Chula Med J Vol. 57 No. 1 January-February 2013

Utility of real-time ultrasound-guided central venous catheterization in infant patients in interventional radiology at KCMH

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Kiatrungruangdee P, Pinjaroen N, Tantivattana J. Utility of real-time ultrasound-guided central venous catheterization in infant patients in interventional radiology at KCMH. Chula Med J 2013 Jan - Feb; 57(1): 1 - 12

Background : *Central venous catheterization (CVC) is an essential procedure in critical care of pediatric patients.Ultrasound-guided CVC shows higher success rate and lower complication rate than conventional anatomical landmark guidance, and has been routinely performed in Interventional Radiology unit, King Chulalongkorn Memorial Hospital (KCMH) for many years. Focusing on infant patient, we want to know the outcomes at our hospital.*

Objective : *To study the outcomes (success rate, complications and complication rate) of using real-time ultrasound-guided CVC in infant patients at KCMH.*

Design : *Retrospective study.*

Setting : *Department of Radiology, Faculty of Medicine, Chulalongkorn University.*

Methods : *We retrospectively reviewed medical records of 144 ultrasound-guided CVC in 90 infants, that have been performed at the Intervention Radiology Unit of KCMH between 2007 - 2010. We collected the patient demographics, operative data, success rate, complications and complication rate. Subgroup analysis was created according to their body weight, history of previous catheterization, and duration of catheterization.*

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Results : *Of the total 144 catheterizations, the overall success rate was 97.9%. Acute complication was found in 4 procedures (2.8%). Late complication was found in 85 procedures (60.3%) most of which mostly were infection (58 procedures, 41.1%). There was no procedure-related mortality in the study. Following the subgroup analysis, significant higher success rate were observed in the subgroup of infant >3,000 grams (100% versus 93% in infant ≤ 3,000 grams, P = 0.01). The subgroup analysis of the patients with history of previous catheterization showed more significant infectious complication (50.0% in previous catheterizationversus 28.8% in new case, P = 0.01). Another subgroup analysis showed higher infectious complication in the group of patients with retaining catheter >7 days but the result was not statistically significant (34.4% versus 43.1%, P = 0.38 in duration ≤ and > 7 days, respectively).*

Conclusion : *Real-time ultrasound-guided CVC in infants had a high success rate and low acute complications. However, catheter-related infection is the most common late complication, especially in infants with previous catheterization.*

Keywords : *Central venous catheterization, real-time ultrasound guided, infant, interventional radiology.*

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Received for publication. January 15, 2012.

ปิยะวรรณ เกียรติรุ่งเรืองดี, ณัชชา ปิ่นเจริญ, จาตุรนต์ ตันติวัตนะ. ประโยชน์ของการใช้คลื่นเสียงความถี่สูง เพื่อช่วยในการใส่สายสวนทางหลอดเลือดดำใหญ่ในผู้ป่วยทารก ที่หน่วยเอ็กซเรย์หลอดเลือด และรังสีร่วมรักษา รพ.จุฬาลงกรณ์. จุฬาลงกรณ์เวชสาร 2556 ม.ค. – ก.พ.;57(1): 1 – 12

เหตุผลของการทำวิจัย : *การใส่สายสวนทางหลอดเลือดดำใหญ่ เป็นหนึ่งในหัตถการที่จำเป็นในการดูแลรักษาผู้ป่วยทารกในภาวะวิกฤต การใช้คลื่นเสียงความถี่สูงนำทางเพื่อช่วยในการใส่สายสวนทางหลอดเลือดดำใหญ่นั้น พบว่ามีอัตราผลสำเร็จสูง และภาวะแทรกซ้อนต่ำกว่าการใส่สายสวนทางหลอดเลือดดำใหญ่ โดยการอาศัยจุดกำหนดทางกายวิภาคแบบเดิม ผู้วิจัยต้องการศึกษาประโยชน์ผล สำเร็จและภาวะแทรกซ้อนของเทคนิคดังกล่าว*

วัตถุประสงค์ : *เพื่อศึกษาผลลัพธ์ของการนำคลื่นเสียงความถี่สูงเพื่อช่วยนำทางในการใส่สายสวนทางหลอดเลือดดำใหญ่*

รูปแบบการวิจัย : *การศึกษาแบบย้อนหลังเชิงพรรณนา*

สถานที่ทำการศึกษา : *ภาควิชารังสีวิทยา คณะแพทยศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย*

วิธีการศึกษา : *ศึกษาจากหัตถการทั้งสิ้น 144 ครั้ง ในผู้ป่วยทารกจำนวน 90 ราย ที่เข้ารับการใส่สายสวนทางหลอดเลือดดำใหญ่ด้วยการใช้คลื่นเสียงความถี่สูงช่วยนำทางในหน่วยรังสีร่วมรักษา โรงพยาบาลจุฬาลงกรณ์ ตั้งแต่ปีพ.ศ. 2550 - 2553 โดยทำการศึกษาผลลัพธ์ ได้แก่ อัตราผลสำเร็จ และภาวะแทรกซ้อนจากเทคนิคดังกล่าว และทำการวิเคราะห์กลุ่มย่อยเมื่อจำแนกผู้ป่วยตามน้ำหนัก ประวัติการทำหัตถการ และระยะเวลาที่คาสายสวนในหลอดเลือดดำใหญ่*

ผลการศึกษา : *จากหัตถการทั้งสิ้นจำนวน 144 ครั้ง มีอัตราผลสำเร็จ 97.9% พบมีภาวะแทรกซ้อนระยะเฉียบพลันจำนวน 4 ครั้ง (2.8%) ภาวะแทรกซ้อนในภายหลังจำนวน 85 ครั้ง (60.3%) ซึ่งภาวะแทรกซ้อนในภายหลังที่พบมากที่สุดได้แก่ การติดเชื้อ ซึ่งพบทั้งสิ้น 58 ครั้ง จากการศึกษาไม่พบผู้ป่วยที่เสียชีวิตจากการทำหัตถการจากการวิเคราะห์กลุ่มย่อยเมื่อจำแนกตามน้ำหนักตัวพบว่าในกลุ่มผู้ป่วยทารกที่มีน้ำหนักตัวมากกว่า 3,000 กรัมมีอัตราผลสำเร็จสูงกว่าทารกที่มีน้ำหนักตัวน้อยกว่า 3,000 กรัมอย่างมีนัยสำคัญ (100% เปรียบเทียบกับ 93%,*

P = 0.01) เมื่อจำแนกตามประวัติการทำหัตถการพบว่าในกลุ่มผู้ป่วยที่มีประวัติการทำหัตถการมาก่อน มีภาวะแทรกซ้อนจากการติดเชื้อสูงกว่าอย่างมีนัยสำคัญ (50% เปรียบเทียบกับ 28.8%, P = 0.01) และเมื่อจำแนกตามระยะเวลาในการคาสายสวนหลอดเลือดดำใหญ่ พบว่าในกลุ่มผู้ป่วยที่คาสายสวนหลอดเลือดดำใหญ่มากกว่า 7 วัน มีภาวะแทรกซ้อนจากการติดเชื้อสูงกว่ากลุ่มผู้ป่วยที่คาสายสวนหลอดเลือดดำใหญ่น้อยกว่า 7 วัน แต่อย่างไรก็ตามยังไม่พบว่ามีนัยสำคัญทางสถิติ (43.1% เปรียบเทียบกับ 34.4%, P = 0.38)

สรุป : *การนำคลื่นเสียงความถี่สูงเพื่อช่วยนำทางในการใส่สายสวนทางหลอดเลือดดำใหญ่ในผู้ป่วยทารก เป็นหัตถการที่มีอัตราผลสำเร็จสูงและมีภาวะแทรกซ้อนในระยะเฉียบพลันต่ำ แต่อย่างไรก็ตามพบว่าการติดเชื้อเป็นภาวะแทรกซ้อนในภายหลังที่พบบ่อย โดยเฉพาะอย่างยิ่งในผู้ป่วยที่มีประวัติการทำหัตถการมาก่อน*

คำสำคัญ : *คลื่นเสียงความถี่สูง, การใส่สายสวนทางหลอดเลือดดำใหญ่, ผู้ป่วยทารก, รังสีร่วมรักษา.*

Central venous catheterization (CVC) is an essential procedure in critical care of pediatric patients such as blood transfusion, long-term antibiotic course, parenteral nutrition, hemodialysis, plasmapheresis, and chemotherapy. Peripheral venous access difficulty is another major indication in pediatric patients with very low weight or chronic illness. In general, central venous catheterization in neonates and infants is a challenging due to limited working field, smaller target vessel and less safety margin than adult, lack of patient co-operation and anatomical difficulty. By using conventional anatomical landmark guidance, the success rate in infants is much lower than in children and adults. On the other hand, the complication rate is also much higher.[1-3] The ultrasound-guided CVC has been proved that it is more precise in targeting the vein, resulting in higher procedural success rate and lower the complication rate as compared to the conventional anatomical guidance technique.[4-8]

Nowadays, the ultrasound-guided technique for central venous catheterization in pediatric patients is widely accepted in many centers. At King Chulalongkorn Memorial Hospital (KCMH), real-time ultrasound guided approach has been routinely performed for central venous catheterization in Interventional Radiology unit for many years.

This study is designed to evaluate the outcome of real-time ultrasound-guided central venous catheterization in neonates and infants at the interventional radiology unit of KCMH, in terms of success rate and complication rate including early and late complications.

Materials and Methods

Following the approval of the institutional review board, retrospectively reviewed all the medical records of 145 central venous catheterization procedures in 91 patients under 1 year of age that have been performed at the intervention radiology unit of KCMH from Jan 2007 to Dec 2010. One patient was excluded from the study due to incomplete medical data. The collected data included patient demographics, diagnosis, indicationfor CVC, site of catheterization, success rate, operative outcome, and complications. Subgroups were created according to the body weight (under 3,000 grams and over 3,000 grams), history of previous cannulation, and duration of retaining catheter (less and more than 7 days).

KCMH protocol for Central venous catheterization

Preoperative preparation

1. Communicating with pediatrician about child's condition and therapeutic need, indication and expected duration of catheterization
2. Checking coagulation
   - o Platelet > 50000/cm^3
   - o INR < 1.4
3. NPO for 4 - 6 hours
4. Matching / grouping of blood products for correcting thrombocytopenia and coagulopathy as needed
5. Consulting anesthesiologist in selected case
6. Preparing nursing care and monitoring team

Instruments

1. An ultrasound machine with high frequency, linear probe
2. A fluoroscopy
3. A full sterile set

4. A needle, guide-wire and dilator
5. A central venous catheter, the size and length of which match with the patient's weight and indication

Operation

Before starting the operation, an accessible vein was evaluated using Philips iU22 xMATRIX ultrasound system; probe L15-7io (7 - 15 MHz frequency). Right internal jugular vein was a first selection. Subclavian vein was used in case that both internal jugular veins were exhausted. Catheter selection was based upon indication and purposes.

A sterile draping is prepared. We used 2% chlorhexidine solution for skin antiseptic preparation. Local anesthesia was performed by infiltration of 1% Lidocaine (calculated dose based on patient's weight) at the puncture site with or without general anesthesia. The cannulation site was re-evaluatedby real-time ultrasound before starting the procedure. Under real-time ultrasound guidance, 22-gauge sheathed needle was navigated into the target vein. Then, 0.018" guide-wire was cannulated into the IVC under fluoroscopic guidance.Skin tract was dilated up to the desired catheter size. Indwelling catheterwas then installed over the guide wire. The catheter position was confirmed under fluoroscopy, with its tip in the SVC or the right atrium. The catheter was flushed with heparinized NSS. Additionally, a single-spot film was taken for record.

Finishing the operation, the operative record was filled in two copies: one for OPD-card and theother for admission record.Together with this, an online report in RIS/HIS was done.

Sample size and Statistical analysis

We estimated that the assignments of at least 73 procedures are needed to provide an 80% power at a 5% significant level. The data were analyzed on an intention-to-treat principle and comparison using Chi-square test for categorical variables and t-tests for continuous variables. The descriptive data are expressed as mean and SD. Kaplan-Meier estimates of the times to infection complication were created using the log-rank test. Statistical significance was defined whenP value was less than 0.05.

Results

One hundred and forty-four catheterizations in 90 patients were enrolled in this study. The baseline characteristics of the study groups are shown in Table 1. The patients ranged in age from 4 to 360 days, with mean age of 124.6 days. Their weight ranged from 475 to 8,800 grams, with mean weight of 4,177.7 grams. The most common indication for central venous catheterization in this study was for total parenteral nutrition, 47.2%.

Ultrasound-guided CVC was success in 141 procedures (overall success rate of 97.9%). The catheterization failed in three procedures: one from carotid artery puncture and two from vessel injury related with venous thrombosis. In the case of punctured carotid artery, the patient had active bleeding with hypovolemic shock and was then sent to the operating room for repair of the common carotid artery. Other operative data are shown in Table 2.

In this study, acute complication was found in 4 procedures: one from carotid artery injury as described, and three others were from bleeding complications. All three acute bleeding complications were only minor bleeding or hematoma around the puncture sites which improved after conservative

treatment. There was no procedure-related mortality in this study (Table 3).

The duration of retaining the central venous catheter ranged from 1 to 36 days, with mean of 13.5 days. Late complications were found in 85 procedures (60.3%), most of them were from catheter-related infection (58 from 141 procedures, 41.1%), followed by displacement (20 procedures, 14.2%) and pull-out (2 procedures, 1.4%). Thirty-nine procedures (27.5%) successfully retained the CVC untilthe end of treatment. Regarding the subgroup analysis of the body weight of equal or less than 3,000 grams and higher (Table 4), significant difference in success rate was observed (93% success in infant d" 3,000 grams and 100% in infant >3,000 grams; P = 0.01). No significant difference in overall complications and mortality rates between subgroups.

Table 1. Patient information data.

Variable	Data
No. of patient	90
Total no. of procedure	144
Age (day)	124.6 ± 96.9
Gender (male : female)	80 : 64
Body weight (g)	4177.7 ± 1968.6
0-3,000 g (n, %)	47 (32.64 %)
>3,000 g (n, %)	97 (67.36 %)
Preterm (n, %)	55 (38.2 %)
Indication for central line insertion (n, %)	
Chemotherapy	12 (8.3 %)
Antibiotics	43 (29.9 %)
Peripheral access difficulty	18 (12.5 %)
Hemodynamic monitoring	1 (0.69 %)
Hemodialysis	1 (0.69 %)
Total parenteral nutrition	68 (47.2 %)
Frequent blood sampling	1 (0.69 %)
Patient with previous cannulation (n, %)	78 (54.2 %)
Platelet counts (platelet/cm^3)	
< 50,000 platelet/cm^3	10 (6.9%)
≥ 50,000 platelet/cm^3	134 (93.1%)
INR	
< 1.5	127 (88.2%)
≥ 1.5	15 (10.4%)
Patient receive blood component before operation (n, %)	25 (17.4 %)

Table 2. Operative data.

Variable	Data
Anesthesia	
Local	127 (88.2%)
General	17 (11.8%)
Type of central venous catheter (n, %)	
Single lumen	3 (2.1 %)
Double lumen	139 (97.9 %)
PICC	1 (0.7 %)
Size of catheter (Fr)	
4 Fr	138 (95.8%)
5 Fr	4 (2.8%)
Site of cannulation (n, %)	
RIJ	96 (67.6 %)
LIJ	33 (23.2 %)
RSC	4 (2.8 %)
LSC	8 (5.6 %)
Collateral v.	1 (0.7 %)
No. of procedure with GA (n, %)	17 (11.8 %)
Success	141 (97.9 %)

Table 3. Postoperative outcome.

Variable	Data
Duration of retained catheter (days)	13.5 ± 7.7
Acute complications (n)	4 (2.8 %)
Bleeding	3 (2.1 %)
Others (tear common carotid a.)	1 (0.7 %)
Late complications (n)	85 (60.3 %)
Displacement	20 (14.2 %)
Pull out	2 (1.4 %)
Leakage	1 (0.7 %)
Blockage	2 (1.4 %)
Catheter-related infection	58 (41.1 %)
Central v. thrombosis/stenosis	2 (1.4 %)
End of treatment	39 (27.5%)

Table 4. Comparisons of operative results between subgroups based on weight.

	BW 0-3,000 g	BW >3,000 g	P Value
No. of patient	47	97	
Gender (male : female)	24 : 23	56 : 41	0.45
Previous catheter placement (n, %)	26 (55.3%)	52 (53.6%)	0.85
Operative times (min)	43.1 ± 22.4	33.2 ± 8.9	0.14
Success	44 (93%)	97 (100%)	0.01*
Complications			
Acute complications	1 (2.2%)	3 (3.0%)	0.78
Late complications	24 (51.1%)	61 (62.9%)	0.18
End of treatment	12 (25.5%)	27 (27.8%)	0.94

Regarding the subgroup analysis of the patients with and without history of previous catheterization (Table 5), no significant difference in success rates or acute complications was observed. Whereas, the patients with history of previous catheterization, there were more significant late complications (66.7% complication rate in previous catheterization group and 50% in new cases; P = 0.043). The subgroup analysis of late complications in patients with history of previous catheterization showed significant difference only in infectious complication (50.0% in previous cannulation group versus 28.8% in the new case; P = 0.011)

Table 5. Comparisons of operative results between groups.

	Patient with previous		
	New case	Catheter	P Value
No. of patient	66	78	
Gender (male: female)	44:22 (66.7%)	36:42 (46.2%)	0.014*
Age (days)	99.12 ± 88.4	146.19 ± 99.1	0.003*
Success	65 (98.5%)	76 (97.4%)	0.66
Complications			
Acute	2 (3.0%)	2 (2.6%)	0.86
Late	33 (50%)	52 (66.7%)	0.043*
Displacement	11 (16.7%)	9(11.5%)	0.47
Pullout	2(3.0%)	0	0.21
Leakage	0	1 (1.3%)	1.00
Blockage	1 (1.5%)	1 (1.3%)	1.00
Catheter-related infection	19(28.8%)	39(50%)	0.011*
Central v. thrombosis	0	2(2.6%)	0.50

Kaplan-Meier estimates for the risk of catheter-related infection according to the duration of catheterization showed increasing in infection rate by the duration of retained catheter (as high as 80% over 30 days), but no significant difference between new cases and the patients with history of previous catheterization (P = 0.95) (Figure 1).

Another subgroup analysis was done between patient that retained catheter d" and > 7 days (Table 6). Group of patients that retained catheter more than 7 days has more infectious complication but the result was not statistically significant (34.4% versus43.1%; P = 0.38 in duration d" and > 7 days, respectively.

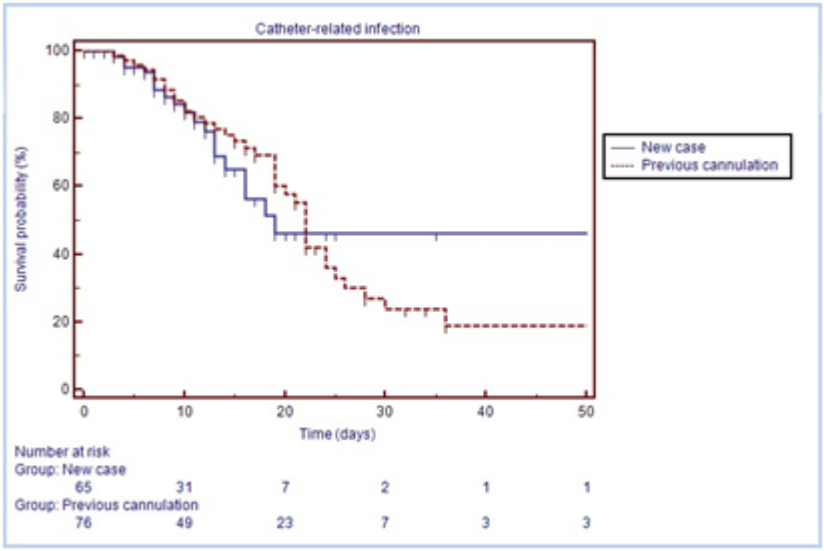

Figure 1. Kaplan-Meier plot of catheter-related infection survival. The horizontal axis represents the time since initiation of catheterization.

Table 6. Comparisons of operative results between subgroups based on duration of retaining catheter.

	≤ 7 days	> 7 days	P Value
No. of patient	32	109	
Gender (male : female)	20 : 12	60 : 49	0.54
Age (days)	133.15 ± 102.8	122.12 ± 95.5	0.57
Catheter-related infection	11 (34.4%)	47 (43.1%)	0.38

* There were missing data in 2 patients.

Discussion

Central venous catheterization (CVC) in neonates and infants is challenging due to anatomical difficulty in these patients. In addition, using conventional anatomical landmark guidance is associated with numbers of potential complications. The success rate in infant is much lower than in children and adults. The major advantage with the real-time ultrasound-guidance is the ability to visualize the structures at the puncture site before cannulation is attempted.

In the meta-analysis by Daniel Hind *et al*.[1]they found that compared with the anatomical landmark technique, real-time ultrasound guidance for cannulating the internal jugular vein in adults was associated with a significantly lower failure rate both overall (RR = 0.14; 95% CI 0.06 to 0.33) and on the first attempt (RR = 0.59, 95% CI 0.39 to 0.88) and three studies in infants confirmed a higher success rate for internal jugular procedures (RR = 0.15, 95% CI 0.03 to 0.64). Hokosawa *et al*.[6] reported a similar results that real-time ultrasound-guided approach showed faster procedure of time and fewer attempts of puncture than only skin surface marking method. Fewer than 3 attempts were made in 100% of patients with the real-time ultrasound guidance, *versus* 74% of patients in another group.

In King Chulalongkorn Memorial Hospital (KCMH), real-time ultrasound guided approach has been routinely performed for central venous catheterization in interventional radiology unit for many years. In this retrospective study of 144 catheterizations in neonates and infants, we found 97.9% success rate with ultrasound-guided in central venous catheterization. The incidence of acute complication was very low and there was no any procedural-related mortality, representing safety and effectiveness of this method.

Our study showed 60.3% of late complication mostly from catheter-related infection (41.1%). Our incidence of catheter-related infection was 26.7 per 1,000 catheter days, which was higher than previous study.[9] This result may be due to medical recording problems. Someof the diagnoses may be over diagnosed by clinicians and referred to only clinical data without microbiological data support.

In subgroup analysis, we found that infection rate is statistically higher in a group of patients with previous history catheterization (50.0% in previous catheterization group versus 28.8% in the new case, $P = 0.01$). In addition, we found that the infection rate was strongly related with the duration of catheterization (as high as 80% over 30 days). Although, a group of patients with duration of catheterizationmore than 7 days tends to have more infectious complication (34.4% *versus* 43.1%, $P = 0.38$ in duration of catheterization $\leq$ and $>$ 7 days, respectively), but the result was not statistically significant. These results were influenced by many factorsnot only aseptic techniques, but also underlying disease of the patient, pre-cannulated bacteremia, and nursing care.

We sub-grouped the patients based on their body weight, and found statistically significant difference in the success rates between the groups of body weight equal or less than 3,000 grams and more than 3,000 grams (93% and 100%, respectively). This result reasonably reflected more difficult anatomy in smaller patients.

Conclusions

The real-time ultrasound-guided central venous catheterization technique in infants had a high success rate and very low complications. However, the catheter-related infection is the most common late complication, especially in infants with previous history of catheterization.

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