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Comparison of Ultrasound-Guided and Landmark Techniques for Central Venous Catheter Insertion into the Internal Jugular Vein in Critically Ill Children

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Abstract

Aim: Maintaining continuous intravenous access is essential for critically ill children, particularly in emergencies. Central venous catheter insertion can be performed under ultrasound guidance or using the landmark technique. The main goal of this study is to compare the outcomes between ultrasound-guided and landmark techniques for central venous catheter insertion.

Study Design: Patients admitted to the pediatric intensive care unit between April 2021 and April 2023 requiring central vascular access to the internal jugular vein were included in the study. The patients were divided into two groups based on the catheter insertion method: the landmark technique (Group I) and ultrasound-guided technique (Group II). All catheterization procedures were performed by the same team of healthcare providers. Outcomes evaluated included demographic data, successful catheter insertion, and the occurrence of complications.

Results: A total of 126 internal jugular vein catheterization procedures were included in this study. In Group I, the mean hemoglobin level before catheter insertion was 10.32±2.37 g/dL, and the mean hemoglobin level after catheter insertion was 9.25±1.82 g/dL. In Group II, the mean hemoglobin level before catheter insertion was 11.70±1.28 g/dL, and the mean hemoglobin level after catheter insertion was 11.25±1.28 g/dL. The decrease in hemoglobin levels was statistically significant (p=0.01). Similarly, the reduction in platelet count was greater in Group I (328,723.40±167,272.84 vs. 272,170.21±141,128.72) than in Group II (273,886.08±140,184.31 vs. 261,126.58±143,932.17), and this difference was also statistically significant (p=0.01).

Conclusions: The findings indicate that ultrasound-guided catheterization reduces complications associated with catheter insertion. Therefore, ultrasound-guided catheterization is highly recommended for critically ill children.

Keywords: Ultrasonography; Jugular vein catheterization; Pediatric; Complication.

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Introduction

The effective management of fluids and the administration of medical therapies for critically ill pediatric patients primarily relies on intravenous routes.[1] However, securing peripheral venous access can be challenging, especially in emergencies or critically ill situations.[2] Moreover, certain emergency or antiepileptic drugs can only be administered intravenously.[3] Therefore, the use of a central venous catheter (CVC) becomes essential to ensure the effective delivery of treatment.[4] Placing central venous catheters percutaneously is a common practice in the pediatric intensive care unit (PICU) to monitor hemodynamic parameters and administer fluids and medications.[5] While physician preferences may vary, the femoral vein is often favored for central venous cannulation in children due to its safety and ease of insertion.[6] Ultrasound guidance for internal jugular vein (IJV) catheterization was first reported in 1977 and has since been recognized as a safe and advantageous method, even in neonates.[7] Numerous studies have demonstrated that ultrasound-guided catheterization results in higher success rates, a lower incidence of complications, and shorter catheterization times compared to the landmark technique.[8] During central venous catheterization, complications such as pneumothorax, hemothorax, arterial puncture, and hematoma may occur.[9] Although these complications are more frequently reported in adult patients, meta-analyses and various studies have shown that complications are less frequent with ultrasound guidance.[10, 11] The primary aim of this study is to compare the complications between ultrasound-guided and landmark techniques for central venous catheter insertion into the IJV in the pediatric intensive care unit.

Materials and Methods

Children admitted to the pediatric intensive care unit from April 2021 to April 2023 who underwent central venous catheter insertion into the IJV were included in this study. Patients aged 1 month to 18 years were enrolled. A central venous catheter was meticulously inserted into the IJV either using the landmark method (Group I) or ultrasound guidance (Group II). Based on previous data, with a significance level of α=0.05 and β-1=80%, a minimum required sample size of 103 participants was determined for the study.[12]

The landmark technique for central venous catheterization was employed when an ultrasound device was unavailable. When an ultrasound device was available, all catheterization procedures were performed exclusively under ultrasound guidance.

Ethical approval for the study was obtained from the Non-Invasive Clinical Research Ethics Committee of Batman Training and Research Hospital (Approval Number: 313, Date: 30.04.2022). The study was conducted in accordance with the Declaration of Helsinki.

For the procedure, a rolled towel was placed transversely under the patient's shoulder, and the head was slightly turned to the right side to create a smooth surface for the ultrasound probe. The skin was sterilized with a 10% povidone-iodine solution to ensure the highest level of sterile barrier protection and was then covered with sterile drapes. All staff wore sterile gloves, aprons, masks, and bonnets. All catheterization procedures were performed by the same personnel. The ultrasound probe was covered with a sterile sheath. A view of the child's IJV was projected onto the ultrasound screen to ensure the catheter needle was accurately inserted into the center of the vein. Once blood was aspirated into the syringe during venipuncture, a round-tipped guide wire was advanced through the needle lumen, and the needle was withdrawn. An appropriate CVC kit was selected based on the child's age and weight. The length of the catheter was determined to ensure proper placement at the confluence of the superior vena cava and the right atrium for IJV catheters. Routine radiological imaging (posteroanterior chest X-ray) was performed to confirm the catheter's placement. In the landmark method, catheter insertion was guided by arterial palpation and medial retraction. The Seldinger technique was employed in both methods, ensuring precision and efficacy.

During catheterization, the use of a heparin flush or infusion was not common practice. Patients were sedated with either intravenous midazolam (0.1 mg/kg) or ketamine (0.5-1.0 mg/kg); however, there was no standardized protocol for the use of midazolam and ketamine, and no comparison was made between the two sedation methods.

The outcomes included demographic data, correct catheter placement, and the development of acute and chronic complications. A drop of 1 gram per deciliter (g/dL) in hemoglobin levels following catheterization was considered an indicator of bleeding. Patients who re-

ceived erythrocyte transfusions prior to catheterization, as well as those with hemodialysis or femoral catheters, were excluded from the study.

Statistical Analysis

Continuous parameters were presented as means with standard deviations, while discontinuous parameters were presented as medians. Categorical parameters were expressed as percentages and frequencies. Comparison of the baseline features of the two groups was assessed using the Mann-Whitney U test for quantitative characteristics and Fisher's exact test for qualitative parameters. The occurrence of complications per patient was compared between the groups using nonparametric Mann-Whitney tests. Student's t-test, χ^2 analysis, or Fisher's exact test was used as appropriate for comparing categorical parameters between the groups. A p value of <0.05 was considered statistically significant. All evaluations were performed using SPSS Statistics 22 software (IBM, Armonk, NY, USA).

Results

During the study period, 176 CVC attempts were recorded. However, 50 patients were excluded from the study: 35 with femoral catheters, five with hemodialysis catheters, and 10 who had received erythrocyte transfusions. Therefore, the study included 126 patients with a median age of 20 (30) months. Among the patients, 72 were male (57%) and 54 were female (43%). The median value of the Pediatric Risk of Mortality II (PRISM II) score was 8.50. All patients were assessed according to their systematic diagnosis. The most common group of disorders observed was respiratory system disorders, accounting for 27% (34 patients) of all cases. This was followed by neurological system disorders at 17.5% (22 patients), cardiovascular system disorders at 10.3% (13 patients), trauma at 7.9% (10 patients), renal system disorders at 7.1% (nine patients), and post-cardiac arrest at 6.3% (eight patients). Table 1 presents the characteristics of the patients.

Table 1. Characteristics of the patients

	n (%)
Sex, male (%)	72 (57)
Age, median (IQR)	20.00 (30)
PRISM II score, median (IQR)	8.50 (15)
Diagnosis:	
• Respiratory system	34 (27)
• Neurologic system	22 (17.5)
• Cardiovascular system	13 (10.3)
• Trauma	10 (7.9)
• Renal system	9 (7.1)
• Post-arrest	8 (6.3)
• Others (intoxication, endocrine system, hematologic system, sepsis)	30 (23.9)

IQR: Interquartile Range; PRISM II Score: Pediatric Risk of Mortality II Score; PDR: Pediatric Death Rate.

Table 2 presents the laboratory and clinical features of patients who had CVC inserted with and without the use of ultrasonography, allowing for the comparison of complications. In Group I, where ultrasonography was not used, the mean hemoglobin level upon admission was 10.32±2.37 g/dL, and the mean hemoglobin level after CVC insertion was 9.25±1.82 g/dL. In Group II, where ultrasonography was used, the mean hemoglobin level upon admission was 11.70±1.28 g/dL, and the mean hemoglobin level after CVC insertion was 11.25±1.28 g/dL. The decrease in hemoglobin levels was statistically significant in Group I compared to Group II (p=0.01). In Group I, the mean hematocrit level upon admission was 32.35±8.11%, and the mean hematocrit level after CVC insertion was 28.22±5.60%. In Group II, the mean hematocrit level upon admission was 35.41±4.32%, and the mean hematocrit level after CVC insertion was 33.43±3.05%. The decrease in hematocrit was higher in Group I, but this difference did not reach statistical significance. In Group I, the mean platelet count upon admission was 328,723.40±167,272.84 103/μL, and the mean platelet count after CVC insertion was 272,170.21±141,128.72 103/μL. In Group II, the mean platelet count upon admission was 273,886.08±140,184.31 103/μL, and the mean platelet count after CVC insertion was 261,126.58±143,932.17 103/μL. The decrease in platelet count was greater in Group I, and this difference was statistically significant (p=0.01).

During the CVC procedure, macroscopic bleeding was observed in a total of six patients: five patients in Group I and only one patient in Group II (p=0.27). Pneumothorax was observed in two patients in Group I (p=0.137). Respiratory arrest occurred in two patients in Group I, with no cases in Group II (p=0.137). No patient in either group experienced cardiac arrest. Arterial puncture was observed in three patients, all of whom were in Group I (p=0.05). Subcutaneous hematoma was observed in two patients—one in Group I and one in Group II (p=1.000). Thrombosis was observed in two patients in Group I and

Table 2. Laboratory and clinical features of the patients and comparison of complications

	Group I (without US)	Group II (with US)	p
HGB g/dL at admission, mean±SD	10.32±2.37	11.70±1.28	p=0.01
HGB d/dL after catheter, mean±SD	9.25±1.82	11.25±1.28	
HTC% at admission, mean±SD	32.35±8.11	35.41±4.32	p=0.27
HTC% after catheter, mean±SD	28.22±5.60	33.43±3.05	
Platelet $\times 10^3/\mu L$ at admission, mean±SD	328,723.40±167,272.84	273,886.08±140,184.31	p=0.01
Platelet $\times 10^3/\mu L$ after catheter, mean±SD	272,170.21±141,128.72	261,126.58±143,932.17	
Macroscopic bleeding, n (%)	5 (10.6)	1 (1.3)	p=0.27
Pneumothorax, n (%)	2 (4.3)	0	p=0.137
Respiratory arrest, n (%)	2 (4.3)	0	p=0.137
Cardiac arrest, n (%)	0	0	
Arterial puncture, n (%)	3 (6.4)	0	p=0.05
Subcutaneous hematoma, n (%)	1 (2.1)	1 (1.3)	p=1.000
Infection, n (%)	1 (2.1)	2 (2.5)	p=1.000
Thrombosis, n (%)	2 (4.3)	1 (1.3)	p=0.555
Invasive MV, n (%)	31 (41.3)	44 (58.7)	p=0.256
Mortality, n (%)	12 (25.5)	15 (19)	p=0.387

HGB: Hemoglobin; HTC: Hematocrit; SD: Standard Deviation; US: Ultrasonography; MV: Mechanical Ventilation.

one patient in Group II (p=0.555). Catheter-associated infection was seen in three patients—one in Group I and two in Group II (p=1.000).

Discussion

This study focuses on comparing complications associated with central venous catheter insertion into the IJV, with and without the use of ultrasound. Significant changes were found in some laboratory parameters before and after catheterization, particularly the reduction in hemoglobin and platelet levels, which was significantly different between the two groups. Although not statistically significant, we observed a reduction in some complications with the use of ultrasound. Macroscopic bleeding, pneumothorax, respiratory and cardiac arrest, arterial puncture, and thrombosis were less frequent in Group II.

When examining the demographic characteristics of the patients, there were no statistically significant differences, consistent with findings in the literature.[13] Similarly, when comparing the PRISM II scores of the patients, there was no significant difference between the two groups. Likewise, a recent study demonstrated that PRISM II scores showed no statistically significant difference between the groups with and without ultrasound.[14, 15]

Upon analyzing the systemic diagnosis groups of the patients, respiratory system disorders were the most prevalent diagnosis. This category represents the most frequently hospitalized patient group in the intensive care unit. In the study conducted by Cruzeiro et al.,[16] neoplasms were identified as the predominant group, as they prospectively investigated the utilization of central venous catheters in children. Central venous catheters were also used in a variety of disorders affecting different systems, including the cardiovascular, renal, neurologic, trauma, post-arrest conditions, and endocrine system dysfunctions. This highlights the importance of using central venous catheters in pediatric care. Nearly all patients admitted to intensive care units require a catheter for various reasons. Central venous catheters are inserted in pediatric patients for multiple purposes, including blood sampling, hemodynamic monitoring, administration of vasoactive medications, and providing parenteral nutrition.[6]

Placing central venous catheters in children is more challenging compared to adults, with neonates and infants being particularly difficult cases.[17] However, with the advent of ultrasound in pediatric cases—a previously unreported phenomenon—an increasing number of studies suggest a significant reduction in complexity in this challenging scenario.[4, 7]

Ultrasound-guided CVC insertion has become the recommended technique for both pediatric and adult patients, particularly due to its success in adults.[18] A meta-analysis of 23 studies involving nearly 4,000 procedures revealed a higher success rate and fewer complications with the ultrasound-guided technique compared to the landmark technique.[19]

In this study, complications from procedures conducted using ultrasound-guided and landmark techniques were categorized as laboratory and clinical findings. Pre-procedure hemoglobin and platelet values were compared with post-procedure values, showing significantly smaller decreases in hemoglobin and platelets in ultrasound-guided procedures compared to the landmark technique. This finding has been corroborated by literature, indicating that these decreases are often due to bleeding and arterial puncture.[4, 13] Across all studies, a reduction in bleeding and arterial puncture incidents was observed when using the ultrasound-guided technique. The current study found statistically significant reductions in both hemoglobin levels and platelet counts in the group using the landmark technique. These results are important as they provide a numerical indication of bleeding occurrence.

Arterial puncture emerged as a significant concern when analyzing common complications during catheter insertion. In a meta-analysis, arterial puncture was documented across 22 studies.[19] The use of ultrasound guidance has notably reduced the incidence of arterial punctures compared to the landmark technique. In the present study, no arterial punctures occurred in the ultrasound-guided group, whereas three patients in the group without ultrasound experienced arterial punctures.

Ultrasonography effectively reduces the incidence of complications such as pneumothorax and hematoma.[20] Similarly, in this study, pneumothorax was observed in two patients in Group I, but none in Group II.

Infection rates are often expected to increase with the use of ultrasound due to the variety of instruments involved.[20] However, no studies have shown a significant difference in infection rates.[19] In the present research, no significant difference in infection rates was detected between the two groups.

Thrombosis is a frequent complication of CVC, with an incidence ranging from 0.5% to 15%.[12, 21] The use of ultrasound to visualize potential thrombosis in the target venous system offers significant advantages.[20] In this study, no significant difference in thrombosis incidence was found between the groups.

Limitations

This study has certain limitations. The pediatric patients varied in age, weight, and the presence of comorbid conditions. Additionally, the number and duration of catheterization attempts were not documented, which limited their inclusion in the analysis.

Conclusion

Insertion of a central venous catheter is crucial for critically ill children, with the internal jugular vein being the preferred site. The use of ultrasound guidance reduces complications associated with catheter insertion, such as decreases in hemoglobin levels and thrombocytopenia. Instances of pneumothorax, artery puncture, and thrombosis are also less frequent.

Ethics Committee Approval: The study was approved by the Non-Invasive Ethic Committee of Batman Training and Research Hospital (Approval Number: 313, Date: 30.05.2022).
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