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Research Article

Current Status and Risk Factors of Complications Associated with Central Venous Catheterization in Pediatric Intensive Care Unit

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Abstract

Background: The objective of this study was to evaluate incidence and influencing factors of complications related to central venous catheters (CVCs) in the Pediatric intensive care unit (PICU) of Xi'an Children's Hospital. **Methods:** We analyzed the complications of all children that had CVCs and were hospitalized between June 2020 to February 2021. A total of 334 CVCs were inserted in 310 children. **Results:** We noted 102 (30.54%) CVCs-related complications. Complications related to CVCs insertion were infection of catheter (13.17%) and malposition of catheter (8.38%), occlusion of CVCs (2.99%), accidental removal (0.6%), puncture site exudate (4.79%), central venous thrombosis (0.6%). Infection mainly due to Staphylococcus epidermidis. 88 cases (24.55%) of CVCs were extubated due to complications. Analysis of the frequency of maintenance-related complications except for center vein thrombosis showed no differences between the jugular, femoral and subclavian vein access ($p>0.05$). It was found that the duration of the catheterization use was critical for the occurrence of CVCs-related infections, puncture site exudate, occlusion ($p<0.05$). Suture-off, bleeding of insertion site, and the maximum channels of intravenous infusion in patients were dominant risk factors of catheter-related complications. **Conclusion:** The risk factors of complications during catheter indwelling are suture-off, bleeding of insertion site and the maximum channels of intravenous infusion in patients. Therefore, strict aseptic operation in various operations, control of the infusion channel, effective fixation of the central venous catheter, reduce the malposition and pull of the catheter, and reduce the infiltration of blood at the puncture point, are particularly important to prevent the complications related to the central venous catheter.

Keywords: *central venous catheterization, complications, pediatric intensive care unit, cather-related infection*

Background

Central venous catheters (CVCs) have been become indispensable in pediatric intensive care units (PICU). 40% to 60% of children require indwelling CVC in PICU [1]. It is more important for children who need long-term intravenous treatment, especially hemodialysis, long-term parenteral nutrition, and chemotherapy [2]. CVC is an indispensable vital channel in the treatment of hospitalized children in critical care medical department. Children in PICU are in serious condition and need multiple venous channels [3]. Insertion of CVC is amongst the most frequently performed invasive procedures. Unfortunately, the complications during the catheter indwelling affected the use of CVC and the rescue and treatment of patients. As literature pointing, complications appeared 6h after placement were defined as the catheter indwelling complications or maintenance-related complications. Some common maintenance-related complications CVCs were catheter displacement, puncture side limb swelling, occlusion, accidental extubation, central venous thrombosis and so on. The percentage of known catheter-related complications range from 0.7 to 36% [4].

In domestic, research on children's maintenance-related complications of CVCs most were for small sample and retrospective summary, or only analysed and researched a single complication. In their process of research seldom did statistical analysis the in-risk factors of complications [5]. Simultaneously, Studies on maintenance-related complications of CVCs were focused on adults, but no study of CVCs maintenance-related complications in PICU has been reported [6].

In the present study we had two objectives. The first was to evaluate maintenance-related complications and the main causes of unplanned extubation of CVCs in PICU. Second, we wanted to investigate the common maintenance-related complications and risk factors of CVCs in PICU. By analyzing the obtained results, our intention was to provide theoretical support for making the preventive measures.

Materials and Methods

Participants

A prospective study was conducted from November 2020 to March 2021 in Xi'an Children's Hospital. Parental written informed consent was obtained. 340 CVCs were inserted in 315 patients in the PICU. During this period, 2 CVCs were placed in other hospitals, 2 CVCs were extubated due to death, 2 CVCs were extubated because of signing discharge. At last, a total of 334 CVCs were inserted in 310 patients.

Inclusion criteria: (1) Aged 28 days to 14 years; (2) Patients who met the indications of catheterization and were both first-time catheterized; (3) No patients with other serious underlying diseases. Exclusion criteria: (1) Patients' CVCs were inserted in other hospitals; (2) The CVC indwelling time <6h. There were 159 males (51.29%) and 151 females (48.70%) in the experimental group. The age ranged from 28.9 days to 13.8 years, with an average of (3.8 ± 1.18) years, and their weight 2.8-49.9 kg. Categories of patients' diseases: 115 patients were congenital heart disease, 64 patients were simple congenital heart diseases, 45 patients were complex congenital heart diseases; 86 patients were other diseases.

CVCs indwelling time ranged from 6 h to 28 days, with an average of (7.31 ± 4.1) days; The duration of catheterization was <7 day in 227 cases (67.96%); ≥ 7 days in 107 cases (32.04%). Catheter placement: femoral vein in 58 times (17.36%); 257 cases of jugular vein (76.95%); Subclavian vein 19 cases (5.69%).

Study protocol

The data on indications for CVCs access site, duration of catheterization, total number of inserted CVCs, catheter type and the most frequent complications related to CVCs were evaluated. Routine examination of blood coagulation function is performed, including but not limited to activated partial thromboplastin time (APTT), prothrombin time (PT) and platelet count (PLC). For patients with severe coagulation dysfunction, CVC was performed after correction, and the platelet count before puncture was ≥ 5×10^9/L. Sedation of the patient was achieved with midazolam and fentanyl if patient was concussing and vigorous, except in critically ill or comatose children.

All CVCs were placed in aseptic conditions with continuous monitoring of heart rate, patient's electrocardiogram, and oxygen saturation. All catheterizations were performed by an experienced staff anesthetist or a pediatrician under supervision. CVCs were used in the disposable double or three cavities of Shenzhen Yixinda brand or Zhengzhou Di'ao medical brand. CVCs were catheterized through the subclavian vein, internal jugular vein and femoral vein as needed. Choice of access site was based on physician preference and the availability of the access. The access site was fixed with double suture.

After catheterization, the insertion site was cleansed, and a sterile dressing was applied. The access site was routinely disinfected with 1% povidone iodine solution and was covered with 6.5 × 7.0 cm transparent dressing (9534HP, 3M). Two to three hours following catheter insertion, patient's electrocardiogram, heart rate and oxygen saturation were monitored.

The transparent dressings should be replaced routinely the next day. The puncture site should be changed once a week if it is dry. After routine disinfection, the puncture site was covered with sterile gauze or cotton ball, and the transparent dressing of 9534HP (3M) was pressurized and fixed. The external catheter was properly fixed, and the

dressing was replaced at least once for 24h. After the bleeding stopped, the dressing was replaced once a week. The central venous ducts of all children were sealed with positive pressure of 3-5 mL of normal saline.

Patients were carefully observed and evaluated the situation at the puncture site, and immediately pulled out the CVCs if there were signs of skin infection (redness, induration, glandular secretions) at the site of catheterization or patients with unexplained systemic infection symptoms (T>38.5°C, WBC>15 × 10^9/L). Peripheral blood and catheter blood were collected by the nurse for culture before extubation. Pulling in venous catheter operation performed by competent doctors. Using 1% povidone iodine solution to disinfect the CVC in ready to pull out the first puncture point and its surrounding skin. When the catheter was pulled out, with a sterile scissors shearing 2-3 cm catheter tips on dedicated seedlings in vitro, closely after encapsulation, sent to laboratory for general bacterial culture, identification and routine drug sensitivity test. All operating procedures under aseptic conditions.

Statistical analysis

SPSS 20.0 statistical software was used for data collection and statistical analysis. Descriptive analysis was used to calculate the incidence of various complications, and single factor analysis was determined to statistically significant risk factors. Measurement data were based on whether they were normal distribution, test or non-parametric statistical test. Statistical data were counted by χ^2 test or Fisher's test. Risk factors with statistically significant in univariate analysis (p<0.05) were as independent variables, and then a multivariate logistic regression analysis model was constructed based on the risk factors, with the test level α=0.05.

Ethics approval and consent to participate

Ethical approval: This is an observational and retrospective study. This study is in accordance with the ethical standards of 1964 Helsinki declaration and its later amendments or comparable ethical standards. It has a positive approval by the Investigational Ethical Commission of Xi'an Children's Hospital Informed. **Consent:** For this type of study formal consent is not required. This is an observational retrospective study without interventions and without medicaments.

Results

Maintenance-related complications and the main causes of unplanned extubation

In 334 placed CVCs, 102 (35.4%) had the complications related to CVC insertion (Table 1). The most frequent complication was catheter-related infection occurring in 44 (13.17%) patients, then catheter malposition of CVCs occurring in 28 (8.38%) patients, puncture site exudate in 16 (4.79%) patients. The main reasons for unplanned removal were catheter-related infection (13.17%), catheter malposition (4.19%), puncture site exudate (4.79%). There were two or more complications of the CVCs in 11 cases, catheter-related infection and malposition in 3 cases, catheter malposition and puncture site exudate in 5 cases, catheter-related infection and catheter occlusion in 1 case. Three kinds of complications were found in 2 cases, including catheter malposition, catheter occlusion and catheter associated infection.

Table 1. The Incidence of complications and unplanned removal of CVC

Complications	Total number of complications n (%)	Extubation cases in advance n (%)
Catheter-related infection	44 (13.17%)	44 (13.17%)
Catheter malposition	28 (8.38%)	14 (4.19%)
Puncture site exudate	16 (4.79%)	16 (4.79%)
Obstruction	10 (2.99%)	4 (1.20%)
Accidental removal	2 (0.60%)	2 (0.60%)
Central venous thrombosis	2 (0.60%)	2 (0.60%)
Combined	102 (30.54%)	88 (24.55%)

Complications related to catheter placement and duration

Maintenance-related complications except for center vein thrombosis were independent of access sites (jugular vein, femoral vein and subclavian vein) (p>0.05). Due to the low incidence of accidental removal and central venous

thrombosis, the incidence of accidental removal of the jugular vein catheter was compared with that of the femoral vein catheter and subclavian vein catheter by Fisher's test (p>0.05), which showed no statistical significance.

The longer the duration of catheterization, the higher the incidence of total complications, such as catheter-related infection, puncture site exudate and obstruction. (p<0.05). The comparison between different indwelling time is statistically significant. When catheters are in place for extended periods, the catheter probably plays a major role in providing access for microorganism to the bloodstream by migrating endoluminally (Tables 2 and 3).

Table 2. The incidence of complications at different access sites

Complications	Total (n=334) n (%)	Femoral (n=58, 17.36%) n (%)	Jugular (n=257, 76.95%) n (%)	Subclavian (n=19, 5.69%) n (%)	χ^2	*P*
Catheter-related infection	44 (13.17%)	8 (12.12%)	32 (12.90%)	4 (21.05%)	2.435	0.271
Catheter malposition	28 (8.38%)	2 (3.03%)	24 (9.68%)	2 (10.53%)	2.995	0.289
puncture site exudate	16 (4.79%)	3 (4.55%)	13 (5.24%)	0	3.213	0.332
Obstruction	10 (2.99%)	4 (6.06%)	6 (2.42%)	0	5.065	0.063
Accidental removal	2 (0.60%)	0	2 (0.81%)	0	-	0.465
Central venous thrombosis	2 (0.60%)	2 (3.03%)	0	0	-	0.054
Combined	102 (30.54%)	19 (28.79%)	77 (31.05%)	6(31.58%)	0.095	0.543
Note: "-" is Fisher's test						

Table 3. The incidence of complications at different catheterization time

Complications	Total (n=334) n (%)	≤ 5 d (n=131, 39.22%) n (%)	5-10 d (n=141, 42.22%) n (%)	>10 d (n=62, 18.56%) n (%)	χ^2	*p*
Catheter-related infection	44 (13.17%)	11 (3.29%)	21 (6.29%)	13 (3.89%)	5.783	0.021
Catheter malposition	28 (8.38%)	9 (2.69%)	14 (4.19%)	5 (1.50%)	1.874	0.071
puncture site exudate	16 (4.79%)	6 (1.20%)	4 (1.20%)	8 (2.40%)	10.763	0.011
Obstruction	10 (2.99%)	0	5 (1.50%)	5 (1.50%)	14.643	0.001
Accidental removal	2 (0.60%)	0	1 (0.30%)	1 (0.3%)	-	0.123
Central venous thrombosis	2 (0.60%)	2 (0.60%)	0	0	-	0.435
Combined	102 (30.54%)	28 (21.37%)	45 (31.91%)	32 (51.61%)	19.764	0.000
Note: "-" is Fisher's test						

Catheter-related infection

In catheter-related infections cases, 28 (8.38%) cases were infections of the access site. Catheter-related bloodstream infections (CRBI) developed in 13 (3.89%) patients, the infection rate was 5.3/1000 catheter days. 3 (0.9%) cases were catheter colonization. 47 pathogens were monitored out 44 cases of catheter-related infections. Details are shown in Table 4. Three patients detected two kinds of pathogenic microorganisms (*Staphylococcus epidermidis* and *Candida albicans*). Monitoring results: 22 cases were *Staphylococcus epidermidis* and *Acinetobacter baumannii* 6 cases, 7 cases with *Klebsiella pneumoniae*, *Pneumococcal* in 2 cases, 2 cases of *Staphylococcus aureus*, *Candida albicans* 8 cases.

Table 4. Distribution and composition ratio of multi-drug resistant pathogens

Bacterial infection	Number (n)	Constituent ratio (%)
Staphylococcus epidermidis	22	46.81%
Acinetobacter baumannii	6	12.77%
Klebsiella pneumoniae	7	14.89%
Pneumococcal	2	4.26%
Staphylococcus aureus	2	4.26%
Candida albicans	8	17.02%
Combined	47	100.00%

Analysis of the frequency of infection by insertion site showed no differences between the jugular, femoral and subclavian vein access. The risk of catheter-related infection was higher when the duration of catheterization was longer (p=0.021).

Results of analysis of risk factors associated with total complications

To evaluate the relationship between the risk of factors and total complications, we studied the probability of risks factors by univariate analysis. Catheter-related complications were not related to the gender, age, weight, catheter brand, access site, place, or whether the procedure was performed by anesthetist or pediatrician and so on. Univariate analysis showed suture-off, catheter type, duration of catheterization, bleeding of insertion site, the patients' maximun channels of intravenous infusion were statistically significant (p<0.05). The five risk factors were possible influencing factors for the complications of CVCs in PICU (Table 5).

Table 5. Univariate analysis of factors affecting CVC complications

Factors	Kinds	No complications (cases)	Complications (cases)	$\chi 2$	p
Gender	male	116	55	2.893	0.193
	female	114	49		
Age	≤ 3	63	27	0.432	0.563
	>3	169	75		
The puncture site person	anesthetist	169	76	0.004	0.843
	pediatrician	63	26		
The puncture place	operating room	144	65	0.432	0.321
	PICU	88	37		
Suture-off	yes	9	27	11.432	0.000
	no	223	75		
Catheter type	double cavities	34	7	8.732	0.002
	three cavities	198	95		
Duration of catheterization	≤ 5 d	102	31	9.821	0.01
	5-10 d	94	43		
	>10 d	36	28		
Parenteral nutrition	yes	121	54	0.043	0.982
	no	111	48		
Catheter brand	Yixinda	161	67	1.232	0.223
	Di'ao	71	35		
Access site	Femoral vein	39	19	0.043	0.964
	Jugular vein	180	77		
	Subclavian vein	13	6		
Bleeding of insertion site	yes	85	62	11.213	0.000
	no	147	40		
Maximum channels of intravenous infusion	≤ 4	167	38	12.229	0.000
	>5	65	64		

The five risk factors with statistically significant in univariate analysis were as independent variables, and then a multivariate logistic regression analysis model was constructed based on the risk factors. Multivariate Logistic regression analysis showed suture-off, bleeding of insertion site, and the maximum channels of intravenous infusion channels of patients, were three dominant risk factors for CVCs-related complications (Table 6).

Table 6. Multivariate unconditional Logistic regression analysis of complication

Factors	*β*	*χ2*	*OR*	*95%CI*	*P*	Precedence
Suture-off	1.632	16.923	4.858	2.313 ~ 10.321	0.001	1
Bleeding of insertion site	0.701	7.203	1.837	1.132 ~ 3.041	0.008	2
Maximun channels of intravenous infusion	0.185	5.921	1.238	1.032 ~ 1.543	0.009	3
Catheter type	-0.053	0.321	0.985	0.987 ~ 1.255	0.168	4
Duration of catheterization	-0.051	0.289	0.945	0.778 ~ 1.219	0.184	5

Discussion

Most complications related to CVCs are minor, but some of them can be serious and can result in patient death. In the present study, complications were similar to previous reports, our complication rate is within the limits of published data [6-8].

The statistical results of this study showed that the overall complication rate of CVCs in PICU was 30.54%. The incidence of catheter-related infections was highest (13.17%). The incidence of catheter malposition was 8.38%. The rate of puncture site exudate was 4.79%. Catheter obstruction was 2.99%. The rate of accidental removal was 0.6%, and the frequency of central venous thrombosis was 0.6%. The rate of infection was 13.17%, while that reported by Karapinar et al. [8] was 17.3%. The types and incidence of complications were basically consistent with those reported by Karapinar et al. [8]. The incidence of complications during catheter indwelling in the study center was 30.54%, and the frequency of catheter unplanned exudate due to complications was 24.55%, which were mainly due to two reasons. On the one hand because of catheter suture-off can still continue to use, only the malposition further cause catheter slippage or concurrent puncture point drainage tube drawing. On the other hand, this study any cavity in patients with central venous catheter jam of catheter occlusion, but patients with indwelling for two cavity or three cavity catheter, the clogging one cavity, duct still can continue to use.

In this study, catheter-related complications were not related to the access sites (jugular vein, femoral vein and subclavian vein), which was similar to the research results of Shin H J et al. [9,13]. The duration of catheterization was longer, the incidence rates of all over complications was higher. The results showed that the incidence of indwelling time greater than 10 days was as high as 51.61%. In this study, catheter-associated infection was the most important complication associated with venous catheterization in PICU, with an incidence of 13.17%, which was basically consistent with the incidence of 11.5-5.5% reported in domestic literature in adults. In our study, a total of 47 strains of pathogenic bacteria were detected in 44 cases, mainly due to Gram-positive cocci, among which Staphylococcus epidermidis took the first place (46.81%), basically consistent with the adult pathogenic bacteria reported by Henrique C P et al. [10]. It can be emphasized again that the adherence with the procedures for maintaining sterile conditions has a major [11].

Catheter suture-off, bleeding of insertion site, and the maximum channels of intravenous infusion channels in patients were independent risk factors for CVCs-related complications in PICU ($p<0.05$).

At present, the CVC is usually fixed with sutures and covered with transparent dressings in clinical practice [12]. However, the long-term use of the catheter may lead to the aging and suture-off, thus losing the strengthening effect of the catheter and resulting in the catheter malposition. The loose suture leads to catheter instability, and the catheter will move in and out of the puncture site with the patient's activities, which may lead to increased injury at the puncture site and bleeding of insertion site. It is important to reduce the bleeding of insertion site and fixing catheter properly for reducing the complications of CVCs [13].

In 334 cases, 41 (12.28%) CVCs were double cavities, 293 (87.72%) CVCs were three cavities. Because multiple lumen catheters provide multipurpose access to central circulation and eliminates a need for additional intravenous access [14]. The use of multiple lumen catheters for parenteral nutrition is highly desirable. However, the maximum channels of intravenous infusion channels in patients are the increased risk for catheter-related complications [15].

In this study, bleeding of insertion site was an important risk factor for complications related to the CVCs. Bleeding of insertion site will lead to increased frequency of dressing changes, resulting in increased duct traction and contamination of the puncture site, increasing the risk of catheter malposition and infection. Blood is the best medium for bacteria, which easily leads to local infection at the puncture site and increases the incidence of catheter-related infection. Reducing the bleeding of insertion site can not only reduce the workload of nurses to change dressings, but also reduce the complications during the indwelling of the CVCs [16]. When bleeding of insertion site, medical staff should be careful to prevent complications, change the dressings in time, avoid pulling the catheter when changing the dressings, and strictly abide by the principle of asepsis during operation [17]. At the same time, we should take reasonable preventive measures to reduce the rate of bleeding of insertion site, such as reducing the local and limb movements at the insertion site, pay attention to the blood coagulation function of patients, and timely deal with abnormal conditions. Some foreign scholars have concluded that the inserted large-caliber catheter may be an independent risk factor for bleeding of insertion site [18,19]. Therefore, an appropriate catheter was chosen based on the size of the patient in clinic.

Due to the limitation of sample capacity, this study did not analyze the related factors of all complications. Due to the limited factors included in the study, it may not be possible to analyze the risk factors of complications comprehensively and systematically during catheter indwelling in PICU.

Conclusion

There were many risk factors for complications of CVCs in PICU, among which the main complications were catheter-related infection, catheter malposition and puncture site exudate, which were also the main reasons for unplanned catheter extubation. Catheter-associated infection is still the most important complication, and prevention is still a priority. The location of catheterization is not the influencing factor of complications during catheter indwelling, and the access site can be selected according to the actual situation of patients and the least complications of puncture. Suture-off, bleeding of insertion site, the patients' maximum channels of intravenous infusion are the risk factors for complications during catheter indwelling. Therefore, operating strict aseptic operation, control of infusion channel, effectively fixed central venous catheter, reducing pipeline malposition and reduce the puncture point ooze blood, are particularly important for the prevention of CVCs-related complications.

Conflicts of interest

The authors declare no conflict of interest.

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