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CLINICAL REPORT

Radial artery catheterization using a novel T-type ultrasound probe: a single-center randomized study

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Abstract

Ultrasound guidance has been reported to facilitate radial artery catheterization compared with the palpation method. However, a recent meta-analysis showed that there was not significant differences in the first attempt success rate between the long-axis in-plane (LA-IP) method and the short-axis out-of-plane method. In 2023, we started using a novel T-type probe. We can recognize the needle first during the radial artery access with the short-axis view and then dose it with the long-axis view using the T-type probe. Therefore, we hypothesized that the T-type probe-guided method might heighten the first attempt success rate in radial artery catheterization, even for non-expert practitioners, compared with the LA-IP technique. One hundred and fifty adult patients, older than 20 years, ASA I to III, were randomly assigned to the T-type probe-guided group (Group T: $n=75$) or the LA-IP group (Group L: $n=75$). The primary outcome was the first attempt success rate. The first attempt success rate in Group T (49/71, 69%) was significantly higher than that in Group L (31/68, 46%) ($p=0.0062$). The present study showed that the T-type probe might facilitate the radial artery catheterization rather than the LA-IP method.

Keywords T-type probe · Ultrasound-guided · Radial artery catheterization

Introduction

Radial artery catheterization has been performed by the pulse palpation method. However, the pulse palpation method is sometimes difficult for the practitioner, for various reasons, such as the diameter of the radial artery [1], the variations in the slope of the artery [2], meandering of the vessel [3], physiological changes [4], radial artery spasm [5], and the practitioner's technique [6]. Recent studies [7] have suggested that the dynamic needle tip-positioning (DNTP) technique has improved the first attempt success rate of radial artery catheterization. In 2023, a novel T-type probe (HLS-882, Honda Electronics Co., Ltd., Tokyo, Japan) became available (Fig. 1). Considering of the shape of the T-type probe, we hypothesized that the T-type probe-guided method increases the first attempt success rate even for non-experienced practitioners.

Methods

This study was approved by the institutional review board of Sapporo Medical University School of Medicine (342–175), and was registered in the UMIN Clinical Trial Registry (ID: UMIN000050117) on January 25th, 2023. All participants in the study gave their written, informed consent. One hundred and fifty adult patients older than 20 years, ASA-PS I to III, scheduled for operations, were prospectively enrolled. Allen's test was preoperatively performed for all patients. There were four exclusion criteria: did not consent to participate in clinical research; prothrombin time-international normalized ratio > 2; activated partial thromboplastin time > 54 s; and platelet count $< 5 \times 10^4$/mL. All participants were randomly assigned to treatment groups using a block randomization method (1:1 ratio). Thus, patients were divided into a novel T-type probe-guided group (Group T) and the long-axis in-plane (LA-IP) group (Group L). After induction of general anesthesia, the practitioners performed the procedure. According to the past report [8], it was

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Fig. 1 A newly T-type probe (HLS-882, Honda Electronics Co., Ltd., Tokyo, Japan)

indicated that the risk of mechanical complications increases significantly if the doctor performing the procedure (or the supervising physician) has inserted less than 50 central venous catheterizations. Therefore, we decided empirically that the non-expert practitioners should have attempted less than total 50 cannulations using an ultrasound-guided method. All resident practitioners were in postgraduate years (PGY 3), and non-residents were in PGY 8–15. The novel T-type probe consists of 15 mm region-1 and 25 mm region-2. We can recognize the needle first during the radial artery access with the short-axis view on the right display monitor (Fig. 2A) of the HS-1600 (Honda Electronics Co., Ltd., Tokyo, Japan) (Fig. 2B) and then with the long-axis view on the left display monitor (Fig. 2A). The BD insight-A™ 22G (30 mm) (Becton Dickinson & Co., Tokyo, Japan) was used for radial artery access in this study. The procedure in the both groups was as follows: (1) the wrist was extended, and the hand was fixed. (2) The practitioners confirmed the radial artery in the T-type probe or long-axis view by linear probe. (3) Before the radial access, we explained that the distal region of radial artery and the needle should be visualized in the right side of the screen in Group L. (4) In Group T, the practitioners could visualize simultaneously the short-axis view and the long-axis view during the advancing the needle. (5) If the reflux of blood into the catheter was recognized and the practitioners thought that the needle could be visualized into the vessel in the screen, they could advance the guidewire to the object. (6) If the enough reflux of blood was recognized after the pallium was inserted, the evaluator recognized that the attempt was successfully finished (catheterization success). (7) If the reflux of blood was not done, the practitioners performed

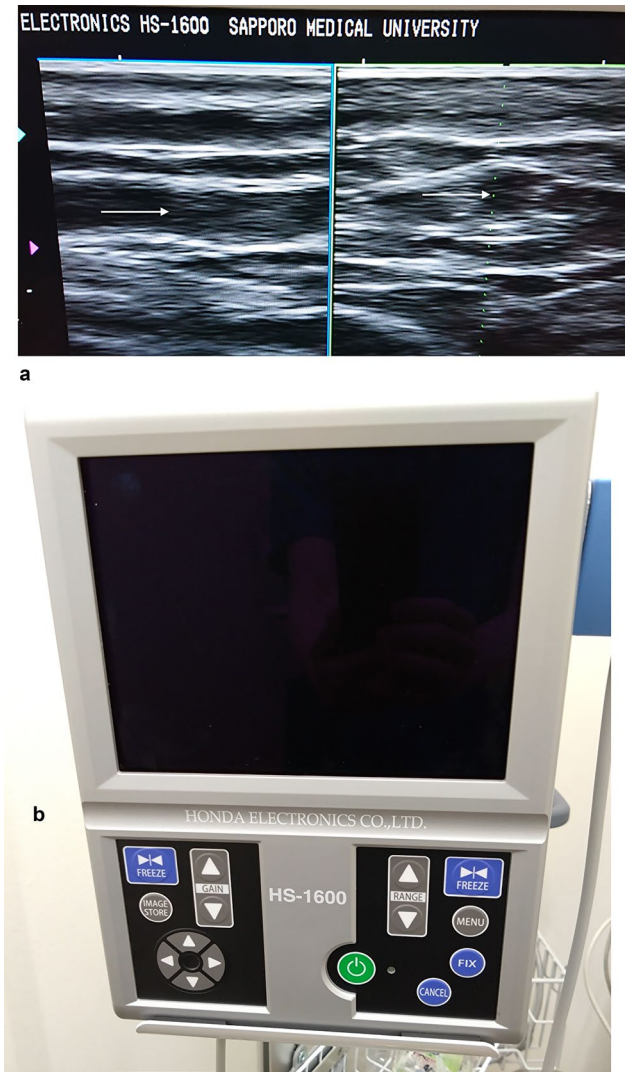

Fig. 2 **A** The long-axis view of the radial artery is seen on the left display monitor (white arrow), and the short-axis view is seen on the right display monitor (white arrow). **B** The display monitor of the HS-1600 (Honda Electronics Co., Ltd., Tokyo, Japan)

the procedure again (catheterization failure). The primary outcome was the first attempt success rate of radial artery catheterization. The secondary outcomes were the total number of attempts for successful cannulation, the time required for successful cannulation, and the time required for catheter fixation, the incidence of posterior wall puncture, and vital signs at the start of the procedure. If the attempt was unsuccessful, the procedure was re-attempted. Measurement of the time to cannulation was re-started for each attempt.

Sample size calculation

According to our previous report [9], the first attempt success rate using the conventional LA-IP method was 44%. In the preliminary clinical trial, the first attempt success

rate of radial artery catheterization of five practitioners using a T-type probe was 80%. Considering the ratio 80/44 (1.82) and the first attempt success rate using DNTP [7], we guessed that a minimum of 43 subjects would be required as primary sample size to detect a difference in the first attempt success rate using the Chi-squared test with a power of 80% and a significance level (α) of 0.05. In the interim groups ($n=50$), the first attempt success rate using a T-type probe method was 76%, and that using the LA-IP method was 54%. Although we evaluated that that the probability of finding a clinically relevant difference is promising, the sample size proposed is too small [10, 11]. Then, we evaluated re-estimation the sample size [12] and the adaptive minimum of 135 by the ratio of 76/54 (1.40) was required. A total of 150 subjects (75 in each group) were enrolled to take into account a 10% dropout rate (G* power 3, Heinrich Heine University Dusseldorf, Dusseldorf, Germany).

Statistical analysis

The primary outcome, total attempts for radial artery access, sex, the number of practitioners, and cannulation site (right hand or left hand) were analyzed by the Chi-squared test or Fisher's exact test. In addition, total attempts for success catheterization was analyzed unpaired *t* test with welch analysis. The other data are expressed as median (IQR: interquartile range) values, and the Mann–Whitney *U* test was used for the analysis. Statistical analysis was performed with GraphPad Prism version 6 software (MDF Co., Tokyo, Japan). p values <0.05 were considered significant.

Results

The patient flow chart is shown in Fig. 3. One hundred and thirty-nine patients (Group T; $n=71$, Group L; $n=68$) were finally analyzed in the present study. Eleven patients were dropped out (visualization difficulty: one patient, the attempt abandoned: 7 patients, the others: 3 patients). Seven patients (Group T; $n=1$, Group L; $n=6$) abandoned the procedures; it was thought that the radial artery cannulations were difficult for practitioners. A total of 18 residents and 11 inexperienced anesthesiologists performed the procedure in the both groups. The patients' characteristics and anesthetics data at the time of attempting radial artery access are each listed in Table 1. They were similar between the two groups. The outcomes are shown in Tables 2 and 3. The first attempt success rate for radial artery catheterization in Group T (49/71, 69%) was significantly higher than that in Group L (31/68, 46%) ($p=0.0062$). In addition, total number of attempts for successful cannulation was significantly different between the two groups ($p=0.0052$, mean difference 0.54, 95% CI: 0.164 to 0.912). In Table 3, the Chi-squared test for the total number of attempts for success cannulation did not show significant value ($p=0.06$). The other data were similar between the two groups. In addition, the incidence of posterior wall

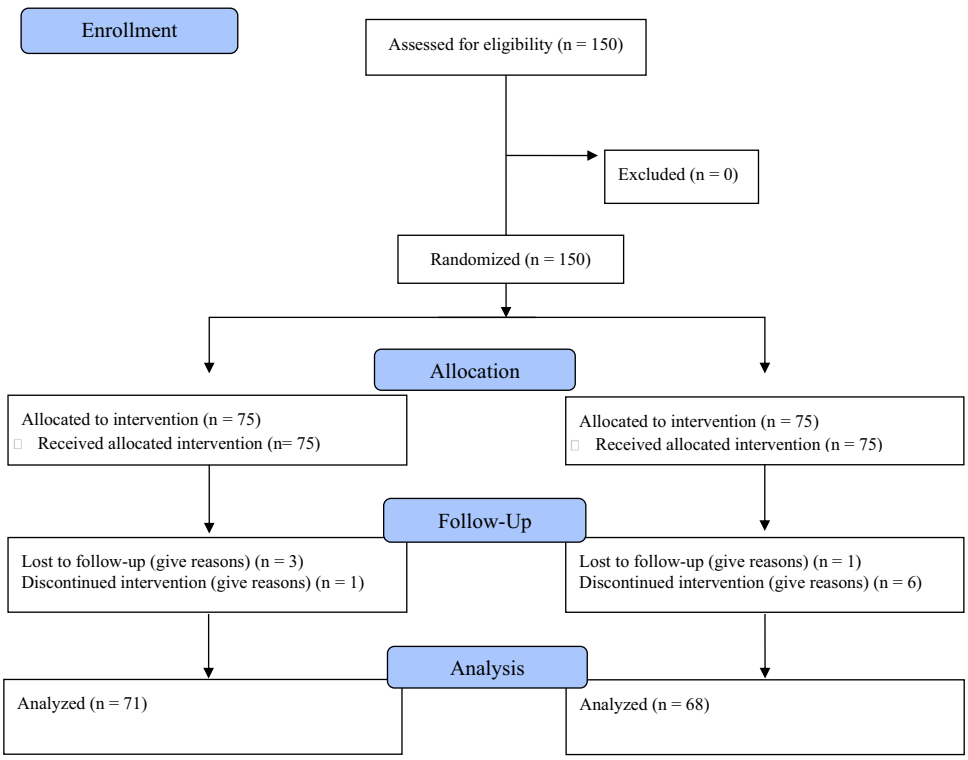

Fig. 3 Study flow chart

Table 1 Characteristics of the patients in the two groups by group

	Group T $N=71$	Group L $N=68$	p value
Sex (male/female)	37/34	27/41	0.17
Practitioner (resident/non-residents)	18/11	18/11	1.0
Access site (right/left)	39/39	29/38	0.50
Age (years)	67 (55–72)	68 (53–74)	0.93
Height (cm)	161 (156–168)	160 (155–167)	0.54
Weight (kg)	60 (50–69)	60 (52–70)	0.70

Values represent median (1st quartile–3rd quartile) values or number of patients

Group T: Novel T-type probe-guided group

Group L: Long-axis in-plane ultrasound-guided group

* $p<0.05$

puncture was not significantly different between the two groups. Vital signs at the start of the radial artery access procedure were similar between the two groups.

Discussion

This is the first report of a randomized study of radial artery catheterization using the novel T-type probe. In the present study, the first attempt success rate using T-type probe was significantly higher than that using LA-IP method. In addition, the total number of attempts for successful cannulation was significantly lower using T-type probe by analyzing unpaired t test. According to a recent meta-analysis [13], the first attempt success rates for adults and children were significantly higher with the ultrasound-guided method than with the pulse palpation method (adults: risk ratio 1.44 [1.28–1.64], $I^2=0\%$; children: risk ratio 1.96 [1.34–2.85], $I^2=23\%$). On the other hand, an updated meta-analysis [14] showed that there were not significant differences in the total success rate (risk difference 1.02 [0.96–1.03], $I^2=0\%$) and the first attempt success rate (risk difference 1.02 [0.79–1.32], $I^2=87\%$) between the long-axis in-plane method and the short-axis out-of-plane method. However, it was expected that there would be a learning curve when using the ultrasound-guided approach [15]. Therefore, for radial artery catheterization, there is room for improvement with the ultrasound-guided method.

Recently, the DNTP method was introduced as a novel ultrasound-guided approach for radial artery access. In a previous report [7], the method of handling the needle was summarized. Using the DNTP approach, the first attempt success rate for radial artery catheterization was increased.

Table 3 The details of total attempts for successful cannulation in the two groups

Total attempts for successful cannulation	Group T $N=71$	Group L $N=68$	p value
1	49 (69%)	31 (46%)	0.06
2	11 (15%)	18 (26%)	
3	8 (11%)	8 (12%)	
4	2 (3%)	7 (10%)	
5	1 (1%)	3 (4%)	
6	0	1 (1%)	

Values represent numbers of persons (percentage)

Data were analyzed by the Chi-squared test

Group T: Novel T-type probe-guided group

Group L: Long-axis in-plane ultrasound-guided group

Table 2 Outcomes by group

	Group T $N=71$	Group L $N=68$	Differences	95% CI	p value
First attempt success rate (%)	49/71 (69)	31/68 (46)			0.0062 *
Total number of attempts for successful cannulation	1.52 ± 0.90	2.06 ± 1.27	0.54	0.16 -0.91	0.0052 *
Time required for successful cannulation (sec)	49.8 (28.8–70.3)	40.5 (25.5 -60.2)			0.16
Time required for the catheter fixation (sec)	156.5 (127.3–200.9)	148.2 (118.6—190.7)			0.4
Incidence of posterior wall puncture (%)	8/71 (11)	4/68 (6)			0.37
Systolic blood pressure (mmHg)	96 (87–112)	95 (85—105)			0.50
Diastolic blood pressure (mmHg)	58 (51–65)	57 (50—66)			0.80
Heart rate (bpm)	67 (62–78)	63 (57—76)			0.11

Values represent median (1st quartile–3rd quartile) values or number of patients or mean ± SD

Group T: Novel T-type probe-guided group

Group L: Long-axis in-plane ultrasound-guided group

95% CI 95% confidence interval

* $p<0.05$

Considering the shape of the novel T-type probe, we thought that practitioners could advance the needle toward the radial artery without moving the T-type probe. Although the T-type probe-guided method was different from the DNTP approach, T-type probe might facilitate the radial artery catheterization rather than the LA-IP method.

Study limitations

First, DNTP or the short-axis out-of-plane method is the preferred technique in many centers. Thus, a randomized study comparing the novel T-type ultrasound probe and DNTP or the short-axis out-of-plane method may be necessary in the future. Next, Allen test was evaluated for all patients. Although the judgment of negative was none, it was not included in the exclusion criteria.

Conclusion

The present study showed that the T-type probe might facilitate the radial artery catheterization rather than the LA-IP method.

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Data availability The data supporting the findings by our study are available from the corresponding author upon reasonable request.

Declarations

Conflict of interest The authors declare no conflicts of interest with respect of research, authorship, and publication of this article.

Ethical approval This study was approved by the institutional review board of Sapporo Medical University School of Medicine (342-175), and was registered in the UMIN Clinical Trial Registry (ID: UMIN000050117).

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