

Ultrasound-guided percutaneous central venous catheterization in infants: Learning curve and related complications

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Abstract

Background: This study was performed to evaluate the learning curve and related complications of ultrasound (US) guided central venous catheter (CVC) insertion in infants.

Materials and Methods: This study was performed in Imam Hosein Hospital of Isfahan from September 2014 to March 2015. Participants were infants consecutively candidate for CVC insertion. Three steps were designed to complement the learning. For each step of learning, 20 patients were considered and for every patient one CVC was inserted: (1) In the first step, venous puncture and guide wire passage was performed by an experienced radiologist and the surgeon was taught how to do it, then CVC was placed by the surgeon. (2) In the second step, venous puncture and guide-wire passage was performed by the surgeon under the supervision of the same radiologist, and then CVC was placed by the surgeon. (3) In the third step, US-guided CVC insertion was performed by the surgeon completely, and the radiologist came to the operating room only if it was necessary. In each of these steps, the time spent of the US probe on the skin until the guide wire passage into the vein was recorded for every patient. All perioperative complications were recorded.

Results: The mean point for the time spent of the US probe on the skin until the guide wire passage into the vein was 84.9 ± 13.6 , 119.1 ± 15.2 , and 90.3 ± 11.2 s in the step 1, 2 and 3, respectively ($P = 0.04$). There was no significant difference between the frequencies of complications among three steps.

Conclusion: US-guided percutaneous CVC insertion is a safe and reliable method which can be easily and rapidly learned.

Key Words: Learning curve, perioperative complications, ultrasound-guided central venous catheter insertion

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INTRODUCTION

Central venous catheter (CVC) placement is a reliable vascular access and is necessary for anticancer chemotherapy or bone marrow transplantation.^[1] Also,

these catheters are indicated for the administration of intravenous medication treatments, fluids, or total parenteral nutrition and repeated blood sampling.^[2] More than 5 million CVCs are placed each year in the

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United States.^[3] CVC placement in the young children is more difficult than the adult patient because the vessel dimensions are smaller, and routes of the subclavian and internal jugular veins (IJVs) are sharper and more angulated in infants.^[4] Common methods for CVC placement include the traditional open surgical venous cut-down (OSC) procedures and percutaneous procedures. OSC can be either onto a peripheral tributary such as the cephalic, facial, or external jugular vein, or directly into the IJV.^[5-7] In OSC approach, the vein is dissected and controlled via small skin incision and an appropriate size catheter is tunneled from a separate stab wound into the previous incision and inserted under direct vision via a venotomy that is, then repaired with a fine nonabsorbable suture or ligated.^[6] The risk of thrombosis and the difficulty of reoperation will be increased after OSC because of the traumatization of the vein due to dissection and repair of the venotomy.^[8,9]

In the percutaneous procedures, Seldinger wire technique is used. The desired vessel is punctured with a sharp hollow needle. A round-tipped guide wire is then advanced through it, and the needle is withdrawn. The track is then dilated, and a cannula is passed over the guide wire into the vessel and the guide-wire is withdrawn.^[10] Traditionally anatomical landmarks on the skin surface were used for localization of the vein but it was a blind procedure and several complications included hemothorax (accumulation of blood in the space between the lung and the chest wall), pneumothorax (the presence of air in the pleural space), failure to cannulate the vein, pericardial tamponade (collection of blood in the pericardial sac), arterial puncture (insertion of the needle into the artery instead of the vein), and even death have been described.^[9,11,12] Alderson *et al.* reported that among children undergoing cardiac surgery 18% had abnormal jugular venous anatomy.^[13] The use of ultrasound (US) for percutaneous central venous cannulation results in fewer needles passes to cannulate the vein and decreased complication rate and increased success rate compared with the landmark technique.^[14-19] The UK's National Institute of Clinical Excellence has recommended that the preferred method for CVC insertion into the IJV is two-dimensional imaging US guidance in elective situations and also should be considered in most clinical circumstances either electively or in an emergency situation.^[20] Shifting to US-guided percutaneous CVC insertion from OSC involves a learning curve, which is probably associated with higher complication rates.

This study focused on learning curve and related complications experimenting US-guided percutaneous

technique in infants as a novel technique at our hospital (Imam Hosein Children Hospital located in Isfahan, Iran).

MATERIALS AND METHODS

This descriptive study was performed in the pediatric surgery ward of Imam Hosein Hospital in Isfahan from September 2014 to March 2015 to evaluate the learning curve and related complications of US-guided CVC. Approval for the study was obtained from the university and hospital Ethics Committees. Written consent was obtained from the parents after discussion of study propose for them.

Participants were infants consecutively candidate for CVC insertion. Patients with established coagulopathy (international normalized ratio > 1.5) or platelet count below 100,000/mm³ and patients with body weight <2 kg were excluded.

Three steps were designed to complement the learning. According to previous studies, after a theoretical course, placement of eight CVCs under the supervision of a person conversant with US-guided CVC insertion is sufficient for training.^[21,22] Therefore, in this study to ensure adequate training for each step of learning, 20 patients were considered.

In the first step, venous puncture and guide wire passage was performed by an experienced radiologist and the surgeon was taught how to do it, and then CVC was placed by the surgeon.

In the second step, venous puncture and guide wire passage was performed by the surgeon under the supervision of the same radiologist, and then CVC was placed by the surgeon.

In the third step, US-guided CVC insertion was performed by the surgeon completely, and the radiologist came to the operating room only if it was necessary.

Demographic data, type of disease (infectious, cardiologic, hematological, metabolic, gastroenterological, neurological and others), and the site of insertion of the catheter was recorded for every patient. In each of the steps, the time spent of the US probe on the skin, until the guide wire passage into the vein was recorded. All intraoperative and postoperative complications such as failure to cannulate the vein, arterial puncture, hemothorax, pneumothorax, hematoma, and death were recorded up to 48 h after operation.

To analyze the data, we use SPSS 20 software (SPSS Inc, Chicago, IL). Required tests were Chi-square,

one-way ANOVA and *post-hoc*. Quantitative variables were shown as a mean \pm standard deviation and quantitative ones as percent. $P < 0.05$ was considered as significant.

Intervention

All patients underwent IJV cannulation. For this purpose under the sterile field, a shoulder roll was placed to hyper extend the neck and the patient was placed in trendelenburg position with the head turned slightly away from the insertion site. The vein was located under the guide of US. The 2100 Honda US machine made in Japan and a linear 5–7.5 MHz probe was used [Figure 1]. By keeping the probe gently on the IJV the needle was advanced into the vein. After aspiration of venous blood, the guide wire was introduced, and the catheter was placed using standard Seldinger technique by a 16 G. Arrow catheter, and its proper position was established by C-arm. The catheter was anchored using nylon 3-0 suture placed on the skin at the exit site. Chest X-ray was done to rule out intraoperative complications.

RESULTS

In each step, 20 CVCs were inserted for 20 patients. The mean age of the patients was 50.7 ± 9.1 , 53.6 ± 11 and 39.5 ± 8.2 days in step 1, 2 and 3 respectively ($P =$ not significant [NS]). The mean weight of the patients was 4225 ± 251 , 4250 ± 288 and 4260 ± 262 g in step 1, 2, and 3, respectively ($P =$ NS). Male to female ratio was 1.2, 1.1, and 0.8 in step 1, 2, and 3, respectively. The causes of hospitalization among patients were shown in Table 1.

The mean point of time spent of the US probe on the skin until the guide-wire passage into the vein was 84.9 ± 13.6 , 119.1 ± 15.2 , 90.3 ± 11.2 s in the step 1, 2, and 3, respectively [Figure 2].

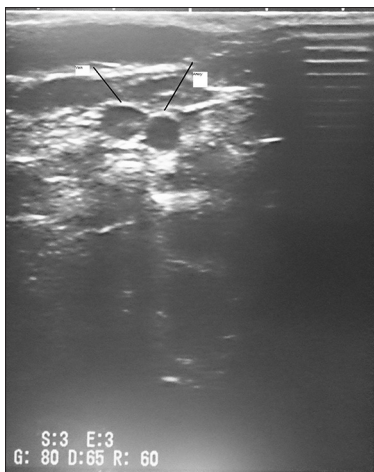


Figure 1: Ultrasonic view of neck vessels

The mean of time spent of the US probe on the skin until the guide wire passage into the vein was not similar in three steps ($P = 0.04$). *Post-hoc* LSD showed the mean time was similar between step 1, step 3 ($P = 0.39$), but was significantly more in step 2 than step 1 ($P = 0.03$) and step 3 ($P = 0.045$). Complications were listed in Table 2. The Chi-square test showed that there was no significant difference between the frequencies of complications among three steps.

DISCUSSION

Central venous lines insertion is one of the most common procedures in a major tertiary-level pediatric hospital, often involving the dedicated surgical team. As far as our surgical group is involved, the OSC has been the technique of choice, especially in very young babies requiring central venous cannulation. We have recently introduced and experienced the use of US guidance and progressively shifted the preferred approach to the percutaneous technique.

In our patients, by using The US, the perioperative complication rate of 3% was similar to that of 3% reported by Basford *et al.*^[23] in their small series of 18 pediatric patients undergoing Hickman lines insertion using a similar method. The overall complication rate in US-guided CVC insertion in pediatric age ranges

Table 1: Classification of patients based on the cause of hospitalization

Type of disease	Step 1 (n)	Step 2 (n)	Step 3 (n)	Total n (%)
Infectious disease	4	3	2	9 (15)
Cardiovascular disease	3	5	2	10 (17)
Hematologic disease	1	1	1	3 (5)
Metabolic disease	2	4	3	9 (15)
Gastroenterological disease	4	1	6	11 (18)
Neurological disease	1	3	4	8 (13)
Other disease	5	3	2	10 (17)
Sum	20	20	20	60

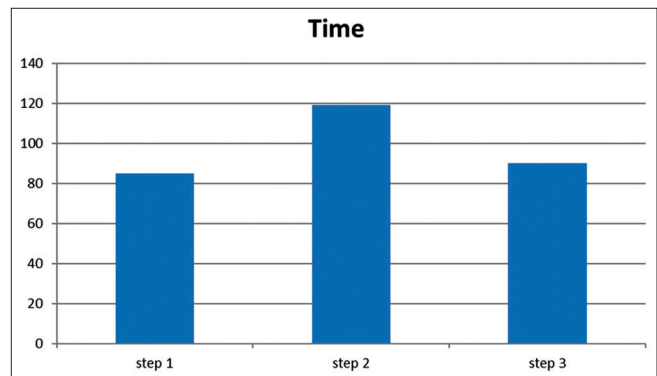


Figure 2: The mean of time (s) spent of the ultrasound probe on the skin until the guide wire passage into the vein

Table 2: Perioperative complications related to US guided CVC insertion

Complications	Step 1 n (%)	Step 2 n (%)	Step 3 n (%)	P
Failure to cannulate the vein	0	0	0	1
Arterial puncture	1 (5)	1 (5)	0	0.44
Hemothorax	0	0	0	1
Pneumothorax	0	0	0	1
Hematoma	0	0	0	1
Death	0	0	0	1
Arrhythmia	2 (10)	1 (5)	2 (10)	0.79

CVC: Central venous catheter, US: Ultrasound

between 2.4% and 4.6% according to the international literature.^[17,18] This suggests that visualization of the central vein at the time of insertion of the venous catheter using the US is important in reducing the rate of failure and complications relating to damage to adjacent structures.

Failure to cannulate the vein is a known complication of CVC insertion without US guidance.^[24] No failure occurred in our series. This finding is similar to Arul *et al.* study^[9] in which only one failure of vein cannulation was reported in early stages but is in contrast of Grebenik *et al.*^[25] study in which they found that their success rates were significantly greater in the landmark group (89.3% vs. 78%).

An arterial puncture rate in our series is higher in first two steps than a third step but is similar to literature values. However, Grebenik *et al.*^[25] found that their arterial puncture rates were significantly lower (6.2% vs. 11.9%) using landmark technique. It seems that the learning curve of each surgeon involved may have deeply influenced the arterial puncture complication rate. As the study period proceeded, there have been an increasing number of percutaneous procedures along with a decrease in arterial puncture rate, in the last study period. We may hypothesize that the learning curve of the involved surgeons has been progressively improving during the study, leading to a more reduction of this complication as compared to international standards.

In our experience, the time added to the CVC insertion process by US use was fairly short, as also reported by Froehlich *et al.*^[26] Although in step 2, the senior resident had no experience of US-guided CVC placement, but total time decreased rapidly after a few procedures, to finally reach a mean of 90 s in step 3, similar to that reported in a study by Nguyen *et al.* study.^[21] The main area in which time was saved with experience was between the first skin puncture and aspiration of venous blood into the syringe. Slama *et al.*^[22] considered the technique

as being acquired when this time was <3 min. In our experience, this time can be reduced to <2 min after repeated experiences.

Our study revealed that the transient arrhythmia (nonsustained ventricular tachycardia due to the guide-wire being advanced into the right ventricle) happened in all steps of study at the rate of 5–10%. These findings are similar to results of Dodge *et al.*'s study.^[15] It seems this complication is due to failure of correct percutaneous, or ultrasonic land marking of the tip of the catheter and this experience should be developed in future experiences of ultrasonic guided catheter placement.

One of the limitations of this method is that the US machine is not always in the operating room and sometimes takes a long time to get it out of the radiology department.

CONCLUSION

Standard Seldinger approach combined with US-guided needle insertion have made CVC insertion in children of all ages a safe and reliable method in our hands. Our results demonstrate that CVC placement under US guidance is a simple and safe procedure that can be easily and rapidly learned.

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Conflicts of interest

There are no conflicts of interest.

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