Azizov *et al.*
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Do not trust landmarks and your feelings while inserting pediatric central venous catheters

Shahin Azizov, Cengiz Sahutoglu*, Canan Bor and Taner Balcioglu

Abstract

Background: Central venous catheterization (CVC) is a commonly used procedure in pediatric surgery and intensive care units. For some reasons, catheterizations in children are technically more difficult in comparison to adult patients. The purpose of this study is to evaluate the CVC procedures performed with the aid of anatomic landmarks by experienced (35, 14, 4 years of experience) anesthesiologists and the associated complications. A total of 498 cases under the age of 18 who underwent CVC (temporary, port, or Hickman) between the years 2014 and 2017 were included in this retrospective study. All catheters were inserted with the aid of anatomic landmarks.

Results: The mean age of the patients was 47.1 ± 59.2 months and 54.8% were male. By using anatomical landmarks, the average success rate in central venous catheterizations was calculated as 98.6%. Complications developed included arterial puncture in 8% (*n* 40), temporary arrhythmia in 6.2% (*n* 31) and pneumothorax in 1.4% (*n* 7) of the patients. Only using multiple punctures ($p = 0.005$) and catheterizations lasting more than 10 min (the time to blood return from the catheter, $p = 0.017$) were found to be associated with complications. The experience of the practitioner had no effect on the development of complications ($p = 0.354$).

Conclusions: In CVCs using anatomic landmarks, complications are seen more frequently in children. Even though a decrease in overall complication rates was detected in catheterizations performed by experienced hands, it is seen that experience does not eliminate complications in CVC insertions using anatomic landmarks.

Keywords: Central venous catheter, Children, Complications, Pediatric surgery, Pneumothorax

Key messages

- Central venous catheterizations (CVCs) are invasive procedures and their complications are more common.
- The repetitive punctures in CVC applications are associated with complications.
- In experienced hands, the CVC application using anatomical signs does not eliminate complications.
- To use of ultrasonography should be standardized in CVC applications.

Background

Central venous catheterization (CVC) is a very frequently applied procedure in the follow-up and treatment of critically ill children, in operating rooms and intensive care units. The CVC is applied for many indications such as invasive hemodynamic monitoring, parenteral nutrition, phlebotomy, drug and fluid therapy, delivery of blood and blood products, continuous renal replacement therapy, and plasmapheresis (Karapinar and Cura 2007; Citak et al. 2002). Catheterization procedures in pediatric patients are technically more

*Correspondence: csahutoglu@yahoo.com

Department of Anesthesiology and Reanimation, Ege University School of Medicine, 35100, Bornova, Izmir, Turkey

difficult than adult patients due to small vessel diameters, not fully developed vascular structures, and difficulties in finding the catheter with appropriate caliber and size. Because it is an invasive procedure and complications are more common, especially in pediatric patients, it should be performed by experienced practitioners with the guidance of radiological imaging (Citak et al. 2002; Anil et al. 2011; Bannon et al. 2011). To avoid complications, it is recommended that the catheter tip should not be advanced into the right atrium, but placed in the area other than the pericardial sac. The second recommendation is that the insertion depth of the catheter should be adjusted according to the size and anatomy of the patient and fixed in a way that prevents it from advancing further into the heart (Bannon et al. 2011; Lieberman et al. 2004; Cruzeiro et al. 2006).

Mechanical complications such as arterial puncture, hematoma, and pneumothorax may develop due to its wider indications of use and frequent applications. Most commonly, catheters are inserted into internal jugular vein, subclavian vein, and femoral vein. In the landmark technique, the direction of the vein is determined with the help of anatomical signs, the cannulation is performed, and the catheter is directed percutaneously through the superior vena cava into the atrium (Bannon et al. 2011; Lieberman et al. 2004; Tercan et al. 2008).

In this study, we were aimed to retrospectively evaluate the mechanical complications encountered in CVC applications with the help of anatomical landmarks performed by surgeons with 35, 15, and 4 years of experience in the pediatric surgery operating room and our success rates. The primary aim of the study is to determine the early complications and their incidence rates. The secondary goal is to reveal risk factors for complications.

Methods

A total of 498 patients in whom a port, Hickman or central venous catheter was inserted between 2014 and 2017 in the operating room of the Pediatric Surgery Department after obtaining the approval of the hospital ethics committee (Ethics committee number: 18-9.1/32, Date: 18/09/2018) were included in this retrospective study. Also, the trial is registered with the Australian and New Zealand Clinical Trials Registry, number ACTRN12622000578707. Patients' age, gender, height, weight, anesthesia method, type and size of the catheter, the catheterized vein, the number of punctures, the time to blood return (time from the beginning of the puncture to the control of blood flow from the catheter with aspiration as expressed in minutes), and the short-term mechanical complications emerged during the insertion and follow-up of the catheter, and the health care professional who performs the catheterization were recorded (the data were obtained from the patient catheter follow-up form). All catheterizations were performed by anesthesiologists (faculty member, anesthesiologist, or research assistant) using anatomic landmarks (without the guidance of ultrasonography) and the Seldinger method after necessary sterile conditions were provided in the pediatric surgery operating room.

The anatomical region selected for the catheter insertion was determined taking into account the diagnosis of the patient, the operation to be performed, or the clinical condition of the patient. Subclavian, femoral, and internal jugular veins were preferred for catheterization. Propofol (2 mg/kg) was administered intravenously to patients with available intravenous access, and premedication with midazolam (0.75 mg/kg PO) was given for patients without intravenous access and patients were taken to the operating theater. Heart rate and rhythm, respiratory rate and oxygen saturation, noninvasive arterial pressure monitoring, and end-tidal carbon dioxide monitoring were applied to the patients during the intervention. The catheter insertion site was left uncovered, and the procedure area was covered with a sterile drape. The catheter was inserted using the Seldinger technique and fixed with sutures. The location of the only port catheter was confirmed by fluoroscopy. The location of the catheter between the superior vena cava and the right atrium was accepted as an appropriate location. The pocket was created by the pediatric surgeon in port catheter applications.

Statistical analysis

The Statistical Package for the Social Sciences 23.0 (SPSS Inc., Chicago, Illinois, USA) program was used for statistical analysis. In the evaluation, numerical data were expressed as mean ± standard deviation, median (median), range of distribution (maximum-minimum), and categorical data as percentage (%). Pearson chi-square test was used to evaluate the differences between groups. The relationship between independent variables was analyzed using the independent t test and the Mann-Whitney U test. Analysis of variance (ANOVA) test and post hoc test (Bonferroni) were used for the evaluation of the success of the catheterization according to the catheter insertion site. Logistic regression analysis was used to determine the independent risk factors associated with complications. The $p \leq 0.05$ was considered statistically significant.

Results

A total of 498 children including 273 (54.8%) male infants were enrolled in the study. The mean age of the patients was 47.1 ± 59.2 months (median: 24 months [1 day–18 year]). While the median age in female patients was 18

Table 1 Demographic data of the patients included in the study

Patients (*n* 498)	Median (minimum-maksimum)
Age (months)	24 months (1 day–18 years)
Gender (male, %)	273 (54.8)
Weight (kg)	10 (1.3–82)
Height (cm)	76 (37–183)
BMI (kg/m^2)	15.69 (4.94–43.1)
BSA (m^2)	0.46 (0.12–2.0)

Abbreviations: *Kg* Kilogram, *cm* Centimeter, *BMI* Body mass index, *BSA* Body surface area. Data are given as numbers (*n*), percentages (%), and median (minimum-maximum)

Table 2 Types of anesthesia and catheter used in patients

	Temporary (*n*, %)	Hickman (*n*, %)	Port (*n*, %)	Total (*n*, %)
ITGA	160 (45.1)	7 (17.5)	103 (100)	270 (54.2)
Mask / LMA	195 (54.9)	33 (82.5)	0 (0)	228 (45.8)
Total	355 (71.3)	40 (8)	103 (20.7)	498 (100)

Abbreviations: *ITGA* Intratracheal general anesthesia, *LMA* Laryngeal mask. Data are given as numbers (*n*) and percentages (%)

months (1 day–18 year). It was 24 months (1 day–18 year) in male patients ($p = 0.345$). The demographic data of the cases included in the study are shown in Table 1.

In the study, it was found that 54.2% of the patients (*n* 270) had intratracheal general anesthesia (ITGA) and 45.8% of them had mask anesthesia. While ITGA was applied to all patients in whom port catheters were inserted. Mask or laryngeal mask anesthesia was preferred in patients in whom temporary catheters would be inserted (p <0.001) (Table 2).

The instructors, specialists, and research assistants successfully performed the primary catheterizations in 99.4 % (*n* 170), 79% (*n* 233), and 68.8% (*n* 22) of the cases, respectively. Ten catheters that could not be inserted by the research assistants were successfully inserted by the instructors (*n* 5) and specialists (*n* 5). The success rate of the specialists (238/303) was found to be 78.5% and 59 of the 62 catheters that could not be inserted by the specialists were tried by the instructors and 56 of them could be inserted. Thus, the success rate of the faculty members was found to be 98.3% (231/235). The instructor could not insert only one catheter (p <0.001). Using anatomic landmarks, success was achieved in 98.6% and failure in 1.4% of the central venous catheterizations (Table 3). In our study temporary (*n* 355; 71.3%), Hickman (*n* 40; 8%), and port (*n* 103; 20.7%) catheters were inserted in respective number of patients (Table 4).

While most of the catheters (51.8%) were applied with a single puncture, two punctures were necessitated in 22.1%, three punctures in 10.6%, and four or more punctures in 15.5% of the cases. The median time for blood return was 3 min (1–30) in patients whose catheters can be inserted; time to blood return was 1–5 min in 70.5%, 6–10 min in 17.7%, and over 10 min in 11.2% of the patients. In 1.4% of the patients (7 patients), the catheter could not be inserted despite all efforts. Right subclavian vein catheterization was planned in 353 (70.9%) cases, and the procedure was successfully performed in 306 cases. Although different puncture sites were tried, 3 right subclavian, 2 right vena jugularis interna (VJI), and 2 left VJI catheterizations could not be performed (Table 5). Subclavian (p <0.001) and femoral ($p = 0.016$) catheter insertion success rates were significantly higher than VJI. The success rates of subclavian and femoral vein catheterizations were comparable ($p = 1.000$) (one-way ANOVA, post hoc test, p <0.001). Seventy-eight complications developed in 72 patients during catheterizations. Arterial puncture developed in 8% (*n* 40), temporary arrhythmia in 6.2% (*n* 31), and pneumothorax in 1.4% (*n* 7) of the patients. Thoracic tube and closed underwater drainage were applied in patients who developed pneumothorax. Hemothorax or cardiac tamponade did not

Table 3 Distribution of the physicians who performed the catheterization

The physician who first attempted the catheterization	The physician who performed the catheterization				
	Instructor	Specialist	Research assistant	Failure	Success at first attempt (%)
Instructor	170	0	0	1	99.4
Specialist	56	233	0	6[a]	78.5
Research assist	5[b]	5	22	0	68.8
Total	231	238	22	7	85.3

Abbreviations: *Assist* Assistant

[a] Three catheterization attempts made by the instructor failed

[b] Three catheterization attempts made by the specialists failed

Table 4 Types and calibers of the catheters used in the patients

Type of the catheter	Caliber	*n*	%
Temporary catheter	4 F	223	44.78
	4.5 F	6	1,20
	5 F	84	16.87
	5.5 F	17	3.41
	7 F	25	5.02
Hickman catheter	4 F	11	2.21
	5 F	7	1.41
	5.5 F	1	0.20
	7 F	21	4.21
Port catheter	4 F	3	0.60
	4.5 F	2	0.40
	5 F	64	12.85
	5.5 F	4	0.80
	6 F	1	0.20
	6.5 F	24	4.81
	7 F	2	0.40
	8 F	2	0.40
	8.5 F	1	0.20

Abbreviations: F French. Data are expressed as numbers (*n*) and percentages (%)

develop in any patient. Practitioner experience had no effect on the development of complications ($p = 0.354$) (Table 6).

Age, gender, body surface area (BSA), the physician who first performed the catheterization, type of anesthesia applied, the type of catheter, the anatomical site used, the time to blood return, and the number of punctures were included in the model to determine the risk factors associated with complications. Only multiple puncture applications and catheter applications lasting more than 10 min (time to blood return) were found to be associated with complications. No relationship was found between other parameters such as the physician applying the catheterization, the application site and catheter type, the patient's age and gender, and the complications (Table 7).

Discussion

Central venous catheters are frequently used in operating rooms and intensive care units for different indications. In recent years, the use of ultrasonography (USG) has been recommended to increase the success rate and reduce complications, and therefore, the use of USG in CVC applications is becoming more prevalent in our country. In our study, our experience and early complications in catheterizations were applied in consideration of anatomical landmarks in the period before introduction of USG-guided catheterizations into clinical practice. In our study, the success rate of catheterization was found to be 98.6% (491/498), and no significant relationship was found between the anesthesiologist experience and complications.

Central venous catheterization in children is technically more difficult and risky than adults. Each region

Table 5 Distribution of central venous catheter insertion site

		Central venous catheter insertion sites							
		Right subclavian	**Left subclavian**	**Right VJI**	**Left VJI**	**Right femoral**	**Left femoral**	**Failed attempts**	**Total**
Planned anatomic region	**Right subclavian**	306	0		0	1	3	3	353
	Left subclavian	0	90	0	0	3	0	0	93
	Right VJI	6	1	16	2	1	0	2	28
	Left VJI	4	4	0	2	0	0	2	12
	Right femoral	0	0	0	0	12	0	0	12
	Total	316	135	16	4	17	3	7	498

Abbreviations: *VJI* Vena jugularis interna. Data are expressed as numerical values

Table 6 Distribution of complications developed in patients

	Complication (*n*, %)	**Arterial puncture (*n*, %)**	**Arrhytmia (*n*, %)**	**Pneumothorax (*n*, %)**
Instructor (*n* 171)	24 (14)	15 (8.8)	8 (4.7)	2 (1.2)
Specialist (*n* 295)	46 (15.6)	23 (7.8)	22(7.5)	4 (1.4)
Research assistant (*n* 32)	2 (6.3)	2 (6.3)	1 (3.1)	1 (3.1)
p	0.354	0.867	0.369	0.685

Data are expressed as numerical values (*n*) and percentages (%). Some patients developed more than one complication

Table 7 Risk factors related to complications

	B	OR (95% CI)	*P*
Age	0.004	1.004 (0.999–1.008)	0.09
Number of punctures (once)		1	
Number of punctures (twice)	0.735	2.086 (1.009–4.313)	**0.047**
Number of punctures (≥ 3 times)	1.221	3.392 (1.612–7.137)	**0.001**
Time to blood return (1–5 min)		1	
Time to blood return (6–10 min)	0.284	1.328 (0.671–2.629)	0.416
Time to blood return (≥10 min)	1.001	2.721 (1.194–6.2)	**0.017**
Coefficient	−2.810	0.060	<0.001

to be selected for catheterization has its own advantages and disadvantages. Subclavian and internal jugular veins carry a lower risk of infection and thrombosis in prolonged use, while the femoral region is safer in terms of mechanical complications. In addition, the risk of pneumothorax is higher in subclavian vein catheterization, and bleeding control is more difficult. In the literature, the rates of mechanical complications have been reported to range between 0.3 and 25.5%, and success in catheterizations performed considering anatomical landmarks depends on the expected position, patency, and normal calibration of the vessel (Karapinar and Cura 2007; Citak et al. 2002; Anil et al. 2011; Bannon et al. 2011; Lieberman et al. 2004; Cruzeiro et al. 2006; Tercan et al. 2008; Rey et al. 2009).

Trieschmann et al. (2007) reported their overall complication rate as around 4%. They reported that serious problems were pneumothorax and hemothorax and that misplacement was the most common problem with migration of the catheter into the contralateral subclavian vein or one of the jugular veins. They also found that this problem seems more common when the catheter is inserted from the right side. In our study, the overall mechanical complication rate was found to be 9.4%. Although the risk of pneumothorax was higher when the subclavian vein was used, no difference was found between anatomical regions in terms of complications. Catheter malposition was not studied, since the location of most catheters could not be confirmed with intraoperative fluoroscopy, intracardiac electrocardiography, and ultrasonography.

Isguder et al. (2014) stated that the success rate of catheterization was 95.2% in their study including 120 procedures, and the subclavian vein (88%) was the most preferred vein for catheterization followed by femoral (8%) and jugular (4%) veins. They found that during catheterization using subclavian vein 4 complications (3.3%) developed (2 cases of pneumothorax, 2 cases of accidental arterial puncture). The observation of all mechanical complications encountered during subclavian vein interventions was attributed to the more frequent use of this region (87.5%) compared to other anatomical regions. There was no significant relationship between the complications that developed and the catheterization site. Tercan et al. (2008) found the complication rate of 2.4% in children with central vein catheterizations performed under ultrasound guidance without any serious complications. They had achieved 49% of the catheterizations with a single puncture. They stated that with the use of USG, rates of catheterizations increased through a single puncture. In our study, the right subclavian vein was preferred primarily. The overall catheter success rate was found to be 98.6% after repetitive attempts. In our study, the arterial puncture was detected in 40 (8%) patients, and pneumothorax developed in 7 (1.4%) patients. Subclavian vein catheterization had been performed in all patients who developed pneumothorax. The overall complication rate was found to be 9.4%, which was higher when compared with US-guided interventions. For this reason, the necessity of increasing the number of US-guided interventions and the more widespread use of the US has emerged.

Cruzeiro et al. (2006) stated that they catheterized 127 patients 155 times. They reported that 48.4% of the patients were under the age of two and only 20.7% of the patients were over 20 kg. Besides, 89% of the catheterizations were applied under general anesthesia, and 81.9% in the operating room or pediatric intensive care unit. Internal jugular vein, external jugular vein, subclavian vein, and femoral vein were selected, in order of decreasing frequency, respectively. The procedure was performed in 81.9% of the patients from the firstly selected insertion site and in 73.5% of the patients were achieved using a single puncture. No complications occurred in 94.2% of the patients. Mechanical complications were seen in 9 (5.8%) (arterial puncture in 3 (1.9%) and hematoma in 6 (3.9%) patients.

While in 21 patients the catheter or guidewire was inserted and advanced with difficulty, the catheter could not be inserted in three patients. Hemothorax, pneumothorax, or hydrothorax was not detected. There was no relationship between the patient's age, gender, catheter type, primary disease, and complications. The mean body weight of the patients catheterized with a single puncture was comparatively higher (15.4 ± 11.9 vs 10.2 ± 8.8 kg, $p = 0.01$).

In our study, unlike other studies, any significant relationship was not detected between complications and age, gender, and *body mass index* (BMI) of the patients. Although arterial puncture and pneumothorax were more common in subclavian procedures, statistical significance

could not be detected. Although arterial puncture (8%) was a complication seen with a higher rate, it did not require additional intervention other than compression. Thoracic tube application was required in patients who developed pneumothorax (1.4%). The catheter was inserted in 51.8% of the patients with a single puncture, and this rate was similar to the studies using US-guided catheterizations. Cannulation was performed successfully from the planned area in 87.4% of the cases. For temporary catheter placement, most frequently 4F (44.8%) catheters were used in 71.3% of the patients. The subclavian vein was preferred due to the experience and ease of use, but the complication rates were found to be similar when other insertion sites were used. While repetitive punctures and prolonged catheter applications posed a risk for complications, factors such as catheter type and operator's experience were not found to be associated with complications.

Our study has several limitations. Our study was designed retrospectively with the intention to present our clinical experience. Our results should be supported by randomized controlled USG studies. Secondly, our study focused only on mechanical complications such as intraoperative arterial puncture and pneumothorax. Long-term complications such as catheter-related infections and thrombosis have not been studied.

Conclusions

This study showed repetitive punctures (multiple puncture times) and prolonged catheter application times (over 10 min) pose a risk for complications. No relationship was found between the type of catheter, the catheter insertion site, the age and weight of the patient, and the complications. Although a decrease in the overall complication rates was detected with its application in experienced hands, it was found that the experience of placing CVC using an anatomic landmark did not eliminate the complications. Therefore, it was concluded that the US should be used prevalently and its use should be standardized in CVC applications.

Abbreviations

ANOVA: Analysis of variance; BMI: *Body mass index*; BSA: Body surface area; CVC: Central venous catheterization; F: French; ITGA: Intratracheal general anesthesia; SPSS: Statistical Package for the Social Sciences; USG: Ultrasonography; VJI: Vena jugularis interna.

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Authors' contributions

Concept: CS, CB, and TB; Design: CS and CB; Supervision: CB and TB; Fundings: SA, CS, and CB; Materials: SA and TB; Data collection or processing: SA and CB; Analysis or interpretation: SA, CS, and CB; Literature search: CS and TB; Writing: SA, CS, and CB; Critical review: CS, CB, and TB. The authors reviewed the results and approved the final version of the manuscript.

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

The research permit was obtained from the Ege University Medical Research Ethics Committee (Date: 18/09/2018, number: 18-9.1/32). Written informed consent was obtained from the patients' parents or legal guardians who participated under 13 years old. If the patients were aged 13 and older, informed written consent was obtained from the patients and their parents or legal guardians.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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