

Comparison of the needle tip location with the operator's position during ultrasound-guided internal jugular vein catheterization

A randomized controlled study

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Abstract

Objective: We hypothesized that when a right-handed operator catheterizes the left internal jugular vein (IJV), the tip of the needle might be positioned closer to the center of the vessel after puncture if the operator is standing in the patient's left axillary line, rather than standing cephalad to the patient.

Methods: The study randomly allocated 44 patients undergoing elective surgery under general anesthesia with planned left central venous catheterization to either conventional (operator stood cephalad to the patient) or intervention (operator stood in the patient's axillary line) groups. The left IJV was catheterized by 18 anesthesiologists. The distance between the center of the vessel and the needle tip, first-attempt success rate, and procedure time were compared.

Results: The distance from the needle tip to the center of the IJV after needle puncture was 3.5 (1.9–5.5) and 3.2 (1.7–4.9) cm in the conventional and intervention groups, respectively ($P = .47$). The first-attempt success rate was significantly higher in the intervention group (100% vs 68.2%, $P = .01$). Overall time to successful guidewire insertion was faster in the intervention group ($P = .007$).

Conclusions: There was no significant difference in needle tip position when the right-handed operator was standing in the patient's left axillary line compared to standing cephalad to the patient during left IJV catheterization. However, it increased the first-attempt success rate and reduced the overall time for guidewire insertion.

Abbreviations: IJV = internal jugular vein, US = ultrasound.

Keywords: central venous catheterization, internal jugular vein, operator's position, ultrasound

1. Introduction

Ultrasound (US)-guided central venous catheterization is widely used with high success rates and few complications.^[1] However, unskilled practitioners often miss the tip of the needle during US-guided central venous catheterization.^[2,3] Failure to match the direction of the needle with the direction of the actual blood vessel can result in the needle inadvertently pointing outward and may lead to complications related to vascular access.

Left internal jugular vein (IJV) catheterization has been known to have a higher incidence of complications than right IJV catheterization.^[4,5] One of the main reasons for this is that the left IJV is smaller than the right IJV.^[5–8] However, the operator's conventional standing position and the angle between the left IJV and a right-handed operator's arm may also affect the

procedure results. There has been little discussion of the operator's optimal standing position depending on whether the left or right IJV is targeted. Unlike right IJV catheterization, just standing cephalad to the patient can be problematic when a right-handed operator catheterizes the left IJV because the left IJV direction and operator's right forearm are not aligned while standing cephalad to the patient. Unless the operator recognizes this problem and corrects it, the needle likely follows the direction of the operator's right forearm rather than that of the left IJV. This problem also may occur when an unskilled left-handed operator catheterizes the right IJV while standing cephalad to the patient.^[9]

Nudge strategies, which are any attempt to influence people's judgement or behavior in a predictable way, are used in various ways in medicine.^[10] They have a powerful influence on clinicians, but their effects on central venous catheterization are unclear. We

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The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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hypothesized that if a right-handed practitioner stands in the left axillary line to perform left IJV catheterization, the direction of the IJV and forearm holding the needle will align naturally, so that the needle tip can be manipulated more easily than when just standing cephalad to the patient. To our knowledge, no study has demonstrated whether the operator's position affects the location of the needle tip or the catheterization success rate.

2. Methods

This randomized controlled study was conducted at Seoul Metropolitan Government-Seoul National University Boramae Medical Centre from March to November 2019. After obtaining institutional review board approval (no. 10-2020-14) and informed patient consent, 50 adults undergoing elective surgery under general anesthesia with planned left central venous catheterization were enrolled. The study protocol was registered at ClinicalTrials.gov (NCT03936543). There were no important changes to the methods or outcomes after the trial started. Patients with carotid artery or jugular vein disease, a history of cervical spine surgery, and an immobile cervical spine were excluded.

The randomization sequence was generated using a computer program and consisted of blocks of 2 or 4 with a 1:1 allocation. The random list was generated by a research assistant who was not involved in the study. The random number was kept in an opaque envelope and opened when the patient entered the operating room. Ultimately, 44 patients were randomly allocated to either the conventional or intervention group (both $n = 22$; Fig. 1).

Anesthesia was induced with intravenous remifentanyl (effect site concentration 4.0 ng/mL) and propofol (effect site concentration 4.0 ng/mL). Rocuronium (0.6 mg/kg) was administered for neuromuscular blockade. After tracheal intubation, the patient's head was rotated slightly to the right. The procedure area was sterilized with 2% chlorhexidine and then draped. In all patients, the left IJV was catheterized using the Seldinger technique with a needle with a distal lumen caliber of 7 Fr and length of 20 cm (ARROWg + ard Blue Catheter; Arrow International, Reading, PA). An US machine (CX-50; Philips Healthcare, Seattle, WA) and a sterile covered linear probe (L L15-7io; Philips Healthcare) were used for US guidance. The IJV was catheterized by 18 anesthesiologists, including 16 trainees, who performed more than 20 US-guided central venous cannulations annually. The anesthesiologists were blinded to the study purpose and told where they should stand to perform the catheterization.

In the conventional group, the anesthesiologists stood in the midline and cephalad to the patient to perform central venous catheterization (Fig. 2). In the intervention group, the anesthesiologists moved one step to the left from the midline and stood in the patient's axillary line to start the catheterization. In both groups, real-time cross-sectional images of the left IJV were obtained using out-of-plane technique and the needle was introduced at an angle of 30° to 40°. Immediately after puncturing the anterior wall of the IJV with the needle kept in place, the needle tip was captured on the display. After aspirating blood, a guidewire was inserted through the needle. The guidewire placement within the vessel was confirmed by US of the IJV. A central venous catheter was then inserted.

2.1. Statistical analysis

The primary outcome was the distance between the center of the vessel and the needle tip after vessel puncture. Secondary outcomes included the first-attempt success rate, number of skin punctures, number of needle redirection, time elapsed from skin puncture to guidewire catheter insertion, posterior wall puncture, and any complications related to catheterization, such as carotid artery puncture or hematoma. All study outcomes were observed and measured by a research assistant not involved in the study. Based on a pilot study of 6 subjects, the distance from the needle tip to the center of the IJV when the anesthesiologist performed central venous catheterization standing cephalad to the patient was 4.0 ± 2.3 mm. When the anesthesiologist stood in the patient's left mid-axillary line to perform the procedure, we assumed that a reduction of the distance from the center of the IJV to the needle tip of 50% was clinically meaningful. Assuming a 10% drop-out rate, 50 subjects were necessary for this study.

Data are expressed as the mean (standard deviation), median (interquartile range), or number (%). The Shapiro–Wilk and Kolmogorov–Smirnov tests were used to test for normal distributions. The independent *t* test or Wilcoxon–Mann–Whitney test was used to compare continuous variables, and the chi-square test or Fisher's exact test to compare categorical variables. Time to guidewire insertion data were compared between groups using the log-rank test. A Kaplan–Meier plot was constructed to evaluate time to guidewire insertion data and comparing the conventional and intervention groups. $P < .05$ was considered statistically significant. All statistical analyses were

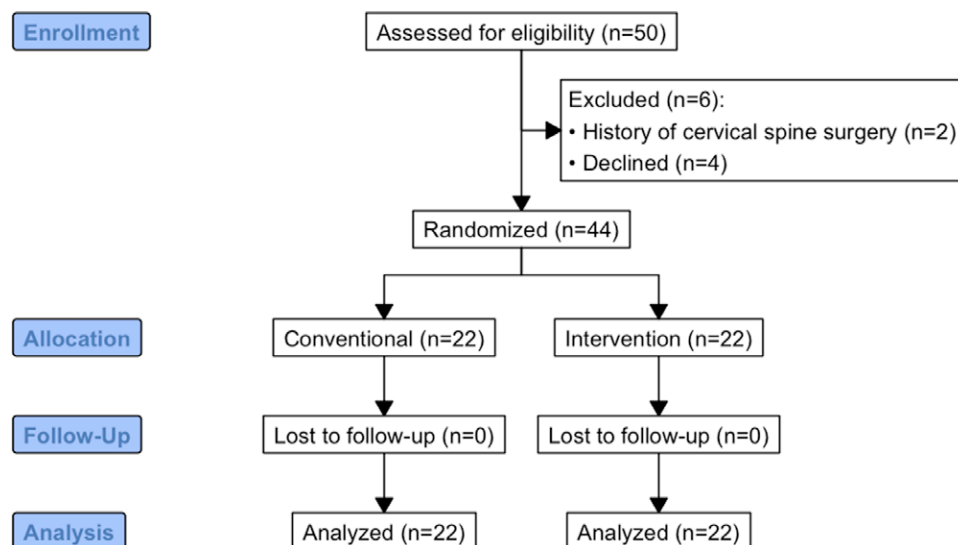
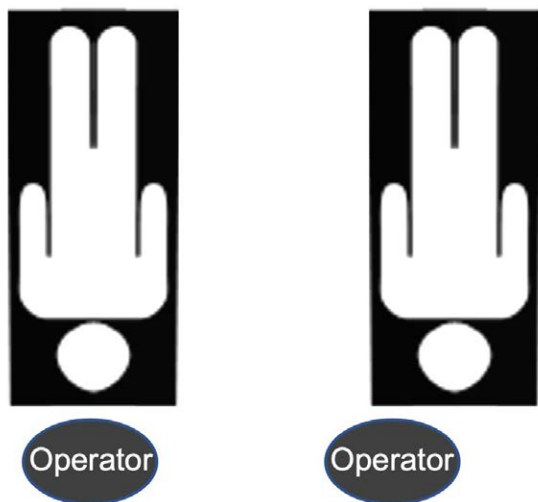


Figure 1. Consort diagram representing patient enrollment.



Conventional Intervention

Figure 2. Operator position during central venous catheterization. In the conventional group, the operators stood cephalad to the patient. In the intervention group, the operators moved one step to the left from the middle and stood at the patient’s axillary line.

done using R ver. 3.4.3 (R Development Core Team, Vienna, Austria, URL <http://www.R-project.org/>).

3. Results

Forty-four patients were randomized to the study groups (n = 22 each). Table 1 summarizes the baseline characteristics of both groups. The diameter and depth of the IJV did not differ between the groups.

The distance from the needle tip to the center of the IJV after needle puncture was 3.5 (1.9–5.5) cm in the conventional group and 3.2 (1.7–4.9) cm in the intervention group (P = .47, Fig. 3). However, the first-attempt success rate was significantly higher in intervention group (100% vs 68.2%, P = .01, Table 2). The number of patients who required multiple skin puncture was 5 in the conventional group and 0 in the intervention group.

The time from puncture to guidewire insertion did not differ between the conventional and intervention groups (56.5 [20.0–114.0] vs 39.0 [28.0–50.0] seconds, P = .12). However, overall time to successful guidewire insertion into the IJV was faster in the intervention group than in the conventional group (P = .007, Fig. 4).

Table 1
Patient demographics and baseline characteristics.

	Conventional group (n = 22)	Intervention group (n = 22)
Age, yrs	63.1 ± 13.0	68.3 ± 9.8
Height, cm	162.0 ± 8.8	162.0 ± 7.7
Weight, kg	60.2 ± 11.7	61.3 ± 11.3
BMI, kg/m ²	22.8 ± 3.3	23.3 ± 3.6
Female	7 (31.8)	7 (31.8)
ASA, 1/2/3	1/11/10	0/12/10
Internal jugular vein profiles		
Anterolateral diameter, mm	8.7 ± 3.1	7.0 ± 2.4
Mediolateral diameter, mm	15.1 ± 5.3	15.8 ± 4.8
Depth from the skin, mm	7.8 ± 1.4	8.0 ± 1.8

Data are presented as the mean ± SD, number (%).

ASA = American Society of Anesthesiologists physical status, BMI = body mass index.

There was no carotid artery puncture in either group (Table 3). The incidence of posterior wall puncture and hematoma formation did not differ between the groups.

4. Discussion

This study shows that a simple intervention that changes the anesthesiologist’s location did not significantly affect the needle tip position, but improved the first-attempt success rate and reduced the overall time to guidewire insertion. This study is the first to show that a simple default type nudge can help central venous catheterization.

Numerous factors can affect central venous catheterization outcomes.^[1] However, there has been little discussion of the best standing location depending on whether the catheterization target is the patient’s left or right side. When a right-handed operator punctures the right IJV, standing cephalad to the patient does not cause problems as the directions of the right IJV and operator’s right forearm direction align. Whereas, when a right-handed operator punctures the left IJV, standing cephalad to the patient can be problematic because the directions of the left IJV and operator’s right forearm are not aligned. As the needle would likely point in the direction of the operator’s right forearm, the needle can easily point outward from the IJV. Even if when operators are aware of the problem, they must twist the torso or forearm while standing cephalad to the patient to correct it. In this study, simply moving the operator to the left increased the first-attempt success rate and reduced the overall time to guidewire insertion. However, the distance between the center of the blood vessel and needle tip did not differ between groups. It was difficult to measure the position of the needle tip objectively after vessel puncture because the position continues to change. Moreover, some trainees even punctured the posterior wall of the vessel when the needle and vessel were well aligned.

Approximately 90% of the population is right-handed,^[11] and the proportion among physicians is likely similar. Some researchers argued that left-handed operators face challenges during their training as most medical environments are set up for right-handed operators.^[9,12] For instance, performing trans-thoracic echocardiography from the right side of the patient is ergonomically disadvantageous for left-handed operators.^[9] Since most IJV catheterization is performed in the right IJV,^[8] right-handed individuals do not face any ergonomic disadvantages when aligning the IJV and their forearm while standing cephalad to the patients. However, in some cases the catheter is inserted into the left IJV instead of the right IJV for surgical or patient reasons. This may not be problematic for experienced clinicians who can perform the procedure by aligning the angle when in an uncomfortable posture, but a simple nudge can be a great help for the less experienced.

A nudge is a concept that was first described in behavioral economics; it is defined as any attempt to influence behavior in a predictable way, without limiting options or significantly changing economic incentives.^[13] Nudge strategies are also used in medicine. Yoong et al^[14] published a systematic review of 42 randomized controlled trials examining nudge strategies in health fields. Of the 57 outcomes, 86% influenced clinician behavior in the predicted direction, and 53% were significant.^[14] Several types of behavioral nudge can be used in clinical practice.^[10] Especially, default options can influence clinician behavior in various ways, such as improving hand hygiene^[15] and preventing fluid overload in the intensive care unit.^[16] In many cases, clinicians perform a IJV catheterization in an uncomfortable position by moving only their hand without changing body position. In these cases, using the default nudge strategy can help people to perform the procedure comfortably. Hand dominance or laterality is important, especially for trainees who have not developed fine-motor skills. We believe this ergonomic concept is important in educational programs on clinical procedures.

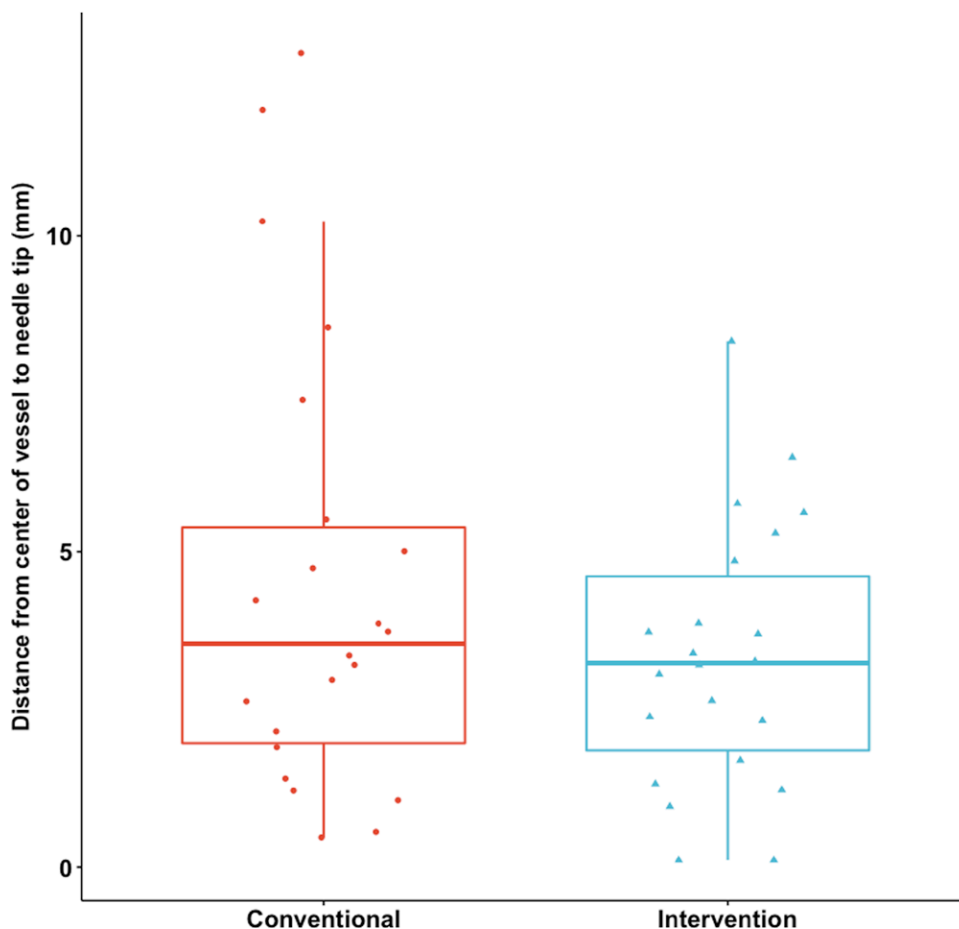


Figure 3. Distance from center of vessel to needle tip after vascular puncture. Boxes indicate the interquartile range, the bold line in the box are the median values, and the whiskers indicate minimum and maximum values that are not outliers.

Table 2
Procedural results according to the study groups.

	Conventional group (n = 22)	Intervention group (n = 22)	P
Distance from needle tip to the center of IJV, cm	3.5 [1.9–5.5]	3.2 [1.7–4.9]	.47
Fist-attempt success rate	15 (68.2)	22 (100)	.01
Number of skin puncture, 1/2/3	17/4/1	22/0/0	.02
Number of needle redirection, 0/1/2/>3	1/4/3/14	2/5/9/6	.08
Time variables			
Skin puncture to needle insertion, sec	19.0 [9.0–75.0]	18.5 [10.0–30.0]	.55
Skin puncture to guidewire insertion, sec	56.5 [20.0–114.0]	39.0 [28.0–50.0]	.12

Data are presented as the number (%) or median [interquartile range].
 IJV = internal jugular vein.

There are several limitations to this study. First, it enrolled right-handed operators, so we could not confirm whether left-handed operators experience the same problems when performing right IJV catheterization. Second, the skill level of the individual operator can affect the study outcome variables. Many left-handed trainees have challenges in clinical situations, but can get accustomed to their non-dominant hand with practice.^[17] Therefore, the effects of default nudge strategies may decrease as the operators’ skills improve. Third, the needle tip position was investigated as a primary outcome, but this did not

necessarily lead to successful catheterization. Even after needle puncture, an ergonomically uncomfortable posture may interfere with catheterization during the stable needle placement or guidewire placement. Fourth, further studies with larger sample sizes are needed to draw a clear conclusion on the effect of the nudge strategy on the success rate of the central venous catheterization.

In conclusion, there was no significant difference in needle tip position when the right-handed operator was standing in the patient’s left axillary line compared to standing cephalad to the patient during left IJV catheterization. However, simply moving the operator to the left increased the first-attempt success rate and reduced the overall time to guidewire insertion.

Author contributions

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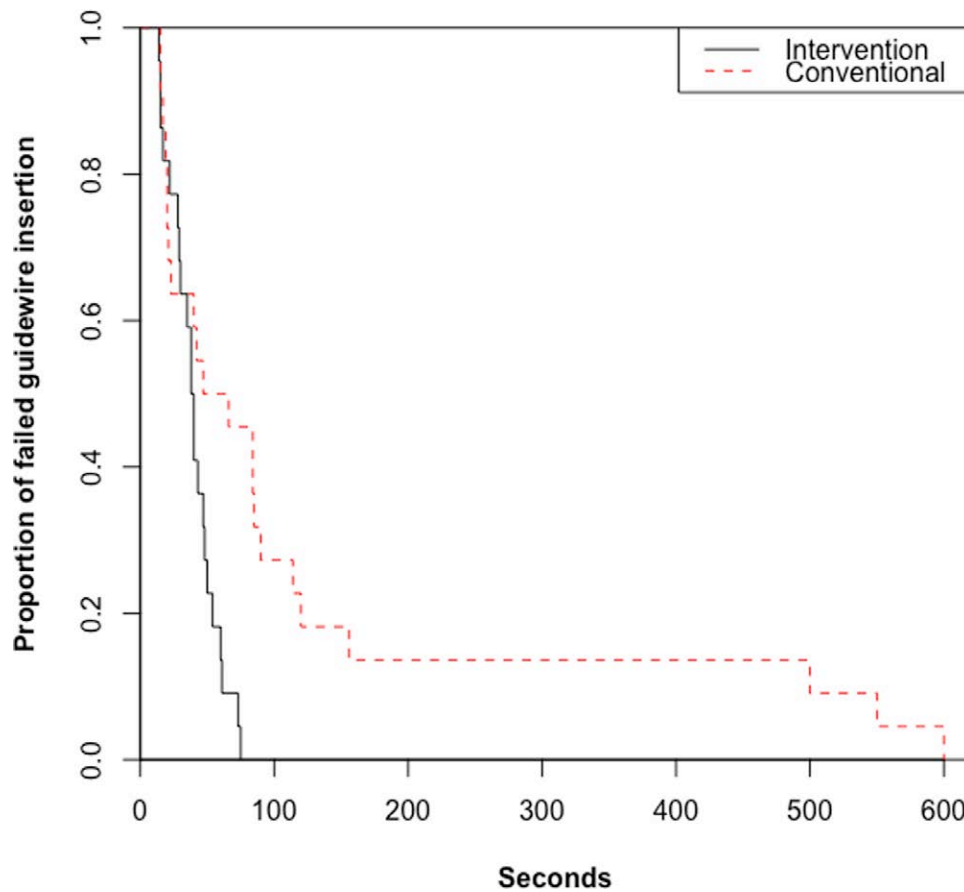


Figure 4. Kaplan–Meier plot demonstrating proportion of subjects with failed guidewire insertion to the internal jugular vein relative to time according to groups. The median (Interquartile range) time (sec) to successful guidewire insertion was 56.5 (20.0–114.0) in the conventional group compared with 39.0 (28.0–50.0) in the intervention group. Data were analyzed using the log-rank test.

Table 3
Complications related to catheterization according to the study groups.

	Conventional group (n = 22)	Intervention group (n = 22)	P
Carotid artery puncture	0 (0)	0 (0)	
Posterior wall puncture	9 (40.9)	7 (31.8)	.75
Hematoma	3 (13.6)	0 (0)	.23

Data are presented as the number (%).

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