

# The three-step method for ultrasound-guided pediatric internal jugular venous catheterization: a clinical trial

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**Abstract** Ultrasound guidance may be a valuable adjunct for pediatric internal jugular vein catheterization. We previously reported a long-axis in plane technique, called the “three-step method”, resulting in high success and a low complication rate by novice operators in adult patients. This is the first report of ultrasound-guided internal jugular vein catheterization (US-IJV) using the three-step method in pediatric patients. Fourteen junior residents underwent simulation training, and then participated in a clinical trial. They performed US-IJV in 14 pediatric patients with

congenital heart disease before undergoing cardiac surgery under supervision of an experienced clinician. The overall success rate was 93 %, and all catheterizations were performed within two venipunctures. There were no complications associated with the procedure. The three-step method may facilitate pediatric US-IJV even by a novice operator during their first experience.

**Keywords** Internal jugular vein · Ultrasound-guided · Central venous catheterization · Pediatrics · Novice operator

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## Introduction

Recently, some reports have shown the efficacy of ultrasound-guided internal jugular vein catheterization (US-IJV) in pediatric patients [1–4]. However, the real-time ultrasound-guided approach may not meet the standard minimal requirements for training in insertion techniques, and may require a long training period, particularly in pediatric patients [5].

We reported a novel method called the “three-step method” for ultrasound-guided central venous catheterization [6]. The method includes: (1) identifying a straight section of the vein in the short axis; (2) using a needle guide; and (3) observing the view along the true axis by rotating the distal and then proximal portions of the ultrasound probe. The merits of this method are high success and a low complication rate, regardless of the operator’s experience. In the previous study, this method was used only in adult patients, but we expected it to also be applicable in pediatric patients.

In this report, junior residents performed US-IJV in pediatric patients using the three-step method, as their initial experience.

## Simulation training and clinical trial

This clinical trial was approved by the hospital ethics committee, and written informed consent was obtained from the parents of each patient.

### Simulation training

Fourteen junior residents [clinical experience:  $13.5 \pm 3.0$  months (mean  $\pm$  SD)] without prior experience performing US-IJV in pediatric patients participated. They had some experience in performing US-IJV in adult patients [ $3.3 \pm 1.5$  times (mean  $\pm$  SD)] using the short-axis out of plane technique with free-hand placement.

Before the clinical trial, all participants underwent hands-on simulation training to learn the US-IJV technique with the three-step method. Five successful insertions of the guide-wire into the phantom vein (diameter 3 mm) were considered adequate to demonstrate sufficient skill.

The time needed to perform each successful insertion (from initial scan to insertion of the guide wire into the vein) was as follows: first try 13.3 [6.7, 28] [median, (min, max)], second try 7.2 [4.1, 16], third try 5.9 [3.7, 10], fourth try 6.0 [2.5, 17], and fifth try 6.6 [4.0, 11] minutes. The time for the first insertion was significantly longer than the second through fifth insertions, but there was no significant difference between the second through fifth insertions ( $P$  value  $<0.05$ , Friedman test following the Wilcoxon signed-rank test with a Bonferroni correction for multiple comparisons).

### Clinical trial

A total of 30 patients with congenital heart disease undergoing cardiac surgery were evaluated for participation in this study. Sixteen patients were excluded because of body weight  $<5$  kg in two patients and ASA status  $\geq 3$  in 14 patients. Exclusion of patients with ASA  $\geq 3$  was stipulated by the ethics committee. The supervising anesthesiologist performed US-IJV in patients excluded from the clinical trial. Fourteen patients were enrolled in the clinical trial. The patients' characteristics were as follows: age 23.5 [11, 88] [median, (min, max)] months, height 81 [68, 120] cm, weight 10.5 [6.1, 21.6] kg and gender 7:7 (male:female).

After induction of general anesthesia, the patient was placed in a 15–20° head-down position, the head was turned to the left about 30°, and the neck was extended with a rolled towel placed under the shoulder [7]. Pre-puncture scanning was performed to identify the right IJV and evaluate suitability for catheterization. The patient's

**Table 1** Results of ultrasound-guided internal jugular vein catheterization

	Median [Min, Max]
Depth (mm)	6 [4.7, 7.0]
Transverse diameter of the right internal jugular vein (mm)	8.8 [3.4, 14]
Antero-posterior diameter of the right internal jugular vein (mm)	5.9 [3.3, 7.5]
Success in the first attempt	8/14 (57 %)
Success within 2 attempts	13/14 (93 %)
Complications	0
Posterior wall puncture	0
Procedure time (min)	7.5 [5.5, 25.0]
Scan to set-up (3-steps) (min)	5.7 [3.5, 21.8]
Skin puncture to guide-wire insertion (min)	2.0 [0.8, 4.8]

neck was then disinfected with povidone-iodine, and draped in the usual sterile fashion. The ultrasound probe (6–13 MHz linear probe,  $36 \times 12.8$  mm, iLook 25<sup>®</sup>, Sonosite Co., WA, USA) was covered with a disposable sterilized plastic sheath containing ultrasound gel, and the needle guide (Infiniti Plus<sup>™</sup>, CIVCO Medical Solutions, IA, USA) was attached. The participant attempted US-IJV using the three-step method. The insertion of the guide-wire was performed under real-time visualization by the supervisor.

The results of the clinical trial are shown in Table 1. The overall success (correct insertion of the guide-wire into IJV) rate was 93 %. Thirteen participants performed US-IJV within two attempts. The time to perform the US-IJV (from skin puncture to finishing the guide-wire insertion) was 7.5 [5.5, 25] [median, (min, max)] minutes. There were no double-wall punctures or complications. US-IJV could not be performed in one patient by the participant, and was completed by the supervisor.

### Discussion

The long-axis in plane technique (LAX-IP) has been recommended for US-IJV in adult patients [8]. However, there are no previous reports applying the LAX-IP to pediatric patients. The reason why the LAX-IP is not used in pediatric patients may be the difficulty in handling the ultrasound probe in a limited space, and the technical difficulty of keeping the needle in the ultrasound beam plane during the procedure [9]. The LAX-IP has an additional benefit for patient safety since the insertion of the guide-wire is performed under real-time visualization. Longitudinal imaging

of the guide-wire might be helpful to confirm the presence of the guide-wire in the vessel [10].

The short-axis out of plane technique (SAX-OOP) is commonly used in pediatric US-IJV [11]. However, the SAX-OOP also requires specific training, especially in pediatric patients [12]. The requisite skills for the SAX-OOP are thought to be hand-eye coordination and needle tip visualization during venipuncture [13]. Lamperti [13] et al. commented that at least 25 successful supervised central venous catheterizations are needed to achieve the needed skill level.

In this clinical trial, junior residents succeeded in performing pediatric US-IJV using the three-step method. However, we excluded small pediatric patients (<5 kg) due to the mismatch between the size of the probe and the patient's neck space. As currently described, this method is not applicable in small pediatric patients, but might be applicable with a smaller probe. This will also require development of a novel needle guide in the future. Additionally, we could not include a large number of pediatric patients in this trial, because of the strict exclusion criteria. This technique should be further evaluated in a large study with a comparison group, to demonstrate the usefulness of the three-step method in pediatric patients.

## Conclusion

In summary, we demonstrate that novice operators can perform pediatric US-IJV using the three-step method with a high success rate and no complications. The three-step method may be useful for an inexperienced operator to perform US-IJV safely, in relatively large pediatric patients (>5 kg).

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**Conflict of interest** The second author, Dr. Tokumine is a technical adviser of Nippon Covidien Co. (Japan) and has conducted an ultrasound-guided technical training course held by the company.

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