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US-guided central venous catheter placement in the neonatal intensive care unit: Brachiocephalic vein or internal jugular vein?

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Abstract

Background: Centrally inserted central catheters (CICCs) are commonly used to monitor venous pressure and administer parenteral nutrition and drugs in newborns. In the present study, we evaluated cannulation success rates, cannulation time, and frequency of complications in catheterization of the internal jugular vein (IJV) and brachiocephalic vein (BCV).

Methods: The present study included patients who underwent IJV and BCV catheterization under ultrasound (US) guidance. The patients were divided into two groups, IJV and BCV, depending on the vein in which the CICC was utilized. We documented the diameters of the IJVs and BCVs, first attempt and overall success rates, mean cannulation time, and complication rates.

Results: A total of 79 patients were evaluated, 37 in the BCV group and 42 in the IJV group. No significant differences were observed between the two groups in terms of sex, mean age, or weight range ($p > 0.05$).The mean vein diameter was significantly larger in the BCV group than in the IJV group ($p < 0.001$); the mean number of attempts was significantly higher in the IJV group than in the BCV group ($p < 0.001$); the mean cannulation time was significantly longer in the IJV group than in the BCV group ($p < 0.001$); and the first attempt success rate was 50% in the IJV group, versus 94.6% in the BCV group. The overall success rate was 100% in both groups. The rate of complications was 8.6% in the IJV group, while no complications developed in the BCV group.

Conclusions: Given the larger diameter of the vessel, BCV catheterization was found to result in quicker cannulation and lower complication rates. The results of the present study suggest that BCV catheterization should be the first choice for neonatal intensive care unit (NICU) patients who require parenteral support or close venous pressure monitoring.

Keywords

Central venous catheterization, neonatal, ultrasound guidance, brachiocephalic vein, internal jugular vein

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Introduction

During the neonatal period, a centrally inserted central catheter (CICC) can be utilized for many reasons, such as when there is a requirement for parenteral nutrition, intravenous drug administration, or central venous pressure monitoring.[1] Although anatomic landmarks are traditionally used for central venous catheter placement in neonates, this method is regarded as high-risk because complications such as pneumothorax, hemothorax, and arterial puncture are common.[2] It has recently been

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recommended that neonatal CICCs should be placed under ultrasound (US) guidance,[3] as detailed anatomical information can be visualized with US imaging, avoiding unnecessary punctures and potential complications that may develop during the catheter placement. Generally, the internal jugular vein (IJV) is used for CICC placement in neonates; however, various difficulties can be experienced during neonatal IJV catheterization, such as small vein diameter, narrow neck region, and collapse of the vein with respiration.[4] Therefore, the use of the brachiocephalic vein (BCV) has recently been evaluated for the placement of CICCs in newborn and pediatric patients. The benefits for using the BCV include its larger diameter and the fact that it is not affected by respiration, as it is located between the clavicle and fascia, as well as the ability to follow the needle more easily with in-plane access using US guidance.[5]

The aim of the present study was to compare the success rates, cannulation time, and complication rates of IJV and BCV catheterizations performed on newborns requiring CICCs in the neonatal intensive care unit (NICU).

Materials and methods

The present prospective study, conducted between April 1, 2018 and October 1, 2021 in the NICU of a tertiary hospital in Turkey, included a total of 79 patients. Written informed consent was obtained from the parents of the patients prior to involvement in the study. All study procedures conformed to the principles of the 2008 Declaration of Helsinki, and approval was granted by the local ethics committee.

Patient preparation and central venous catheterization procedure

Demographic data, including sex, birth weight, gestational age at birth, and weight at time of catheterization were recorded. All patients included in the study had undergone a failed attempt at umbilical catheterization, peripheral venipuncture for cannulation, or peripherally inserted central catheter (PICC) due to circulatory disorders or various anatomic disorders. The patients were separated into two groups, IJV and BCV, based on the vein in which the CICC was utilized. The vein diameters, first attempt and overall success rates, cannulation times, and complication rates were recorded for all patients.

All CICCs were placed by an interventional radiologist (O.D.) with 5 years of experience in this field. Based on each patient's clinical condition, sedation was administered using midazolam, fentanyl, ketamine, or local anesthetics. All procedures were performed using a Vivid S5 ultrasound machine (General Electric Healthcare, Milwaukee, WI, USA) with a linear probe (4.0–13.0 MHz frequency, 14 × 48 mm footprint, 38 mm field of view).

Figure 1. Probe position for BCV catheterization with the operator positioned behind the head of the patient.

The procedures were performed in the NICU, with the patient positioned supine and lying crosswise in the incubator, with the head at the side of the physician (Figure 1). Support was placed below the shoulders to provide sufficient extension of the neck, and the patient's head was turned approximately 45° to the left, after which the site of insertion was cleaned with povidone-iodine and draped. The US probe was covered with a sterile sheath, and using the probe in the transverse plane, the IJV, which is susceptible to collapse, was detected adjacent to the common carotid artery (CCA). In cases where the BCV was chosen, the probe was moved caudally, and tilted behind the clavicle until an optimum long-axis view of the BCV was obtained. The BCV catheter was inserted at this site. Before starting the procedure, the anterior-posterior diameter of the vein was obtained, and the interventional radiologist performed the rapid central vein assessment (RaCeVa) to select the central vein.[6] Because placement in the BCV is more stable than the IJV, it is preferred for newborns with deep and rapid respiration. To avoid inadvertent arterial injury due to the needle potentially puncturing the IJV, the BCV was utilized in cases where the IJV was observed anterior to the CCA. The procedure was initiated by inserting a 21G (3.81 cm) thin-walled introducer needle (Arrow International Inc., Reading, PA, USA), which was attached to the injector, into the vein using US guidance (Figure 2). The punctures were made in-plane to the BCV and out-of-plane to the IJV. Upon US and blood aspiration confirmation that the introducer was in the vein, a 0.018 inch spring-wire guide (straight soft tip on one end, "*J*" tip on the other) was advanced within the needle. Tract dilatation was achieved, and a 4F, 5 cm radiopaque polyurethane indwelling catheter was placed (Pediatric Two-Lumen Central Venous Catheterization Set with Blue FlexTip® Catheter; Arrow International Inc., Reading, PA, USA). A posterior-anterior chest radiograph was obtained after the procedure to visualize the tip of the catheter and verify placement. The patients included in the study were those who had undergone the successful catheterization of the vein in which the CICC was meant to be placed.

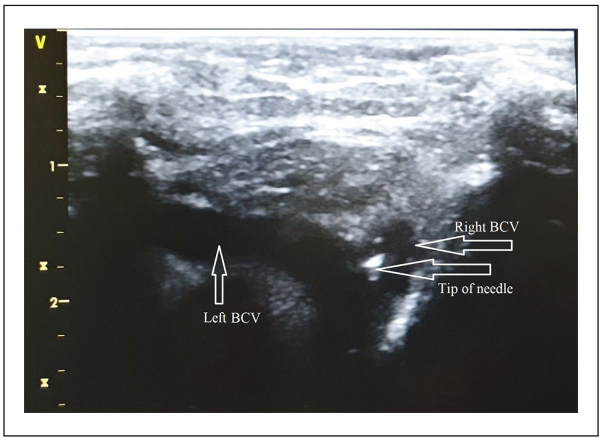

Figure 2. Image of the needle tip in BCV in the same patient.

Patients with a catheter placed in a different central vein were excluded. The duration of catheter placement was defined as the time from the skin puncture to the placement of the catheter.

Statistical analysis

Statistical analyses of the study data were performed using SPSS software version 24.0 (SPSS Inc., Chicago, IL, USA). Descriptive statistics were summarized as numbers, percentages, medians (minimum-maximum), means, and standard deviations, as applicable. The conformity of variables to a normal distribution was investigated using visual methods (histogram and probability graphs) and the Kolmogorov-Smirnov test. The Student's *t*-test was applied to continuous variables with normal distribution, while the Mann Whitney *U*-test was utilized for continuous data without a normal distribution. Categorical variables were analyzed using the Pearson Chi-square or Fisher's exact test when any of the theoretical values observed on a 2×2 table were <5. Pearson's correlation analysis was used to investigate the relationships between parameters. A value of $p < 0.05$ was considered statistically significant in all tests.

Results

A total of 79 patients were evaluated in the present study. The BCV group included 37 patients, 19 males and 18 females with a mean age of 11.11 ± 4.16 days (range, 1–16 days). The IJV group included 42 patients, 22 males and 20 females with a mean age of 11.74 ± 3.84 days (range, 3–18 days). The demographic characteristics of the study population are presented in Table 1. No statistically significant differences were found between the groups with respect to sex, catheterization side, mean age, median birth week, mean birth weight, and weight at the time of insertion (Table 1) ($p > 0.05$). Additionally, no significant difference was observed in the median length of hospital stay between the IJV and BCV groups. The mean vein diameter was significantly larger in the BCV group than in the IJV group ($p < 0.001$), and the mean number of attempts in the BCV group (1.05 ± 0.22) was significantly higher than that in the IJV group (1.76 ± 0.9; $p < 0.001$). The mean cannulation time was 134.59 ± 63.49 s in the BCV group and 263.1 ± 142.35 s in the IJV group, which was significantly longer ($p < 0.001$) (Table 2).

Pearson correlation analysis revealed a positive correlation between the number of attempts and the mean cannulation time ($r = 0.855$; $p < 0.001$), while a negative correlation was found between the mean cannulation time and vein diameter ($r = -0.756$; $p < 0.001$) as well as between the number of attempts and the vein diameter ($r = -0.598$; $p < 0.001$). No correlation was found between the vein diameter and patient weight at the time of insertion ($r = -0.112$; $p = 0.325$).

In the BCV group, a venous catheter was inserted in 35 cases (94.6%) on the first attempt, and in two cases (5.4%) on the second attempt. In the IJV group, venous catheters were inserted on the first attempt in 21 cases (50%), on the second attempt in 12 cases (28.6%), on the third attempt in seven cases (16.7%), and on the fourth attempt in two cases (4.8%). The overall success rate was 100% in both groups. The mean cannulation time was 263.1 ± 142.35 s in the IJV group, compared to 134.59 ± 63.49 s in the BCV group. In the IJV group, a self-limiting hematoma developed around the vein at the puncture site in four newborns. The overall complication rate was determined to be 8.6% in the IJV group, with no complications observed in the BCV group.

Discussion

Although CICC placement is an important procedure in neonates who require certain treatments or observations, it is associated with a number of risks. To the best of our knowledge, this is the first study to compare IJV and BCV catheter placement using US guidance in a patient group that only included newborns.

Since 2002, the United Kingdom National Institute for Clinical Excellence has recommended IJV catheterization with US guidance in children.[7] To date, however, there have been a limited number of studies on the efficacy of IJV catheterization using US guidance, especially in neonatal and pediatric ICU patients. In a meta-analysis including both randomized controlled and non-randomized comparative studies, it was shown that the rates of unsuccessful catheterizations and the complication rate of arterial punctures were lower in IJV catheterization using US guidance than in catheterizations performed using anatomic landmarks. A high rate of bias has been reported, however, in studies in which catheterizations were performed using US guidance.[8] In two studies including

Table 1. Demographic characteristics of the study population.

Parameters	IJV (*n* = 42)	BCV (*n* = 37)	*p*
Age (days), mean ± SD	11.74 ± 3.84	11.11 ± 4.16	0.48[a]
Gender n (%)			0.92[b]
Female	20 (47.6)	18 (51.4)	
Male	22 (52.4)	19 (48.6)	
Side n (%)			0.74[b]
Right	34 (81)	31 (83.8)	
Left	8 (19)	6 (16.2)	
Birthweight (gr), mean ± SD	2540 ± 1211	2853 ± 808	0.17[a]
Range of weight at the time of insertion (gr), median (min−max)	3410 (1120–6340)	3450 (1360–6310)	0.49[c]
Birthweek, median (min−max)	37 (24–41)	37 (27–42)	0.74[c]
Length of hospitalization at the time of procedure (day), mean ± SD	11.74 ± 3.84	11.11 ± 4.16	0.48[a]

SD: standard deviation
[a]Independent sample *t* test.
[b]Pearson chi-square test.
[c]Mann-Whitney *U*-test.

Table 2. Comparison of vein diameter, cannulation time, number of attempt, and length of hospital stay parameters between the groups.

Parameters	IJV (*n* = 42)	BCV (*n* = 37)	*p*
Vein diameter (cm), mean ± SD	3.29 ± 0.4	4.32 ± 0.71	<0.001[a]
Cannulation time (s), mean ± SD	263.1 ± 142.35	134.59 ± 63.49	<0.001[a]
Number of attempt, mean ± SD	1.76 ± 0.9	1.05 ± 0.22	<0.001[a]
Length of hospital stay (days), median (min−max)	56.5 (10–220)	38 (10–240)	<0.12[b]

SD: standard deviation.
[a]Independent sample *t* test.
[b]Mann-Whitney *U*-test.

newborns and children treated with Hickman catheters and Broviac lines placed in the IJV using US-guided catheterization, the technical success was reported as 99.8% and 100%, respectively.[9,10]

Di Nardo et al.[11] evaluated 45 newborn infants weighing <5 kg, and obtained IJV catheterization using US guidance with 100% technical success. In that study, the mean cannulation time was found to be 7 ± 4.3 min, and the complication rate was 22.2%. In the present study, however, the cannulation time was shorter and the complication rate was lower. The results of a study by Montes-Tapia et al.[12] which involved 100 newborns who underwent CICC placement in the right IJV, were to those of the present study, with 50% success on the first attempt, and an overall success rate of 94%. The complication rates was also similar, at 5%.

Although high overall success rates of IJV catheterization using US guidance have been obtained in children and newborns in the present as well as previous studies, this procedure is still difficult, especially in preterm infants. Due to a variety of factors, including the narrow neck region, the quick collapse of the IJV with respiratory movements, and small vein diameters, first-attempt success rates fall, cannulation time increases, and complication rates increase in extremely preterm infants. In the present study, a negative correlation was found between vein diameter and the number of attempts and cannulation time, and it was determined that the vein diameter was small in infants where complications occurred or more than one puncture was attempted for catheterization.

US-guided in-plane BCV catheterization has recently emerged as an alternative to US-guided out-of-plane IJV catheterization in children and newborns. The available literature on BCV catheterization using a supraclavicular approach with US guidance in children and newborns indicates an overall success rate that varies between 91% and 100%, and a first attempt success rate between 65% and 82%. Complication rates range from 0% to 9%, with the rate of major complications such as arterial puncture or pneumothorax <1%.[5,13–27] In the present study, the first attempt success rate of US-guided BCV catheterization was 94.6%, and the overall success rate was 100%, which was consistent with the findings in the available literature. No complications developed during the procedure in any case.

To the best of the authors' knowledge, only one other study has compared US-guided IJV and BCV catheterization in newborns and children.[22] That study, however, included not only newborns but also pediatric patients, which differs from the present study in which only newborns were included. The rates obtained in the aforementioned study were a successful first attempt of 37.5% for IJV catheterization and an overall success of 83%, compared to 73% and 95%, for BCV catheterization, respectively. These rates were similar to those found in the present study, with higher success rates observed for BCV than for IJV catheterization. In the aforementioned study, the mean cannulation time was 170 s for the IJV group and 66 s for the BCV group. The mean cannulation time, however, was measured as the time from the first puncture of the needle to the advancement of the guide wire, which could explain the shorter time obtained compared with the present study.

The results of the present study demonstrated that compared to IJV catheterization, US-guided in-plane BCV catheterization in newborns was more effective in terms of higher success rates, shorter procedural times, and lower complication rates. One advantage of BCV catheterization is that veins with larger diameters do not collapse. The close proximity of the BCV to the large upper mediastinal vascular structures and pleura, however, increases the risk of complications. When procedures are performed by those who lack experience with US-guided CICC placement, complications such as large vessel injury and pneumothorax can occur. Therefore, it is recommended that before performing this procedure in the NICU, a sufficient number of US-guided IJV and BCV catheterizations are performed in adult patients.

Limitations

The primary limitation of the present study is the relatively small number of patients. The low rate of first-attempt IJV catheterization was thought to be due to the fact that it can be difficult to keep the needle in the venous lumen in some patients, because the diameter of the IJV is small and the vein may collapse with respiratory movement, which can be considered another limitation of the present study. To determine the location of the catheter tip, to evaluate for complications such as pneumothorax, and to determine the general clinical condition of the patient, chest X-rays were taken of all patients after the procedure. Current guidelines recommend utilizing intracavitary electrocardiogram (ECG) and US to determine the catheter tip location.[28] Therefore, another limitation of the present study could be that intracavitary ECG and US were not used to confirm the location of the catheter tip.

In conclusion, CICC placement in critically ill infants in the NICU is of vital importance. Although the long-term results are not known for BCV and IJV catheterization in neonates, US-guided supraclavicular in-plane BCV catheterization can be considered as the first option, especially in extremely preterm newborns, due to shorter cannulation time, fewer attempts, and lower complication rates. Nevertheless, further multicenter randomized controlled clinical studies are needed to support the results of the present study.

Authors contribution

All authors contributed toward data analysis, drafting and revising the paper and agree to be accountable for all aspects of the work.

Declaration of conflicting interests

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Ethical approval

This study conformed to the principles of the 2008 Declaration of Helsinki and was approved by the local ethics committee of Harran University, Medical Faculty, Turkey.

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