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Comparative Study of Complications in CV Catheter Insertion for Pediatric Patients: Real-time Ultrasound-guided Versus Venography-guided Approach

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ABSTRACT

Background Tunneled central venous catheters (CVC), called Broviac/Hickman catheter, are widely used in the long-term treatment of pediatric patients. Recently, the percutaneous approach for CVC insertion has become dominant as a less invasive intervention. In this study, we reviewed the mechanical and delayed complications according to different procedures of CVC insertion and assessed the risk factors for complications in CVC insertions for pediatric patients.

Methods A total of 159 pediatric patients (85 males and 74 females) were included in this study. Primary reasons for indication of CVC settlement were hemato-oncologic disorders (66 cases, 42%), malignant solid tumors (30, 19%) and other benign diseases (63, 40%). CVC insertion was performed with surgical venous cut-down (CD) in 51 patients (32%), with real-time ultrasound-guided puncture (RTUS) in 57 (36%), and venography-guided puncture (VG) in 49 (31%).

Results CD was dominantly selected and the frequency of venipuncture increased respective to the increased age of patients. RTUS was dominantly selected for one to four year old patients and VG was dominant in 5 to 15 year old patients. Some types of mechanical complication were observed in 4 of 159 (2.5%) and some delayed types were observed in 66 of 159 cases (42%). No mechanical complications occurred in cases with CD and RTUS; on the other hand, 3 (6%) of 49 insertions with VG were observed. However, we could not show any significant risk factors for the mechanical complications. In the meantime, delayed complications and premature removal were significantly observed in patients under 5 years old.

Conclusion RTUS is superior to our conventional VG considering less frequent mechanical complications. High frequent delayed complication and premature removal should be considered, especially for patients under 5 years old.

Key words central venous catheter; children; pediatric intervention; real-time ultrasound guide; venography guide

Tunneled central venous catheters (CVC), so-called Broviac/Hickman catheters, are widely used in the long-term treatment of pediatric patients. These catheters enable continuous secure chemotherapy or total parenteral nutrition for pediatric patients.

Originally, surgical venous cut-down (CD) was a common method for tunneled CVC insertion and is still a first choice for patients with specific conditions.[1] Recently, the percutaneous approach has become dominant as a less invasive intervention and many studies have shown the usefulness of ultrasound-guided venipuncture.[2]

In our institute between 2009 and the beginning of 2012, percutaneous CVC insertion into the subclavian vein was mainly performed under venography-guided puncture (VG) but was then changed to real-time ultrasound guided puncture (RTUS) after 2012.

The aim of this study is to compare the early and late phase complications of two kinds of percutaneous approach for CVC insertion and to assess the usefulness of RTUS over our conventional use of VG. This is the first study to compare the incidence of mechanical failures and complications in two kinds of percutaneous CVC insertions with VG and RTUS.

SUBJECTS AND METHODS

Patients

The subjects of this study were pediatric patients under 16 years old, who were treated at the Department of Pediatric Surgery, Tottori University Hospital from 2009 to 2016. The indications for CVC insertion were i) continuous chemotherapy for pediatric oncologic disorders, ii) intravenous administration of high concentrated med-

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Abbreviations: CD, surgical venous cut-down; CVC, central venous catheter; LM, landmark venipuncture; RTUS, real-time ultrasound-guided puncture; VG, venography-guided puncture

icine, iii) parenteral nutrition for intestinal failure, and iv) difficulty of peripheral venous access. Four surgeons in our pediatric surgical department who are experts in CVC insertion performed all procedures. We mainly chose the cervical venous cut-down or the subclavian venipuncture according to the surgeon's judgement considering age, body weight, platelet count, performance state, and so on. In cases with venipuncture, we performed it under venography-guided approach in between 2006 and 2012, until real-time ultrasound guided approach was introduced after 2012. CVC maintenance has been performed in strict accordance with the regulations of the pediatric ward of our institute.

We reviewed all the patients' medical records concerning CVC insertion procedure and associated complications. We compared the rate of complications between VG and RTUS in patients with the Broviac/Hickman catheter inserted into the subclavian vein. And we also assessed the risk factors for short and long-term complications in multiple regression analysis in each group. Ethics approval of this study was obtained from the Ethics Review Committee of Tottori University Hospital (No. 1701A172).

Venography-guided puncture (VG)

VG was our original method for this procedure. Although we did a complete and thorough search on PubMed, it seems no similar procedures have been reported in the English literature so far. The right subclavian vein is the preferred site for the primary attempt. At first, a peripheral venous line in the ipsilateral upper extremity is needed. Subsequently, a small amount of contrast agent (in most cases, about 5ml/body of Iopamidol 150mg/mL) is injected just before the venipuncture and the location of the subclavian vein under fluoroscopy is visually recognized. Then, the standard Seldinger wire technique is used. The CVC is tunneled from the lateral anterior chest to the previous punctured site (Fig. 1A). VG might be more reliable and safer than blind percutaneous venipuncture, also known as landmark venipuncture (LM). However, VG has some limitations. Because the contrasted image of the subclavian vein disappears in a few seconds, operators must puncture the objective without real-time guidance. Furthermore, this procedure is not suitable for patients with contrast media allergy or where peripheral venous access is difficult.

Real-time ultrasound-guided puncture (RTUS)

As a promising procedure superior to VG, we selected the RTUS technique from 2012 in our department. The left subclavian vein is the preferred site for the primary attempt. We use a kind of portable ultrasonographic

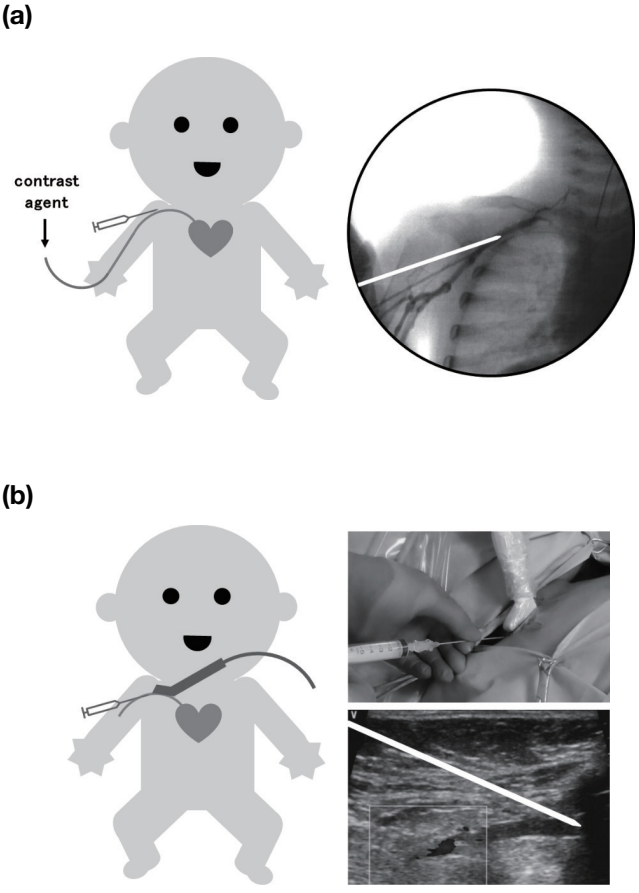

Fig. 1. The procedures of two kinds of venipuncture for central venous catheter (CVC) insertion. (**a**) Venography guided puncture (VG), (**b**) Real-time ultrasound guided puncture (RTUS).

system with a hockey-stick shaped probe (Sonosite Ultrasound System S-Nerve™, Fujifilm Corporation). An assistant from our medical staff puts the probe partially on the clavicle and subclavian region, and identifies the subclavian vein in the longitudinal profile. Then the operator can puncture the subclavian vein in real time, visualizing the needle tip and the vein in the same monitor. Afterwards, the CVC is placed in the subcutaneous tunnel in the same way as that of the VG. Special attention must be paid not to miss the needle tip during the RTUS procedure; this proves to be the most important technique for preventing any mechanical complications. The key is to realize that the puncture point on the skin done by the RTUS tends to be off to the lateral side by the width of the probe. Careful attention must also be paid to keep the area between the puncture points of the RTUS and VG at a minimum (Fig. 1B).

Statistical Analysis

Statistical analysis was conducted using the chi-square

test and Fisher's exact test for categorical variables. Welch's two-sample *t* test was used for continuous variables. $P < 0.05$ was considered significant. Risk factors contributing to complications were investigated with multiple analysis based on the variables selected by each univariate analysis using the logistic regression model and the Cox proportional hazard regression model, respectively.

RESULTS

Patient characteristics

A total of 159 pediatric patients (85 males and 74 females) were included in this study (Table 1). Primary reasons for indication of CVC settlement were hemato-oncologic disorders (66 cases, 42%), malignant solid tumors (30, 19%) and other benign diseases (63, 40%). The CVC insertions were performed with CD in 51 patients (32%), with RTUS in 57 (36%), and with VG in 49 (31%). The average and median indwelling periods were 193 and 155 days. Table 2 shows the distribution of selected procedures according to patient age. For patients under one-year old, CD was dominantly selected and the frequency of venipuncture with RTUS or VG increased respective to the increased age of patients. RTUS was dominantly selected for one to four year old patients and VG was dominant in 5 to 15 year old patients.

We could not compare the operation times between RTUS and VG, because CVC insertions were frequently performed with other surgical procedures and we could not assess the precise required times of CVC insertions from those medical records.

CVC complications

Table 3 shows the frequencies of mechanical and delayed complications in each procedures. And the frequency of premature removal of catheter is also shown. Some types of mechanical complication were observed in 4 of 159 (2.5%). As for the mechanical complications, hemorrhage due to a puncture into other vessels were observed in 2 cases, pneumothorax in one case (0.6%) and hemothorax in one. No mechanical complications occurred in cases with CD and RTUS. On the other hand, complications in 3 (6%) of 49 insertions with VG were observed. As for delayed complications, frequent incidents were bacteremia and catheter dislodgement/accidental removal observed in 22% and 21%, respectively. Some delayed complications were observed in 66 of 159 cases (42%). Premature removal of catheter occurred in 24% of CD, 30% of RTUS and 14% of VG cases. Total premature removals reached 37 of 159 cases (23%).

Table 1. Patient characteristics

Age	*n*	
< 1 y	43	27.0%
1 y	22	13.8%
2–4 y	38	23.9%
5–9 y	29	18.2%
10–15 y	27	17.0%
Sex	*n*	
Male	85	53.5%
Female	74	46.5%
Disease	*n*	
Hematooncological	66	41.5%
Solid malignant	30	18.9%
Others	63	39.6%
Site	*n*	
Rt. Jugular	27	17.0%
Lt. Jugular	11	6.9%
Rt. Subclavian	54	34.0%
Lt. Subclavian	54	34.0%
Others	13	8.2%
Procedure	*n*	
CD	51	32.1%
RTUS	57	35.8%
VG	49	30.8%
Puncture (uncertain)	2	1.3%
Type of the catheter	*n*	
Broviac	87	54.7%
Hickman	45	28.3%
Others	27	17.0%
Days of indwelling	Days	
Range	3–870	–
Average	193	–
Median	155	–

CD, surgical venous cut-down; Lt., left; Rt., right; RTUS, real-time ultrasound-guided puncture; VG, venography-guided puncture; y, year(s).

Table 2. Distribution of procedure by age

	CD	Venipuncture			Total
		RTUS	VG	Uncertain	
< 1 y	36 (83.7%)	4 (9.3%)	2 (4.7%)	1 (2.3%)	43
1 y	9 (40.9%)	9 (40.9%)	4 (18.1%)	0 (0.0%)	22
2–4 y	5 (13.2%)	21 (55.3%)	12 (31.6%)	0 (0.0%)	38
5–9 y	1 (3.4%)	10 (34.5%)	17 (58.6%)	1 (3.4%)	29
10–15 y	0 (0.0%)	13 (48.1%)	14 (51.9%)	0 (0.0%)	27
Total	51 (32.1%)	57 (35.8%)	49 (30.8%)	2 (1.3%)	159

CD, surgical venous cut-down; RTUS, real-time ultrasound-guided puncture; VG, venography-guided puncture; y, year(s).

Table 3. Distribution of complications by procedure

	CD	Venipuncture			Total
		RTUS	VG	Uncertain	
Mechanical complications					
Puncture into other vessel	0 (0.0%)	0 (0.0%)	2 (4.1%)	0 (0.0%)	2 (1.3%)
Pneumothorax	0 (0.0%)	0 (0.0%)	1 (2.0%)	0 (0.0%)	1 (0.6%)
Hemothorax	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (50.0%)	1 (0.6%)
Any of above	0 (0.0%)	0 (0.0%)	3 (6.1%)	1 (50.0%)	4 (2.5%)
Delayed complications					
Bacteremia	9 (17.6%)	15 (26.3%)	11 (22.4%)	0 (0.0%)	35 (22.0%)
Dislodgment a/o Accidental removal	13 (25.5%)	13 (22.8%)	7 (14.3%)	1 (50.0%)	34 (21.4%)
Occlusion a/o Rapture of catheter	2 (3.9%)	7 (12.3%)	3 (6.1%)	0 (0.0%)	12 (7.5%)
Any of above	18 (35.3%)	29 (50.9%)	18 (36.7%)	1 (50.0%)	66 (41.5%)
Premature removal	12 (23.5%)	17 (29.8%)	7 (14.3%)	1 (50.0%)	37 (23.3%)

a/o, and/or; CD, surgical venous cut-down; RTUS, real-time ultrasound-guided puncture; VG, venography-guided puncture.

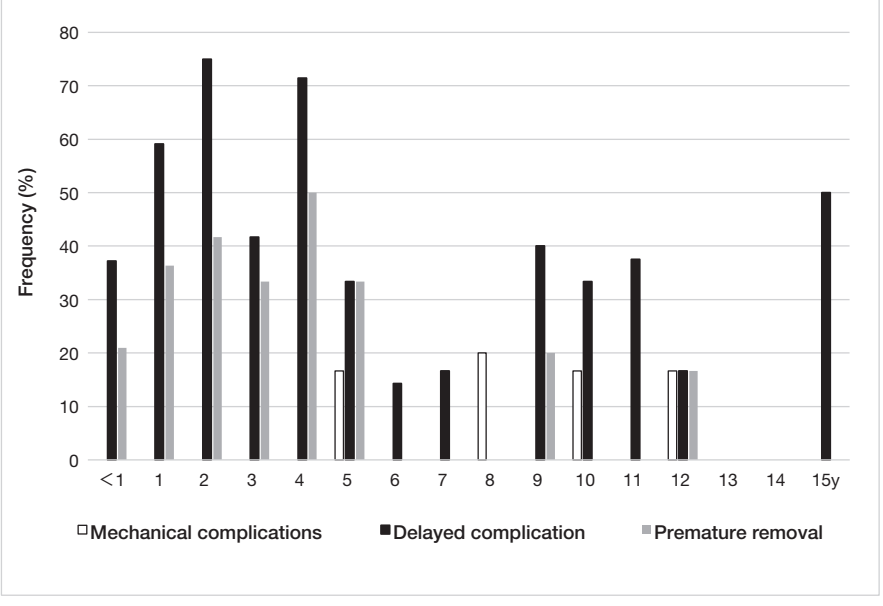

Fig. 2. Frequencies of complications and premature removals according to patient age.

Distribution of complications according to patient age

Figure 2 shows the frequency of complications by age. Delayed complications and premature removal of catheter were frequently observed in patients between one and four years old.

Risk factors for complication

Table 4 demonstrates correlations between any kind of complications and patient background by multiple regression analysis. As for mechanical complications, there were no significant risk factors. On the other hand, delayed complications and premature removal occurrence rate were significantly higher in patients under 5 years old compared to patients 5 years and over.

DISCUSSION

CVC is an essential tool for continuous administration of therapeutic drugs and nutrition to pediatric patients safely. The indication of CVC for pediatric patients are as follows: i) continuous chemotherapy for malignancy, ii) long-term total parenteral nutrition for patients with severe digestive disorder including short-bowel syndrome, chronic idiopathic intestinal pseudo-obstruction

Table 4. Risk factor complications in cases of Broviac/Hickman catheter into the subclavian vein

	Age			Sex		
	< 5 y (*n* = 44)	5y ≤ (*n* = 51)	*P* value	Male (*n* = 52)	Female (*n* = 43)	*P* value
Any kind of mechanical complication	0 (0.0%)	3 (5.9%)	n.s.	2 (3.8%)	1 (2.3%)	n.s.
Delayed complication						
Bacteremia	14 (31.8%)	9 (17.6%)	*P* = 0.03	14 (26.9%)	9 (20.9%)	n.s.
Dislodgment a/o Accidental removal	15 (34.1%)	3 (5.9%)	*P* = 0.001	11 (21.2%)	7 (16.3%)	n.s.
Occlusion a/o Rapture of catheter	9 (20.5%)	0 (0.0%)	*P* = 0.01	5 (9.6%)	4 (9.3%)	n.s.
Any kind of delayed complications	31 (70.5%)	12 (23.5%)	*P* = 0.00001	24 (46.2%)	19 (44.2%)	n.s.
Premature removal	18 (40.9%)	3 (5.9%)	*P* = 0.0001	8 (15.4%)	13 (30.2%)	*P* = 0.03

	Diagnosis			Laterality		
	Malignant (*n* = 82)	Others (*n* = 13)	*P* value	Left (*n* = 45)	Right (*n* = 50)	*P* value
Any kind of mechanical complication	3 (3.7%)	0 (0.0%)	n.s.	0 (0.0%)	3 (6.0%)	n.s.
Delayed complication						
Bacteremia	19 (23.2%)	4 (30.8%)	n.s.	11 (24.4%)	12 (24.0%)	n.s.
Dislodgment a/o Accidental removal	14 (17.0%)	4 (30.8%)	n.s.	12 (26.7%)	6 (12.0%)	n.s.
Occlusion a/o Rapture of catheter	5 (6.1%)	4 (30.8%)	*P* = 0.03	5 (11.1%)	4 (8.0%)	n.s.
Any kind of delayed complications	34 (41.5%)	9 (69.2%)	n.s.	24 (53.3%)	19 (38.0%)	n.s.
Premature removal	16 (19.5%)	5 (38.5%)	n.s.	12 (26.7%)	9 (18.0%)	n.s.

	Procedure			Type of CVC		
	RTUS (*n* = 49)	VG (*n* = 46)	*P* value	Hickman (*n* = 38)	Broviac (*n* = 57)	*P* value
Any kind of mechanical complication	0 (0.0%)	3 (6.5%)	n.s.	2 (5.3%)	1 (1.8%)	n.s.
Delayed complication						
Bacteremia	12 (24.5%)	11 (23.9%)	n.s.	*14 (36.8%)*	9 (15.8%)	*P* = 0.006
Dislodgment a/o Accidental removal	11 (22.4%)	7 (15.2%)	n.s.	6 (15.8%)	12 (21.1%)	n.s.
Occlusion a/o Rapture of catheter	6 (12.2%)	3 (6.5%)	n.s.	3 (7.9%)	6 (10.5%)	n.s.
Any kind of delayed complications	25 (51.0%)	18 (39.1%)	n.s.	18 (47.4%)	25 (43.9%)	n.s.
Premature removal	14 (28.6%)	7 (16.1%)	n.s.	9 (23.7%)	12 (21.1%)	n.s.

	Days of indwelling		
	< 180 days (*n* = 40)	180 days ≤ (*n* = 55)	*P* value
Any kind of mechanical complication	1 (2.5%)	2 (3.6%)	n.s.
Delayed complication			
Bacteremia	12 (30.0%)	11 (20.0%)	n.s.
Dislodgment a/o Accidental removal	7 (17.5%)	11 (20.0%)	n.s.
Occlusion a/o Rapture of catheter	7 (17.5%)	2 (3.6%)	n.s.
Any kind of delayed complications	21 (52.5%)	22 (40.0%)	n.s.
Premature removal	14 (35.0%)	7 (12.7%)	n.s.

a/o, and/or; CD, surgical venous cut-down; CVC, central venous catheter; n.s., not significant; RTUS, real-time ultrasound-guided puncture; VG, venography-guided puncture; y, year(s).

syndrome (CIIPS), and so on, iii) patients with difficulty in for peripheral venous access. Line placement is more technically challenging in these younger patients whose tiny vessel lumina make it difficult to insert and/or maintain venous access. Preventing complications associated with CVC is extremely important especially for very young and fragile patients who typically require long-term CVC. So far, detailed data of complication profiles associated with CVC for pediatric patients are comparatively sparse.[3, 4] Therefore, in this study, we reviewed complication profiles including mechanical and delayed complications associated with CVC using differ-

ent approaches.

In this study, 159 pediatric patients who had undergone CVC were reviewed for CVC associated complications. We divided them into three groups according to the various procedures available (CD, VG, and RTUS). CD had been mainly selected in patients under one year old because of smaller vessel diameter. Through experience, we have learned that it is very challenging to puncture a subclavian vein less than 3mm in diameter. We sometimes failed to place the CVC in the VG, and there were also a few cases when we had to abandon inserting the CVC by RTUS in our initial trials, not because of any mechanical complication. In those cases, we reverted to the CD approach. (We regret we cannot compare the difference between our reattempts with those in the literature because they were not previously recorded.) Although we have no clear rule up to the present time, to be safe and sure, we are apt to select CD in infant cases as a result. In turn, the venipuncture approach (VG and RTUS) has been selected only for patients over the age of 1. VG was our original method before RTUS. RTUS is superior in its availability of real-time observation for needle insertion, in contrast to VG, in which we could only visually recognize the location of the subclavian vein under fluoroscopy and we could not recognize the depth of vein location under the skin. After introducing RTUS, there are no mechanical complications such as arterial puncture, pneumothorax and hemothorax compared to 6% for the VG approach. However, there is no significant difference between RTUS and VG because the number of cases in this study is too small for comparison between mechanical complications that rarely occur.

Although RTUS is probably superior in terms of avoiding mechanical complication, it has proved higher in frequent delayed complication than VG. Also, as for CVC dislodgment and premature removal, both were observed in the RTUS approach. We presume that the increase of those complications is influenced by age, not by choice of insertion technique. In fact, we have been able to choose venipuncture after the introduction of RTUS, while we can also show that the patients under 5 years old are at a significant risk factor for delayed complication and premature removal of catheter in this study. It is easy to imagine that infants and preschool children often try to escape medical treatment, act in unexpected ways, and do not keep still during procedures. We suspect that their repeated activity to avoid discomfort may be the very cause of those delayed complications. This finding was similar to the report by Cesaro et al., who concluded that one of the risk factors of premature CVC removal was age at CVC positioning, less than 6.1 years.[5] Regarding the frequency of bacteremia, it was comparable to the results of literature in the past.[3-5,7] Dual-lumen CVC, or Hickman catheter, is the risk factor for CVC-associated bacteremia in this study. Cesaro et al. also pointed out this one as one of the risk factors for bacteremia.[5] It should not depend on the structural difference between types of catheters. The Hickman catheter is generally used for patients who need high dose chemotherapy or stem cell transplantation and tend to be immunosuppressed. Venous thrombosis is also one of the most important delayed CVC complications, [6] but we took little notice of it since we could not obtain enough data from medical records concerning venous thrombosis.

Kaji et al. suggested that CD is a safer technique than LM or ultrasound-guided CVC insertion into the jugular vein, but it is an issue that CD may cause an exhaustion of accessible vessels.[7] From our experience, the RTUS procedure is safe enough as a CD according to our results, and RTUS may be less-invasive and useful for avoiding exhaustion of vessels. We suggest that RTUS should be selected more for very young patients. The only disadvantage of RTUS is that it may unsuitable for the majority of young infants, for now.

This study has several limitations. First, this is a retrospective one centered observation. Second, the indication for selection in insertion approaches has not been defined and has depended upon the operator's judgement. However, the detailed data on complications associated with CVC in pediatric patients has been sparse and the results may contribute to better counsel the patient's family and to consider the risk-to-benefit ratio of CVC insertion.

In conclusion, RTUS is superior to our conventional use of VG considering less frequent mechanical complications, to say nothing of the classical LM approach. RTUS can be applicable for younger patients and may contribute to the avoidance of CD, which may necessarily scar vessels in fragile patients. Delayed complications and premature removal should be carefully considered especially for patients under 5 years old.

The authors declare no conflict of interest.

REFERENCES

1 Friend J, Lindsey-Temple S, Gollow I, Whan E, Gera P. Review of the radiation exposure during screening of surgically implanted venous access devices. J Pediatr Surg. 2015; 50:1214-9. PMID: 25981990.

2 Arul GS, Lewis N, Bromley P, Bennett J. Ultrasound-guided percutaneous insertion of Hickman lines in children. Prospective study of 500 consecutive procedures. J Pediatr Surg.

2009;44:1371-6. PMID: 19573664.
3 Blum LV, Abdel-Rahman U, Klingebiel T, Fiegel H, Gfroerer S, Rolle U. Tunneled central venous catheters in children with malignant and chronic diseases: A comparison of open vs. percutaneous implantation. J Pediatr Surg. 2017;52:810-2. PMID: 28188038.
4 Ullman AJ, Marsh N, Mihala G, Cooke M, Rickard CM. Complications of Central Venous Access Devises: A Systematic Review. Pediatrics. 2015;136:e1331-44. PMID: 26459655.
5 Cesaro S, Cavaliere M, Pegoraro A, Gamba P, Zadra N, Tridello G. A comprehensive approach to the prevention of central venous catheter complications: results of 10-year prospective surveillance in pediatric hematology-oncology patients. Ann Hematol. 2016;95:817-25. PMID: 26961934.
6 Gonzalez-Hernandez J, Daoud Y, Styers J, Journeycake JM, Channabasappa N, Piper HG. Central venous thrombosis in children with intestinal failure on long-term parenteral nutrition. J Pediatr Surg. 2016;51:790-3. PMID: 26936289.
7 Kaji T, Kawano T, Yamada W, Yamada K, Onishi S, Nakame K, et al. The changing profile of safe techniques for the insertion of a central venous catheter in pediatric patients – improvement in the outcome with the experiences of 500 insertions in a single institution. J Pediatr Surg. 2016;51:2044-7. PMID: 27829522.