Comparison of Needle Insertion and Guidewire Placement Techniques During Internal Jugular Vein Catheterization: The Thin-Wall Introducer Needle Technique Versus the Cannula-Over-Needle Technique

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Objectives: For needle insertion and guidewire placement during central venous catheterization, a thin-wall introducer needle technique and a cannula-over-needle technique have been used. This study compared these two techniques regarding the success rates and complications during internal jugular vein catheterization.

Design: Prospective, randomized, controlled study.

Setting: A university-affiliated hospital.

Patients: Two hundred sixty-six patients scheduled for thoracic surgery, gynecologic surgery, or major abdominal surgery, who required central venous catheterization.

Interventions: Patients were randomly assigned to either the thin-wall introducer needle group ($n = 134$) or the cannula-over-needle group ($n = 132$). Central venous catheterization was performed on the right internal jugular vein under assistance with real-time ultrasonography. Needle insertion and guidewire placement were performed using a thin-wall introducer needle technique in the thin-wall introducer needle group and a cannula-over-needle technique in the cannula-over-needle group.

Measurements and Main Results: The guidewire placement on the first skin puncture was regarded as a successful guidewire insertion on the first attempt. The number of puncture attempts for internal jugular vein catheterization was recorded. Internal jugular vein was assessed by ultrasonography to identify complications. The rate of successful guidewire insertion on the first attempt was higher in the thin-wall introducer needle group compared with the cannula-over-needle group (87.3% vs 77.3%; $p = 0.037$). There were fewer puncture attempts in the thin-wall introducer needle group than in the cannula-over-needle group (1.1 ± 0.4 vs 1.3 ± 0.6; $p = 0.026$). There was no significant difference in complications of internal jugular vein catheterization between the two groups.

Conclusions: The thin-wall introducer needle technique showed a superior success rate for first attempt of needle and guidewire insertion and required fewer puncture attempts during internal jugular vein catheterization. (*Crit Care Med* 2015; XX:00–00)

Key Words: catheterization; hematoma; internal jugular vein; needles; punctures; ultrasonography

Internal jugular vein (IJV) catheterization is widely used for hemodynamic monitoring, fluid resuscitation, and drug administration. However, this procedure is associated with various complications (1–3). Complications occur commonly during needle insertion and guidewire placement (4, 5). Frequent punctures for venous access may increase the likelihood of these complications (6, 7).

There are two techniques for guidewire placement inside the central veins: the thin-wall introducer needle (TWN) technique and the cannula-over-needle (CON) technique (8). In the TWN technique, the guidewire is directly inserted through the introducer needle, and there is a possibility of needle migration during guidewire insertion. In the CON technique, the guidewire is inserted through the venous cannula, which may provide stable venous access during guidewire insertion. However, this technique requires the additional step of cannula advancement into the vessel, which may induce potential complications such as kinking of the cannula or needle migration during cannula advancement.

However, there is no randomized, controlled study to evaluate whether the type of guidewire placement technique is related with higher success rates and fewer complications. The aim of this study was to compare the two techniques with regard to the number of puncture attempt, which is an

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important measure linked to mechanical complications during IJV catheterization.

MATERIALS AND METHODS

This study was approved by the Institutional Review Board of Seoul National University Hospital and registered at ClinicalTrials.gov (NCT01902355). We enrolled patients from August 2013 to July 2014 scheduled for thoracic surgery, gynecologic surgery, or major abdominal surgery, who required central venous catheterization. Written informed consent was obtained from all the patients. Exclusion criteria included patients who had inflammation at the catheter insertion site, previous neck surgery, anatomical variation of neck vessels, left diaphragmatic dysfunction, or previous right side central venous catheterization within 1 month.

Study Protocol

The patients were randomly assigned by computer to the TWN group or the CON group. Central venous catheterization was performed by two experienced anesthesiologists (Y.H.L., Y.S.J.) who had over 50 IJV catheterizations in both techniques (6, 9). After induction of general anesthesia, the patient was placed supine and the head was slightly rotated to the left. A 1-L saline bag was placed under the patient's right shoulder for neck exposure. Then, the patient was positioned at 10 degrees in the Trendelenburg position. After antiseptic preparation and sterile draping, the location and the route of the right IJV were assessed by ultrasonography (Vivid-q; GE Healthcare, Wauwatosa, WI). An adequate insertion site was selected at the level of the cricoid cartilage, and at that point, the diameter of the IJV, the right common carotid artery, and the overlapping area of the two vessels were measured. A double-lumen central venous catheter (7Fr. ARROWg^{+}ard Blue Catheter; Arrow International, Reading, PA) was placed under real-time ultrasonography guidance using either the TWN technique (TWN group) or the CON technique (CON group). The TWN was an 18-gauge needle with a length of 6.35 cm, and the CON was an 18-gauge cannula with a length of 6.35 cm over a 20-gauge introducer needle. A finder needle was not used prior to central venous catheterization. After guidewire insertion, placement of the guidewire in the IJV was verified by ultrasonography in both groups.

When venous puncture and guidewire placement was achieved on the first skin puncture, this was recorded as a successful guidewire insertion on the first attempt. If placement failed on the first attempt, the reason was recorded as the failure of venous puncture, cannula placement, or guidewire placement. Next, needle insertion and guidewire placement were attempted up to three times. Securing the venous route and guidewire insertion within three puncture attempts was considered a successful central venous catheterization (6, 9). After three failed attempts, another experienced anesthesiologist tried right IJV catheterization up to three times. The number of puncture attempts was recorded.

The type of venous blood aspiration was recorded as aspiration-on-advance or aspiration-on-withdrawal. Aspiration-on-advance was defined as free flowing of blood into the syringe during advancing, and aspiration-on-withdrawal was defined as free flowing of blood into the syringe during withdrawal. The central venous catheter was placed over the guidewire after tissue dilation. The difficulty of tissue dilation was recorded: grade I = easy to dilate; grade II = difficult to dilate, but scalpel incision was not needed; grade III = dilation difficult, required a scalpel incision.

Ultrasonographic images were collected at three time points (before venous puncture, after guidewire placement, and after catheter insertion) to evaluate carotid artery puncture or hematoma formation. Severe hematoma was defined as a visible hematoma large enough to be seen outside the skin. Other complications, including pneumothorax and hemothorax, were evaluated the day after surgery by reviewing the medical chart and the chest radiograph.

Statistical Analysis

The primary endpoint of the study was set as the rate of successful guidewire insertion on the first attempt. In our pilot study of 30 patients, central venous catheterization was performed using the TWN technique, and 86.7% of patients (26 of 30) had a successful guidewire insertion on the first attempt. We assumed that a 10% difference in the rate of successful guidewire insertion on the first attempt was clinically significant (10). In order to achieve a type 1 error (α) of 0.05 and a power of 80%, 130 patients per group were needed. The sample size was calculated according to G*power (version 3.1.9.2, Franz Faul, Kiel University, Germany).

Data were presented as number of patients (percentage) or mean ± SD. The independent t test was used to compare the patients' demographic data, the diameter of vessels. The Mann-Whitney U test was used to compare the number of skin puncture attempts between the two groups. The chi-square test or Fisher exact test was used to compare the success rate of guidewire insertion on the first attempt, dilation grade, and complications. A p value of less than 0.05 was considered to indicate statistical significance. Statistical analyses were performed using SPSS version 18.0 (SPSS, Chicago, IL).

RESULTS

Of 294 patients screened for eligibility, 272 were randomly assigned to either the TWN group (n = 136) or the CON group (n = 136), and finally, 266 patients were analyzed (134 in the TWN group and 132 in the CON group) (**Fig. 1**). Patient characteristics were comparable between the two groups (**Table 1**).

The rate of successful guidewire insertion on the first attempt was higher in the TWN group compared with the CON group (87.3% [117 of 134] vs 77.3% [102 of 132]; p = 0.037) (**Table 2**). The reasons for failure of guidewire insertion on the first attempt were failure of venous puncture (nine of 17) or guidewire placement (eight of 17) in the TWN group and failure of venous puncture (14 of 30), cannula placement (11 of 30), or guidewire placement (five of 30) in the CON group.

The overall success rate of IJV catheterization within three attempts was not different between the two groups (99.3% [133 of 134] in the TWN group and 97.7% [129 of 132] in the CON group; p = 0.37). However, there were fewer puncture

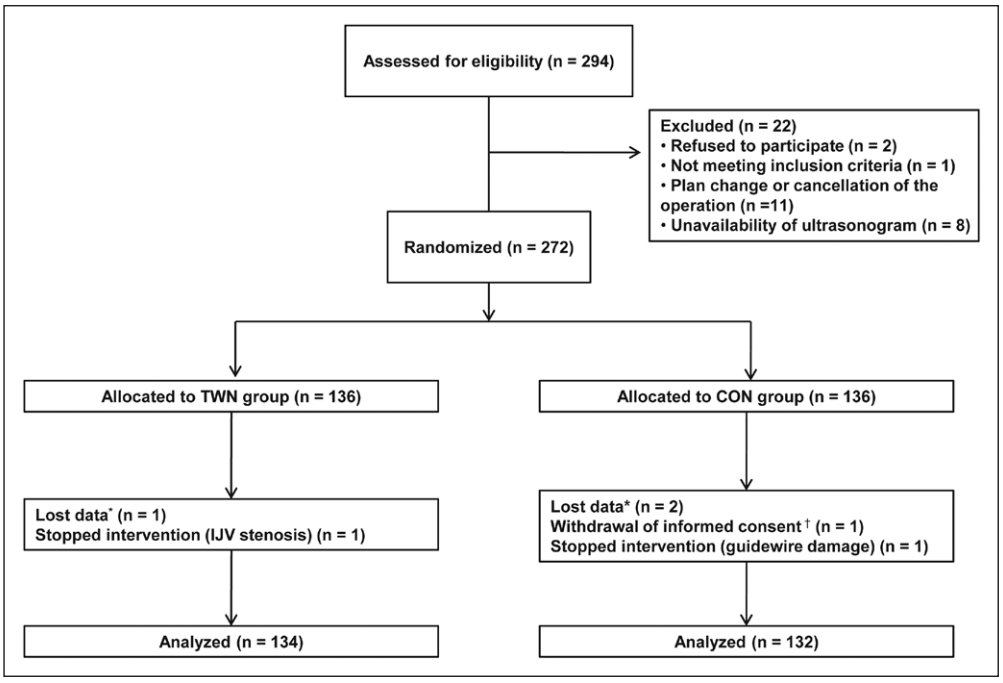

Figure 1. Screening, enrollment, and random allocation of patients. *Lost data, loss of unsaved ultrasonography images before evaluation of vessel diameter and hematoma. †Withdrawal of informed consent, the patient withdrew informed consent after the surgery. CON group = cannula-over-needle group, IJV = internal jugular vein, TWN group = thin-wall introducer needle group.

attempts in the TWN group than in the CON group (1.1 ± 0.4 vs 1.3 ± 0.6; $p = 0.026$).

The type of venous blood aspiration did not differ between the two groups. The occurrence rate of aspiration-on-advance was 79.9% (107 of 134) in the TWN group and 77.3% (102 of 132) in the CON group ($p = 0.6$). Although the occurrence rate of hematoma on ultrasonography was 9.0% (12 of 134) in the TWN group and 15.9% (21 of 132) in the CON group, the difference was not statistically significant ($p = 0.09$). There were no other complications of IJV catheterization, such as severe hematoma, arterial puncture, pneumothorax, and hemothorax.

The CON group experienced more difficulties in tissue dilation for catheter placement. During subcutaneous tissue dilation, 59 of 132 patients (44.7%) required a scalpel incision. Meanwhile, in the TWN group, only two of 134 patients (1.5%) required a scalpel incision. The difference was statistically significant ($p < 0.0001$).

DISCUSSION

The present study revealed that when performed by experienced operators, the TWN technique was associated with a higher success rate of needle insertion and guidewire placement on the first attempt during IJV catheterization. Furthermore, fewer puncture were needed for the TWN technique than for the CON technique. The complication rates between the two techniques were comparable, but the present study was not powered for measuring the differences in complication rates.

Central venous catheter–related mechanical complications are closely related to needle insertion and guidewire placement. Several studies reported that additional needle passes increase the complications (6, 7, 9, 11–13) and suggest that a high number of failed catheterization attempts is the strongest predictor of related complications (14, 15). Therefore, some authors recommend limiting the needle puncture attempts to three to prevent mechanical complications (16). The recent practice guidelines for central venous access (8) reported that there was insufficient evidence to prove whether the occurrence of catheter-related injury and trauma is associated with the insertion technique. One characteristic of the CON technique is

TABLE 1. Comparison of Patient Characteristics Between Two Groups

Variables	Thin-Wall Introducer Needle Group (*n* = 134)	Cannula-Over-Needle Group (*n* = 132)
Age, yr	59.4 ± 11.7	60.1 ± 13.2
Male sex, *n*	68 (50.7)	72 (54.5)
Height, cm	161.2 ± 8.4	162.5 ± 8.7
Weight, kg	62.1 ± 10.5	61.2 ± 10.3
Body mass index	23.9 ± 3.6	23.1 ± 3.2
Internal jugular vein diameter, mm	20.8 ± 5.0	20.4 ± 4.8
Common carotid artery diameter, mm	8.0 ± 1.4	7.8 ± 1.5
Percent overlap[a], %	19.5 ± 12.4	20.9 ± 12.6

[a]The ratio of the diameter of the overlapped distance between the internal jugular vein and the common carotid artery over the diameter of the internal jugular vein. Data are presented as mean ± SD or number of patients (%).

TABLE 2. Variables Related to Central Venous Catheterization

Variables	Thin-Wall Introducer Needle Group ($n = 134$)	Cannula-Over-Needle Group ($n = 132$)	p
Guidewire insertion on the first attempt	117 (87.3)	102 (77.3)	0.037
Success of catheterization within three attempts	133 (99.3)	129 (97.7)	0.37
No. of skin puncture attempts	1.1 ± 0.4	1.3 ± 0.6	0.026
Venous puncture type			
Aspiration-on-advance	107 (79.9)	102 (77.3)	0.6
Aspiration-on-withdrawal	27 (20.1)	30 (22.7)	
Complications			
Hematoma on ultrasonography	12 (9.0)	21 (15.9)	0.09
Severe hematoma[a]	0	0	
Arterial puncture	0	0	
Pneumothorax	0	0	
Hemothorax	0	0	
Dilation grade[b] (I/II/III)	130/2/2	70/3/59	< 0.0001

[a]Severe hematoma: visible hematoma large enough to be seen outside the skin.
[b]Grade I = easy to dilate; grade II = difficult to dilate, but scalpel incision was not needed; grade III = dilation difficult, required a scalpel incision.
Data are presented as number of patients (%) or mean ± SD.

that it can provide more stable venous access when tubing is used as a manometer to verify whether the cannula is inside the vein (8, 17). Needle migration after venous puncture using the TWN technique can lead to mechanical complications and can require additional punctures to reestablish the venous route for guidewire insertion. On the other hand, the additional step of cannula placement using the CON technique can induce potential pitfalls and may lead to additional punctures.

In the present study, the TWN technique showed a higher success rate of needle insertion and guidewire placement on the first attempt. These results suggest that the TWN technique provides sufficient stability of the venous route during guidewire insertion and allows easier venous access than the CON technique. The difficulty of securing venous access in the CON technique seems to be related to the placement of the cannula. This may be due to two reasons. First, after confirmation of the needle tip inside the vein, the needle is slightly inserted further for cannula insertion, positioning the needle tip closer to the posterior or lateral wall of the vein. This may induce puncture of the vessel wall, and additionally, it is possible for the needle to migrate outside the vein due to the pushing force during cannula placement. Second, even if the cannula was advanced completely into the vein, it could be kinked during advance or occluded by the vessel wall.

We also found that the CON technique is associated with difficulty in tissue dilation. Although the same size (18 G) of needle or cannula was used for venous puncture, the rigid needle induced more tissue dilation than did the pliable cannula. Because resistance during tissue dilation can cause guidewire damage, a scalpel incision before tissue dilation is usually recommended to facilitate the dilation during central venous catheterization. However, scalpel incisions may induce bleeding and increase discomfort in awake patients. In the present study, only four of 134 patients (3.0%) undergoing the TWN technique had tissue dilation difficulty, suggesting that the scalpel incision may not be necessary in all cases that use the TWN technique with relatively small-size catheter (7F).

There were several limitations to our study. First, the practitioner inserting the catheter could not be blinded to the group assignment. Although the same study protocol was strictly applied to both groups, this study could not be performed in a double-blind manner. Second, the sample size was not sufficient to compare the rates of complications between the two techniques although the incidence of catheterization-related complications was comparable in the present study. Third, the use of ultrasonography may have reduced complications according to IJV catheterization and there was no case of severe hematoma, carotid puncture, pneumothorax, or hemothorax (18–20). These complications are usually induced by mechanical trauma to the artery, lung, or both, and ultrasonography reduces the possibility of unintended puncture. Finally, the venous placement of the needle, cannula, and guidewire was verified by ultrasonography without manometry. Manometry is widely used to detect arterial punctures of the TWN or cannula before guidewire insertion (21). Additional use of manometry for venous confirmation might increase the safety of central venous catheterization.

CONCLUSIONS

This study revealed that the TWN technique had a superior success rate for needle insertion and guidewire placement on the first attempt compared with the CON technique during IJV catheterization using real-time ultrasonography guidance. The CON technique may provide stable venous access during guidewire insertion but requires more repetitive puncture attempts for IJV catheterization. A larger study is required to compare the IJV catheterization–related complications between the two techniques.

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