomized study revealed that the SC approach yields a significantly shorter puncture time and lower incidences of multiple attempts, along with lower rates of
guidewire misplacements, compared with the IC approach in US-guided SCV catheterization.

Previous research has reported the efficacy and safety of US-guided SCV catheterization using the IC approach. However, disadvantages have also been reported, including difficulty in simultaneous identification of the SCV and the needle below the clavicle on the longitudinal US view because of the acoustic shadow of the clavicle. When the US probe is placed at the SC level, without crossing over the clavicle during the IC approach in older children, the skin puncture point is away from the US probe. In these patients, more time and effort is required to place and advance the needle in the same US plane with SCV.

We postulated that the catheter insertion time would be longer in the IC group compared with the SC group. This hypothesis was based on the observation that in some cases, the thin and flexible guidewires used for children may be bent or kinked during the catheter insertion over the guidewire. This situation arises as a result of the dense ligament beneath the clavicle and the clavicle itself. Contrary to our expectations, catheter insertion times did not differ significantly between the groups. When the guidewire was misplaced in the IJV, data from these patients were not included in the calculations of the catheter insertion time. If the times required to reposition the guidewire from the IJV to the brachiocephalic vein were considered, the catheter insertion times of the IC group exceeded that of the SC group.

In this present study, guidewires were identified in the ipsilateral IJV in the US view for 20% of the patients of the IC group. These guidewire misplacement incidences were higher than those observed in previous studies involving adults. In contrast, no cases of guidewire misplacement were observed in the SC group. This difference in guidewire misplacement incidence, between the SC and IC groups, may be explained by the downward direction of the needle in the SC group. The operator should check to ensure that the correct guidewire placement occurred from the US view after guidewire insertion,
Table 2  Comparison of the study results between the IC group and the SC groups. Results expressed as the median [interquartile range] or number (%) of total patients of each group. IC, infraclavicular; SC, supraclavicular; multiple attempts, number of attempts > 3. *The catheter insertion time was measured in 39 patients

<table>
<thead>
<tr>
<th></th>
<th>IC group (n = 49)</th>
<th>SC group (n = 49)</th>
<th>P-value</th>
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</thead>
<tbody>
<tr>
<td>Puncture time (s)</td>
<td>48 [30 – 114]</td>
<td>36 [24 – 60]</td>
<td>0.02</td>
</tr>
<tr>
<td>Catheter insertion time (s)</td>
<td>126 [108 – 156]*</td>
<td>132 [114 – 150]</td>
<td>0.19</td>
</tr>
<tr>
<td>Successful guidewire insertion at first attempt</td>
<td>24 (49%)</td>
<td>32 (65.3%)</td>
<td>0.10</td>
</tr>
<tr>
<td>Multiple attempts</td>
<td>12 (24.5%)</td>
<td>3 (6.1%)</td>
<td>0.01</td>
</tr>
<tr>
<td>Complications (pneumothorax and arterial puncture)</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Guidewire misplacement</td>
<td>10 (20.4%)</td>
<td>0 (0%)</td>
<td>0.001</td>
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while paying careful attention to the possibility of guidewire misplacement when US-guided IC approaches are used.

The SC approach for US-guided SCV catheterization in children showed high success rates and low complication rates, consistent with the findings of a previous study. These favourable results are probably because of the ease of obtaining and maintaining the longitudinal US view of the SCV without the hindrance of the clavicle and its acoustic shadow.

In neonates and small infants, the SC approach requires slight modifications because of the length of the proximal SCV and the distance between the neck and the clavicle being very short. The ‘hockey-stick’ probe was moved to the medial side and tilted in order to secure the space for skin piercing by the needle after the best longitudinal US view of the SCV was obtained. Gentle pulling of the ipsilateral arm also helps to secure the space for needle puncture. The needle should be advanced more vertically in neonates and small infants than in older children in order to hit the proximal SCV.

This study had some limitations. First, the results of this study were directly dependent on the operator’s experience and skill. Therefore, caution is required when applying our results to procedures where novices or physicians, during their learning curve, are attempting to perform successful US-guided SCV catheterization. It is possible that the learning curve is steeper with one approach than with the other. The operator for this study had a lot of experience in US-guided SCV catheterization. Secondly, the operator in this study was not blinded to the patient group. Thirdly, as we used a J-tip guidewire not a straight guidewire with nitilon soft tip, the results could be influenced by a difficult passing of the J guidewire. The larger J-tip guidewire compared with the vein diameter might influence the successful insertion of the guidewire in small children. Fourthly, all SCV catheterizations were performed on the right SCV. Accordingly, our results may not apply to left SCV catheterization.

In conclusion, when performed by an experienced operator, the SC approach for SCV catheterization yields clinical advantages, such as a shorter puncture time, a lower incidence of multiple attempts and guidewire misplacement, and potentially improved the catheter insertion time in children, when compared with the IC approach.

References

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