Original research article

JVA The Journal of Vascular Access

Short peripheral intravenous cannula and straight-tip guide wire in ultrasound-guided neonatal central venous catheterization

The Journal of Vascular Access
1–8

DOI: 10.1177/11297298221086186
journals.sagepub.com/home/jva
SAGE

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Abstract

Background: Inserting a J-tip guide-wire into a vein's lumen is often difficult when using the Seldinger or modified Seldinger technique for central venous catheterization (CVC) in newborns. This study was designed to compare the efficacy and safety of guide-wire insertion using the combination of a short peripheral intravenous cannula with a straight-tip guide-wire vs. a needle with a J-tip guide-wire for ultrasound-guided (USG) cannulation of the internal jugular vein (IJV) in newborns using an in-plane technique.

Methods: One hundred and thirty newborn patients (weight, 1.4-5.2 kg) scheduled for selective or emergency surgery, were randomly assigned to either the needle group (combined with a J-tip guide-wire) or cannula group (combined with a straight-tip guide-wire). The primary outcome was the rate of successful guide-wire insertion on the first attempt. The puncture attempts, catheter placement attempts, and mechanical complications were also compared between the groups.

Results: The rate of successful guide-wire insertion on the first attempt was higher in the cannula group (97%) than in the needle group (76%) ($p < 0.05$, $\chi^2 = 11.233$). Moreover, fewer insertion attempts were needed in the cannula group (1.0 ± 0.2) than in the needle group (1.7 ± 1.1) ($p < 0.05$, 95% CI [0.449, 1.028]). The time to successful guide-wire insertion was shorter in the cannula group (63 ± 32 s) than in the needle group (92 ± 50 s) ($p < 0.05$, 95% CI [14.024, 43.063]). No differences were found about other catheterization parameters and complications between the groups.

Conclusion: The short peripheral cannula combined with a straight-tip guide-wire was superior to the needle combined with a J-tip guide-wire for USG newborn IJV catheterization in terms of successful guide-wire insertion on the first attempt and overall number of insertion attempts.

Keywords

Central venous catheterization, modified Seldinger technique, newborn, peripheral intravenous cannula, straight-tip guide-wire

Date received: 11 June 2021; accepted: 12 February 2022

Introduction

Central venous catheterization (CVC) in pediatric patients is challenging, even under ultrasound guidance (USG).[1,2] The success rates and complications of CVC are influenced by patient factors like smaller size body, tiny venous lumen, and clinical condition, as well as procedural factors like catheter size, equipment, and operator experience.[3,4]

The right internal jugular vein (IJV) is often chosen for pediatric catheterization, because it directly accesses the superior vena cava, has a relatively large lumen, is easily compressed during bleeding, and is associated with lower complication rates.[5,6] USG provides information on the caliber, trajectory, patency, and adjacent structures of the IJV; therefore, it is recommended as an adjunct in pediatric

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catheterization.[7] Additionally, USG improves venipuncture success rates, reduces complications, and shortens procedure times as compared to the conventional anatomical landmark and palpation technique.[8,9]

The Seldinger technique is most commonly used for CVC. This requires the introduction of the catheter into the vascular lumen through a thin-walled needle with a guidewire. While blood is usually aspirated freely using this technique, the needle tip may be displaced or span the anterior-posterior vessel wall, and the guide wire often coils during insertion, making the procedure technically difficult. In contrast, the modified Seldinger technique employs a short peripheral intravenous cannula as the tunnel for guide wire insertion, which is superior for catheterization and is recommended in pediatric patients.[10]

A cannula may be inserted with a J-tip guide wire; however, cannulation is not always successful when using this combination.[11] A straight-tip guide wire is recommended for CVC, particularly in very low body-weight preterm neonates, because the soft tip does not coil during insertion.[12,13] The practicability and safety of using a cannula with a straight-tip guide wire in the modified Seldinger techniques for newborn CVC has not yet been adequately documented.

The purpose of this prospective evaluation was to compare the efficacy and safety of guide-wire insertion, using either a cannula with a straight-tip guide-wire or a needle with a J-shaped guide-wire, when catheterizing the IJV during CVC in newborns using a USG in-plane technique. The puncture attempts, catheter placement attempts, and mechanical complications were also compared between the two methods.

Methods

Study design

This was a prospective randomized controlled study. The study design was approved by the institutional review board of Lanzhou University Second Hospital (2020A-013). The protocol was registered at http://www.chictr.org.cn (ChiCTR1900025712). The parents or legal guardians of the participants provided informed consent.

Study population

This study was conducted in a tertiary-level teaching hospital between January 2019 and December 2020. In total, 140 newborns, between 1 and 28 postnatal days, who required a CVC for elective or emergency surgery, were enrolled. The surgeries included gastrointestinal, neurosurgical, and cardiovascular procedures. Children with anatomical variations, puncture site infections, coagulation disorders, or thrombosis were excluded.

All children were randomly divided into two groups. In the needle group, a thin-walled needle with a J-tip guide wire was used for CVC, while in the cannula group, a short peripheral intravenous cannula with a straight-tip guide wire was used. The randomization was accomplished by an online program (http://www.randomizer.org). The right IJV was the primary catheterization site, and a 4-French radiopaque polyurethane catheter with an outside diameter of 1.4 mm and a double lumen (Guangdong Baihe Medical Technology Co. Ltd., Guangdong, China) was used for all patients. Catheterization was performed under real-time USG by two anesthesiologists (JHT and ZK), each with more than 50 experiences of CVC cases in infants.

Surgical technique

Upon arrival to the operating room, newborns received continuous electrocardiogram, noninvasive blood pressure, and pulse oximeter monitoring. Scalp venous access was established for the administration of anesthesia. After conventional general anesthesia (sevoflurane) with endotracheal intubation institution, newborns were placed in a supine 30° Trendelenburg position to increase jugular filling. We extended the neck with a shoulder cushion and rotated the head slightly to the opposite side to expose the puncture site fully.

A preprocedural ultrasound scan was performed to evaluate the patency and adjacent structures of the right IJV in both long-axis and short-axis views. A portable ultrasound device with a 13-6 MHz, 25 mm broadband linear-array probe and high-resolution vascular transducer (FUJIFILM SonoSite, Bothell, Washington, USA) provided real-time guidance. We recorded the depth and diameter of the IJV. The puncture site was located at the medial point of the leading edge of the sternocleidomastoid muscle.

We ensured antisepsis by using 2% chlorhexidine gluconate in 70% isopropyl alcohol to clean the skin, and we covered the site with a sterile fenestrated drape. The ultrasound probe was placed into a disposable sterile protective sheath with enough sterile ultrasound gel to cover the probe. Under real-time USG, the needle was guided at approximately 30° for venipuncture using the long axis view/in-plane approach (ultrasound-based tip navigation).[14] A thin-walled 21-gauge Y-type introducer needle (length 33 mm, Guangdong Baihe Medical Co. Ltd., Guangdong, China) connected to a 2 mL syringe was used for venipuncture in the needle group. Once the needle tip was visualized within the vascular lumen, a slight negative pressure was applied to confirm the correct position of the needle tip by aspirating blood freely. Following the standard Seldinger technique, we introduced a flexible J-tip guide wire with a diameter of 0.46 mm (Guangdong Baihe Medical Co. Ltd., Guangdong, China) through the needle and into the vein for approximately 10 cm.

In contrast, a 22-gauge polyurethane peripheral intravenous cannula (length 25 mm) with a style (B. Braun, Melsungen, Germany) was used for venipuncture in the

cannula group. Once the cannula tip was visualized within the vascular lumen, the cannula was fully inserted into the vein, and the style was withdrawn. A soft straight-tip guide wire with a diameter of 0.46 mm (Guangdong Baihe Medical Co. Ltd., Guangdong, China) was introduced through the cannula and into the lumen by approximately 10 cm.

If blood could not be aspirated, the puncture angle, direction, and depth were adjusted. However, if pulsating and bright-red blood was aspirated, the needle was withdrawn, and the puncture site was pressed for 3 min to prevent hematoma formation. If the J-tip guide wire was not successfully inserted within 3 min, the procedure was considered to have failed, and a straight-tip guide wire was used instead (guide wire type cross-over). After the position of the guide-wire was confirmed in the vasculature using ultrasonography in both long-axis and short-axis view, a tissue dilator and indwelling catheter were introduced over the guide wire. An intraprocedural transthoracic ultrasound in subcostal longitudinal view (7-8 MHz micro-convex probe, FUJIFILM SonoSite, Bothell, Washington, USA) or intracavitary electrocardiography (identifying the maximum atrial P-wave) was taken to confirm the position of the catheter tip.[15,16] Additionally, a chest radiograph was obtained immediately after catheterization to detect potential complications, such as pneumothorax, hemothorax, and catheter malposition, if necessary. Finally, the indwelling catheter was fixed with a sutureless device.

Data collection

The following data were collected: sex, age, weight, right IJV depth and diameter at the puncture site, number of puncture attempts, number of cannula advancement attempts, number of guide wire insertion attempts, number of catheter placement attempts, success rates of puncture on the first attempt, success rates of guide-wire insertion on the first attempt, and success rates of catheter placement on the first attempt. We also recorded the operative times for each step. Time to the first successful puncture was defined as the interval between skin penetration and first free aspirate of blood in the syringe. Time to successful cannula placement was defined as the interval between skin penetration and full insertion of the cannula into the vein. Time to successful guide wire insertion was defined as the interval between the first successful free blood aspirate and time at which successful guide wire insertion was confirmed using ultrasonography. Time to successful catheter placement was defined as the interval between successful guide wire insertion and time at which the catheter was confirmed to be within the vascular lumen using ultrasonography. More than three puncture attempts were considered a failure, and another technique or puncture site was utilized thereafter. Catheterization-related mechanical complications (such as arterial puncture and/or cannulation, hematoma formation, guide-wire malposition, pneumothorax, hemothorax, and cardiac tamponade) were also compared between the groups. An assistant anesthesiologist recorded the operation parameters, and another anesthesiologist, who was blinded to the group assignments, collected and analyzed the data.

Statistical analysis

The primary outcome of our study was the rate of successful guide wire insertion on the first attempt. Based on published literature, the first attempt success rate of the Seldinger technique is 75%.[11] To obtain an absolute increase of 20% using the modified Seldinger technique (cannula group), the required sample size, calculated using the PASS software, version 11 (NCSS Statistical Software, Kaysville, Utah), was approximately 61 for each group. Type 1 error (α) and power values of 0.05 and 90%, respectively, were used. Data were recorded and analyzed using Microsoft Office Excel 2010 (Microsoft, Redmond, Washington, USA) and SPSS version 19.0 (IBM, Armonk, New York, USA), respectively. Data on the guide-wire type cross-over were collected and analyzed according to the initial group allocation. Continuous variables were expressed as mean $\pm$ standard deviation (SD), whereas categorical values were presented as frequency and percentage. The independent sample *t*-test and Pearson chi-square test were used to analyze continuous and categorical variables, respectively. The results and differences were expressed as mean $\pm$ SD (range) with a 95% confidence interval (CI) or frequency with chi-square values (χ^2). All statistical tests were two-sided, and a $p < 0.05$ was considered significant.

Results

Among the 140 newborns, there were two cases each of anatomical abnormalities and coagulation disorders. Four newborns whose parents declined enrollment and two who no longer required a CVC for their surgery were excluded. The remaining 130 cases were randomly assigned to the needle ($n = 65$) and cannula ($n = 65$) groups (Figure 1). The indications for CVC included difficult peripheral venous access, total parenteral nutrition, chemotherapy, hemodynamic monitoring, and blood product and vasoactive drug transfusion. The demographic characteristics of both groups are listed in Table 1; no significant differences were noted.

Preprocedural ultrasonography demonstrated that the carotid arteries and IJVs of all the newborns were structurally clear, had patent lumens, and no thrombosis. The diameter and depth of the right IJV were similar in the groups (4.9 ± 0.6 vs. 4.7 ± 0.7 mm, $p = 0.068$ and 5.3 ± 0.9 vs. 5.1 ± 0.8 mm, $p = 0.189$, respectively, Table 1).

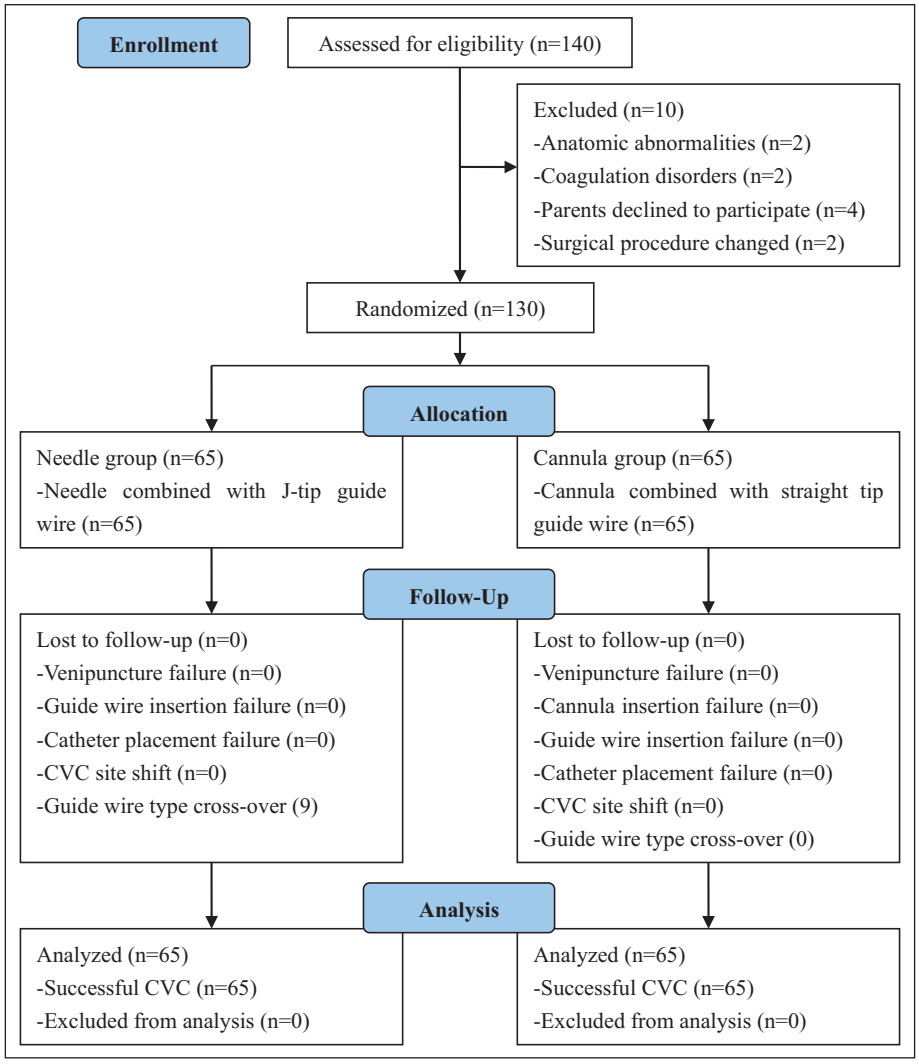

Figure 1. CONSORT flow diagram. CVC: central venous catheterization.

Table 1. Demographic characteristics of newborn patients.

	Needle group ($n=65$)	Cannula group ($n=65$)	p–value
Male:Female	29:36	35:30	0.293
Age, day (range)	13 ± 8 (1–28)	14 ± 8 (1–28)	0.544
Weight, kg (range)	3.7 ± 0.7 (1.4–4.9)	3.9 ± 0.8 (1.5–5.2)	0.064
Right IJV diameter (mm)	4.9 ± 0.6	4.7 ± 0.7	0.068
Right IJV depth (mm)	5.3 ± 0.9	5.1 ± 0.8	0.189

Data are shown as mean ± standard deviation or ratio.
IJV: internal jugular vein.

All catheterizations were performed in the right IJV (Figure 2). The CVC procedural data are summarized in Table 2. The average number of puncture attempts was 1.3 ± 0.6 (range, 1–3) and 1.3 ± 0.4 (range, 1–3) in the needle and cannula groups, respectively, and this was not significantly different ($p=0.880$, 95% CI [−0.186, 0.217]). There was also no significant difference ($p=0.537$, $\chi^2=0.381$ and $p=0.430$, 95% CI [−15.945, 6.923]) in the rate of successful puncture on the first attempt (74% vs. 78%) and time to first successful puncture (62 ± 33 vs. 66 ± 32 s) between the needle and cannula groups, respectively.

Our primary outcome (i.e., successful guide-wire insertion on the first attempt) was significantly higher in

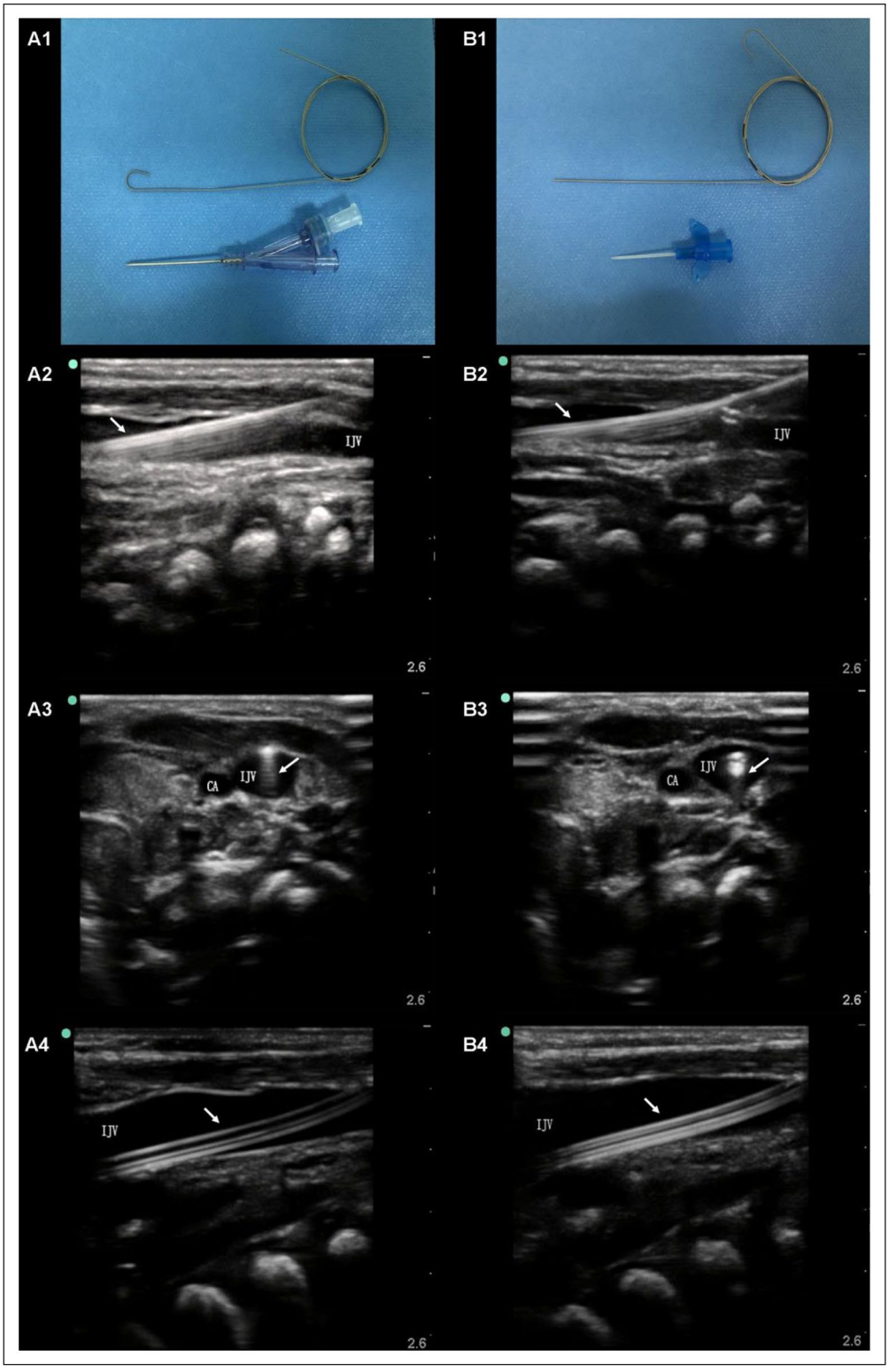

Figure 2. Ultrasonographic images of right IJV catheterization in a 17-day-old infant (Needle group, A1–A4) and in a 4-day-old infant (Cannula group, B1–B4).
A1: J-tip guide wire (0.46 × 500 mm) and 21-gauge Y-type introducer needle (outer diameter 0.9 mm, inter diameter 0.68 mm, length 33 mm). B1: soft straight-tip guide wire (0.46 × 500 mm) and 22-gauge polyurethane peripheral intravenous cannula (outer diameter 0.9 mm, length 25 mm). Ultrasonographic image demonstrating the guide-wire (arrow) passing through the introducer needle (A2, A3) or cannula (B2, B3) within the right IJV lumen in long-axis (A2, B2) and short-axis (A3, B3) views. Successful catheter placement is confirmed by ultrasonography in long-axis view, which demonstrates the indwelling catheter (arrow) perfectly within the IJV lumen in the needle (A4) and cannula (B4) groups. CA: carotid artery; IJV: internal jugular vein.

Table 2. CVC procedural data between the Needle and Cannula groups.

	Needle group ($n=65$)	Cannula group ($n=65$)	p-value	χ^2	95% CI
Catheterization site					
Left IJV:Right IJV	0:65	0:65			
Vein puncture					
Puncture attempts (n) (range)	1.3 ± 0.6 (1–3)	1.3 ± 0.4 (1–3)	0.880		−0.186, 0.217
Successful puncture on the first attempt (n)	48 (74%)	51 (78%)	0.537	0.381	
Time to the first successful puncture (s)	62 ± 33	66 ± 32	0.430		−15.945, 6.923
Guide-wire insertion					
Insertion attempts (n) (range)	1.7 ± 1.1 (1–4)	1.0 ± 0.2 (1–2)	0.000		0.449, 1.028
Successful insertion on the first attempt (n)	43 (76%)	63 (97%)	0.001	11.233	
Guide-wire type cross-over (n)	9 (14%)	0			
Time to successful guide-wire insertion (s)	92 ± 50	63 ± 32	0.001		14.024, 43.063
Catheter placement					
Placement attempts (n) (range)	1.2 ± 0.5 (1–3)	1.1 ± 0.2 (1–2)	0.131		−0.033, 0.248
Successful placement on the first attempt (n)	59 (91%)	61 (94%)	0.510	0.433	
Time to successful catheter placement (s)	142 ± 38	135 ± 36	0.283		−5.883, 19.945
Cannula advancement attempts (n) (range)		1.1 ± 0.37 (1–3)			
Time to successful cannula placement (s)		36 ± 12			
Total time of catheterization (s)	295 ± 97	300 ± 102	0.782		−39.503, 29.813
Complications					
Arterial puncture (n)	0	0			
Hematoma formation (n)	4	2			
Guide-wire malposition (n)	0	0			
Carotid artery cannulation (n)	0	0			
Pneumothorax / Hemothorax (n)	0	0			
Cardiac tamponade (n)	0	0			

Data are shown as frequency (%), mean ± standard deviation or ratio.
CVC: central venous catheterization; IJV: internal jugular vein; CI: confidence interval; s: seconds.

the cannula (97%) than in the needle group (76%) ($p=0.001$, $\chi^2=11.233$). The average number of guide-wire insertion attempts was less in the cannula (1.0 ± 0.2) than in the needle group (1.7 ± 1.1); the difference was significant ($p<0.001$, 95% CI [0.449, 1.028]). The time to successful guide wire insertion was significantly shorter in the cannula (63 ± 32 sec) than in the needle group (92 ± 50 sec) ($p=0.001$, 95% CI [14.024, 43.063]). The J-tip guide wire could not be inserted within 3 min in nine (14%) newborns in the needle group, and successful insertion was accomplished only after replacement with the straight-tip guide-wire. In the cannula group, the average number of cannula advancement attempts was 1.1 ± 0.37 (range, 1–3), and the time to successful placement was 36 ± 12 sec.

The following catheter placement parameters were also assessed between the groups: the average number of catheter placement attempts (1.2 ± 0.5 [range, 1–3] vs. 1.1 ± 0.2 [range, 1–2]), the rate of successful catheter placement on the first attempt (91% vs. 94%), and time to successful catheter placement (142 ± 38 vs. 135 ± 36 sec). None of these measures demonstrated significant difference ($p=0.131$, $p=0.510$, and $p=0.283$, respectively).

Hematoma formation was noted in four and two cases in the needle and cannula groups, respectively. No other complications occurred (Table 2).

Discussion

CVC is a critical procedure in pediatric patients. In this study, we compared the efficacy and safety of a peripheral intravenous cannula with a straight-tip guide wire and a needle with a J-tip guide wire in ultrasound-guided IJV catheterization in newborns. Our data demonstrated that the success rate for CVC on the first attempt was higher when a straight-tip guide wire and cannula were used (97%) than when a J-tip guide wire and needle were used (76%) ($p=0.001$). Additionally, the cannula group had a smaller average number of guide wire insertion attempts ($p<0.001$) and shorter times for successful guide wire insertion ($p=0.001$) than those of the needle group. Consistent with previous studies,[11] our results also showed the superiority of the cannula for ultrasound-guided IJV catheterization in neonates.

Venipuncture is more difficult in newborns because of their small body size and tiny venous lumens. In our study,

there was no significant difference in the success rates of puncture on the first attempt between the two groups (74% vs. 78%, $p = 0.537$), which was comparable with the reports of previous literature.[17]

The J-tip guide wire is used extensively for CVC placement; however, insertion may fail because the J-tip itself exceeds the vessel diameter or coils to block the needle.[18] Repeated insertion attempts may induce needle stick swing, tip displacement, and hematoma formation. Therefore, we used a straight-tip guide wire. The insertion success rate on the first attempt was improved from 76% in the needle to 97% in the cannula group, which was significantly higher than previously reported (80%).[17]

The straight-tip guide wires are rarely used clinically due to concerns of vessel and myocardial injury; however, J-tip guide wires have similar risks.[19] Here, the straight-tip guide wire was advanced gently into the lumen by approximately 10 cm. This appeared to reduce the risk of perforation. Postoperative chest radiography revealed no pleural and pericardial effusion in any patient. Additionally, the J-tip guide wire was not successfully inserted within 3 min in nine (14%) newborns in the needle group. We then converted to the straight-tip guide wire method and successfully cannulated them, which further reflected the advantage of the straight-tip guide wire.

The puncture angle is another important factor for successful guide-wire insertion. The needle tip is more likely to penetrate the posterior wall or span the anterior-posterior wall when the puncture angle is $> 45°$ to the skin.[20] Smaller angles ($\leqslant 30°$) stabilize the needle tip and allow for easier cannula insertion into the lumen.

Successful guide-wire insertion is the decisive factor in successful catheter placement. Here, different guide-wire tips did not affect the success rates of catheter placement subsequently. We performed successful IJV catheterization in 100% of our patients, which was comparable to the reports in the literature.[11]

The USG increases the likelihood of success by easily identifying the direction of the guide-wire (tip navigation).[15,21] We confirmed successful guide-wire insertion into the vasculature using long-axis (Figure 2: A2, B2) and short-axis views (Figure 2: A3, B3); hence, we avoided unintentional arterial dilation and catheterization. USG was also used to identify the position of the catheter (Figure 2: A4, B4). Regarding performing each step under guidance, ultrasonography significantly reduced the incidence of complication but increased the total catheterization time (Table 2). However, we believe that reducing complications in newborn CVC is more important than shortening procedural time based on the Precision Medicine principle.[22] No emergent complications were noted in our study; however, hematoma formation was documented in four and two newborns in the needle and cannula groups, respectively. Furthermore, using an appropriate insertion bundles could further increase the success rate of the procedure and reduce the incidence of complications.[23]

In the cannula group, first attempt insertion of the guide-wire failed in two (3%) cases. Potentially, the full insertion of the entire 22-gauge peripheral intravenous cannula (length 25 mm) may have resulted in abutting the vessel wall, and this may have prevented successful guide-wire insertion. However, we currently have no reliable evidence to explain the probability of this phenomenon, which needs to be explored in further research.

This study has several limitations. First, the operator was not blinded to the subjects' group assignments. Secondly, due to the bevel-associated problems of the needle tip, we did not investigate the practicality of the combination of a needle with a straight-tip guide wire. Moreover, the new nitinol guide wire with a 0.018-inch (0.46 mm) diameter and soft angled platinum coil tip is probably the best choice in small infants. Lastly, we did not fix the catheter through the tunnel in the subclavian area, which was a much better exit site for the catheter. The infraclavicular or brachiocephalic vein may be choices that are more suitable for long-term tunneled CVC in neonates.[23–25] A larger sample size is required to further evaluate the practicality of using peripheral intravenous cannula with a straight-tip guide wire in ultrasound-guided CVC at these sites, especially in low birth weight, preterm infants.

Conclusions

In conclusion, our study demonstrated that a short peripheral intravenous cannula with a straight-tip guide-wire was superior to a needle with a J-tip guide-wire for USG newborn CVC. In particular, CVC performed using a peripheral intravenous cannula and straight-tip guide-wire provided better guide-wire insertion success rates on the first attempt and reduced the overall number of insertion attempts compared to using a needle with a J-tip guide-wire.

Acknowledgements

The Authors would like to thank Editage (www.editage.com) for English language editing.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

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