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Evaluating the Factors Influencing Pediatric Central Venous Catheterization: A Retrospective Study on Complications and Success Rates

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ABSTRACT

Background: Complications correlated with central venous catheterization (CVC) are common and risky in pediatric patients leading to increased morbidity.

Objective: To study the CVC-related complications concerning different access sites and ultrasound (US)-guided catheterization.

Methods: This retrospective study was conducted in a tertiary care teaching institution in central India. Children admitted to pediatric and pediatric surgical intensive care units between 2014 and 2018 requiring CVCs were included in this study. Data was recorded for demographic details, diagnosis, indications, techniques of CVC insertion, and complications associated with CVC. The Central line-associated bloodstream infections (CLABSIs) were defined based on a positive CVC tip culture with a positive blood culture.

Results: 615 CVCs were inserted into 520 patients in children aged 1 month to 14 years. US-guided catheterization was performed only in 15.61% (96) cases, and the landmark method was used in 84.39% (519) of the CVC insertions. The femoral vein was the most accessed site (54.79%) followed by the internal jugular (36.59%), and subclavian vein (8.62%). The median CVC dwell time was 5 (3–8) days. The success rate of CVC insertion in the first attempt (US 53% vs. LM 28%; $p<0.05$) and overall success (US 89% vs. LM 76%; $p<0.05$) was significantly higher in the US group. Although higher complications were observed in the femoral vein, the difference was insignificant ($p>0.05$).

Conclusion: The study's findings were conclusive that US guidance reduces complications significantly and makes the procedure more efficient. No significant correlation was observed between the site of insertion and complications.

Keywords: *Central venous catheters, Ultrasound-guidance, Pneumothorax, central line-associated bloodstream infections (CLABIs), Arterial punctures*

1. INTRODUCTION

Central Venous catheters (CVCs) are frequently used in critically ill children, making them a quintessential part of pediatric intensive care. About 40-60% of children in pediatric intensive care units (PICUs) constantly require CVCs for long-term intravenous treatment, hemodialysis, and chemotherapy1. Although it is generally a safe procedure, catheterization poses a higher threat in children than adults, due to premature vascular structures, small vessel diameter, and the hassle of finding a size and caliber appropriate catheter 2. There has been overwhelming evidence proving the efficiency of ultrasound-guided techniques over the landmark method, but the traditional technique is prevalent. US-guided cannulation has been shown to reduce cannulation duration, decrease the number of repetitions for placement, and increase overall success rates 3–7.

The complication rates correlated with CVC cannulations depend on the patient's age, weight, and access route (internal jugular, subclavian, and femoral). The subclavian vein (SV) is often preferred due to fewer arterial punchers and a higher overall success rate, but the mechanical complications tend to increase significantly as it is harder to access 8. Therefore, the internal jugular vein (IJV) is selected during most CVCs to minimize risks; especially, during blind procedures due to better accessibility. The femoral route of access is known to be riskier, as it causes more infections, and causes thrombosis 9–12.

Complications related to CVC insertion are mainly divided into mechanical, thromboembolic, and infectious. These infections occur either due to microbial colonization of the intracutaneous or intravascular portion of the device or due to contamination of the catheter hub or infusate administered through the catheter. Mechanical complications may include pneumothorax, arterial punctures, hematomas, and pulmonary embolism 13,14. The route is usually chosen based on the individual patient factors, clinicians' expertise, and usage of techniques like Ultrasound. The primary aim of this study was to understand the CVC-related risks and complications associated with various access routes. The secondary aim was to evaluate the impact of US-guided procedures in reducing these risks.

2. MATERIAL AND METHODS

This retrospective study was conducted in a tertiary care teaching institution in central India by reviewing the case records of children aged 1 month to 14 years requiring CVCs. Children admitted to pediatric and pediatric surgical intensive care units between 2014 and 2018 were included in this study. Considering the retrospective nature of the study, ethical approval was waived. Neonates (<1 month of age) and those with missing information were excluded. CVCs were inserted in the PICU or operation theatre in children undergoing major surgery. The site of venous access was chosen based solely on the operator's experience, age, and size of the patient using anatomical landmarks by the Seldinger method and, in some cases, utilizing ultrasound guidance. All the details of CVC, from the time of insertion to removal, were recorded in the CVC checklist. The institutional ethics committee waived the need for informed consent, considering its retrospective nature.

The following data was recorded from the eligible case records: demographic details (weight, height, gender ratio), diagnosis or organ system involved, CVC insertion details (site, number of attempts, CVC dwell time), and complications associated with CVC (infectious and non-infectious). The major non-infectious complications considered in this study were arterial punctures, pneumothorax/ hemothorax, bleeding, central venous thrombosis, and hematoma. In contrast, infectious complications were divided into CVC colonization and central line-associated bloodstream infections (CLABSI). CLABSI was defined when the same organism was grown on the catheter tip culture and blood culture drawn from a peripheral site in the presence of signs of infection and the absence of other known causes. At the same time, CVC colonization was considered in the presence of a positive catheter tip culture but a negative blood culture drawn from a peripheral site. The patients were grouped and analyzed based on their age group, insertion site, and CVC insertion techniques.

All the lines were inserted according to the standard guidelines while following stringent hand hygiene measures. After insertion, CVC was secured with sutures, and covered with a sterile transparent dressing. Multidimensional CVC insertion and maintenance “care bundles” were implemented and followed by the nurses whenever managing the CVC lines. Transparent, adhesive dressings were changed under aseptic precautions on visible soiling. The CVC was removed after fulfilling its need (for parenteral nutrition, intravenous fluids or drug infusion, blood transfusion, or central venous pressure monitoring) or on clinical suspicion of CLABSI (fevers, altered mental signs, and rigors). After removing the CVC, the catheter tips were sent for culture and simultaneous blood culture from a peripheral vein.

For the data analysis, numerical data was presented as mean, standard deviation, and categorical data as number and percentage (%). One-tailed Fischer’s exact test was performed to quantify the significance of US guidance in reducing CLABSI due to small cell counts. The chi-squared test was used in calculations involving larger numbers.

3. RESULTS

615 catheters were inserted into 520 patients in children aged 1 month to 14 years. The maximum number of patients was in the age group 1 year – 5 years, followed by 1 month – 1 year age group. The gender ratio, mean weight, and height are presented in Table 1.

Table 1 - Distribution of patients and catheters inserted into various age groups

Age Group (N, %)	Number of Patients	Number of Catheters	Male/ Female	Weight (kg), Mean± SD	Height (cm), Mean± SD
1 mo - 1 y (Group A)	157 (30.19)	180 (29.27)	96/61	5.9±1.2	63.2±4.5
1 y - 5 y (Group B)	164 (31.54)	207 (33.67)	88/76	13.1±2.1	85.2±6.3
5 y – 10 y (Group C)	134 (25.77)	145 (23.56)	78/56	23.2±4.1	116±6.8
10 y -14 y (Group D)	65 (12.50)	83 (13.50)	41/24	39.3±6.7	144.8±7.6
Total	520 (100%)	615 (100%)	303/217		

The common indications of CVC were head trauma and gastrointestinal, thoracic, neurological, and genitourinary diseases, as shown in Table 2.

Table 2 - Diagnoses/ primary system involvement across patient groups

	Group A		Group B		Group C		Group D	
Diagnosis	**Patients N (%)**	**CVC's N (%)**	**Patients N (%)**	**CVC's N (%)**	**Patients N (%)**	**CVC's N (%)**	**Patients N (%)**	**CVC's N (%)**
Head trauma	12 (7.54)	13 (7.22)	25 (15.24)	35 (16.91)	33 (24.63)	35 (24.14)	21 (32.30)	28 (33.73)
Gastro intestinal surgery	49 (31.23)	54 (30.0)	46 (28.05)	62 (29.95)	34 (25.37)	38 (26.21)	13 (20.00)	18 (21.69)
CNS diseases	54 (34.46)	61 (33.89)	49 (29.88)	58 (28.02)	27 (20.15)	30 (20.69)	11 (16.93)	12 (14.47)
Thoracic Surgery	24 (15.29)	29 (16.11)	28 (17.07)	33 (15.94)	19 (14.18)	20 (13.79)	12 (18.46)	14 (16.86)
Genito urinary surgery	18 (11.48)	23 (12.78)	16 (9.76)	19 (9.18)	21 (15.67)	22 (15.17)	8 (12.31)	11 (13.25)
Total	**157**	**180**	**164**	**207**	**134**	**145**	**65**	**83**

Being a resource-limited setting, US-guided catheterization was performed only in 15.61% (96) of the procedures, and the landmark method was used in 84.39% (519) of the CVC insertions. A total of 54.79% (337) of the catheters were inserted in the femoral, 36.59% (225) in IJV, and 8.62% (53) in the subclavian vein. The median CVC dwell time was 5 (3–8) days. The success rate of CVC insertion in the first attempt (US 53% vs. LM 28%; $p<0.05$) and overall success (US 89% vs. LM 76%; $p<0.05$) was significantly higher in the US group. Out of 615 CVCs analyzed, CVC colonization was observed in 225 (36.58%) CVCs, whereas CLABSI was observed in 80 (13.01%) of the CVCs, and most of them had gram-positive bacterial growth (Table 3).

Table 3 - Organisms isolated from cultures performed on catheters

Pathogen, n (%)	Colonization	CLABSI	Total
Gram-positive	**129 (20.98)**	**59 (9.59)**	**188 (30.57)**
Coagulase-negative Staphylococcus	88 (14.31)	37 (6.02)	125 (20.33)
Staphylococcus aureus	26 (4.23)	13 (2.11)	39 (6.34)
Non-hemolytic Streptococcus sp	8 (1.30)	6 (0.98)	14 (2.28)

Bacillus sp	4 (0.65)	2 (0.32)	6 (0.97)
Enterococcus sp	3 (0.49)	1 (0.16)	4 (0.65)
Gram-negative	**74 (12.03)**	**14 (2.28)**	**88 (14.31)**
Pseudomonas	26 (4.23)	4 (0.65)	30 (4.87)
Enterobacter sp.	22 (3.57)	3 (0.49)	25 (4.07)
Klebsiella sp.	15 (2.44)	4 (0.65)	19 (3.09)
Escherichia coli sp	11 (1.79)	3 (0.49)	14 (2.28)
Polymicrobial	**14 (2.28)**	**4 (0.65)**	**18 (2.92)**
Fungi	**8 (1.29)**	**3 (0.49)**	**11 (1.79)**
Candida albicans	6 (0.97)	2 (0.33)	8 (1.30)
Candida tropicalis	2 (0.32)	1 (0.16)	3 (0.49)
Total	**225 (36.58)**	**80 (13.01)**	**305 (49.59)**

A higher incidence of CLABSI was observed at the femoral insertion site, but the difference was insignificant.

The overall complication rate was 23.41% (144/615) and was comparable between US-guided and landmark techniques (19.79% vs. 24.08%; p = 0.058). The CLABSI rate was higher in the landmark group than in the US-guided group, as shown in Table 4.

Table 4 - Complications observed in landmark-guided vs. ultrasound-based techniques

Complications, n (%)	**Landmark guided (N = 519)**	**Ultrasound-guided (N = 96)**	**Total (N = 615)**
Arterial punctures	19 (3.66)	4 (4.17)	23 (3.74)
Pneumothorax/ hemothorax	3 (0.58)	2 (2.08)	5 (0.81)
Bleeding	11 (2.12)	2 (2.08)	13 (2.11)
Central venous thrombosis	4 (0.77)	1 (1.04)	5 (0.81)
Hematoma	15 (2.89)	3 (3.13)	18 (2.93)
CLABSI	73 (14.07)	7 (7.29)	80 (13.01)
Total	**125 (24.08)**	**19 (19.79)**	**144 (23.41)**

As shown in Table 5, the overall complications were slightly higher in children with the subclavian and femoral vein CVCs than in children with CVC in the IJV; however, the difference was non-significant (p>0.05).

Table 5 - Complications associated with the access routes

Complications, n (%)	**Femoral (N = 337)**	**Internal Jugular (N = 225)**	**Subclavian (N = 53)**	**Total (N = 615)**
Arterial punctures	13 (3.86)	8 (3.56)	2 (5.66)	23 (3.74)
Pneumothorax/ hemothorax	0	1 (0.44)	4 (7.55)	5 (0.81)
Bleeding	7 (2.08)	5 (2.22)	1 (1.89)	13 (2.11)
Central venous thrombosis	1 (0.29)	2 (0.89)	2 (3.77)	5 (0.81)
Hematoma	10 (2.97)	7 (3.11)	1 (1.89)	18 (2.93)

CLABSI	54 (16.03)	22 (9.78)	4 (13.21)	80 (13.01)
Total	**85 (25.23)**	**45 (20.00)**	**14 (26.41)**	**144 (23.41)**

4. DISCUSSION

Central venous catheterization remains a crucial procedure in pediatric care. The process is more complex and delicate in children, putting them at high risk for complications. The study focused on understanding the risk factors and variables associated with CVC in children. In our study, the femoral vein was used in most patients based on the clinician's preference and expertise; however, previous research showed IJV as the preferred vein for CVC insertion 15–17. Lower incidences of complications like pneumothorax and arterial punctures are observed in the IJV; however, its proximity to the carotid artery poses a significant hazard, with incidences ranging up to 25%. Although the evidence clearly shows that subclavian and IJ veins are less risky in the adult population, the research is ambiguous in the pediatric population. Preliminary data, such as mean patient weight and height, were used to study their role in CVC-related complexities.

The findings of this study were concordant with those of other studies, proving the efficiency of US-guided catheterization compared to anatomical landmark-based techniques; however, the difference was non-significant in this study. The cannulation process was also observed to be quicker. Aouad et al., in their study done on femoral vein cannulations on children, observed the amount of time taken for cannulation was shorter [155 (46 – 690) vs 370 (45–1620) seconds] in the US group compared with the LM group 7. Similarly, Eldabaa et al., found significantly lesser time to successful CVC insertion [55 (20–600) vs. 290 (16–1500) seconds; P = 0.02] and complete cannulation [145 (40–650) vs. 350 (40–1600) seconds; P = 0.02] in the US group than in the LM group 18. Similar studies have proven the role of the US in lowering mechanical complications, successful catheterization on the first attempt, and easier insertion 19–21. However, the use of USG for CVC insertion is still far behind the current standards in our setup due to limited resources. It can be improved with better availability of USG machines in the PICU and point-of-care USG training for clinicians.

The dynamics of the success rate were affected by the age and weight of the patient. Froehlich et al. observed that children who had low weight (median weight <16.25 kg) had lower success rates and needed multiple insertion attempts for both procedures, compared to the children who had higher weight (median weight >16.25 kg) 22. The challenge in achieving successful cannulation in younger children (< 1 year) can partly be due to the smaller vessel diameter; thus, posing difficulties in locating appropriate vessels, even under USG guidance. This correlation between body weight and vein diameter was more evident in the femoral vein compared to the IJV 23,24.

US- guidance significantly reduced the incidences of CLASBI. The role of USG in enhancing cannulation across all sites has been well studied; however, the complication rates vary. In this study, femoral vein CVC was associated with a higher incidence of CLABSI, arterial punctures, and hematomas while the SV CVC showed the highest incidence of pneumothorax. Casado-Flores et al. observed the highest incidence of arterial puncture with the femoral approach (6.3%), followed by SV (5.1%), and IJV (0.0%) in a study involving 308 critically ill children (235 SV, 63 femoral, 10 IJV) 25. A meta-analysis on CVC insertion in infants and young children (median age 1.1 yrs) reported that the femoral vein insertion elevates the risk of mechanical complications compared to other sites (10.1% vs. 1.8%) 26.

Although many studies found the IJV to be the preferred access route, the femoral vein was accessed in most patients in our research and we found comparable complication rates with all three sites. Other studies have also observed no influence of the access site on CVC-related complications, and the femoral vein may even be better27–29. Garcia-Teresa et al. observed statistically insignificant higher infections in subclavian lines than in femoral or IJV jugular lines on univariate analysis (p = 0.1); however, multivariate analysis showed that the insertion site was not a risk factor for infection 29.

The association of complications and access route is quite complex; it depends on the clinician's expertise, patient weight, insertion technique, duration of cannulation, disease severity, and many other aspects. A simple straightforward answer is not plausible; therefore, it is always advisable to select it based on the patient and clinician's expertise. With the rise of US-based catheterization, the procedure is safer, and the number of adversaries will be lower. The study acknowledges limitations, such as the retrospective nature of the research, non-rigorous statistical analysis, and lack of diverse sample sizes. The study also encourages a deeper analysis of CVC insertion in children and solutions to solve the morbidities that arise from it.

5. CONCLUSION

Central venous catheterization is an important and common procedure with numerous risks and infectious complications are still common with CVC. In our study, the femoral vein was the preferred access site and we did not find the route of access to be a significant factor influencing the CVC-related complications. Although the number of US-guided CVC insertions was very low, USG guidance can significantly reduce cannulation time, improve the overall success rate, and reduce CVC-related complications.

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