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Clinical feasibility and effectiveness of bedside peripherally inserted central catheter using portable digital radiography for patients in an intensive care unit

A single-center experience

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Abstract

The aim of this study was to evaluate the clinical feasibility and effectiveness of bedside peripherally inserted central catheter (PICC) using portable digital radiography (DR) in intensive care unit (ICU) patients.

Sixty-five ICU patients who underwent PICC were enrolled in this study between May 2016 and May 2017. Of these 65 patients, 45 (69.2%) underwent the procedures bedside in ICU using portable DR, and 20 (30.8%) underwent the procedures at the intervention clinic, both performed by a single interventional radiologist. We retrospectively reviewed electronic medical records for clinical presentation, total procedural time, total radiation dose, total patient transfer time, and clinical outcomes. We performed an independent *t* test to compare the clinical effectiveness between the 2 groups.

The technical and clinical success rates were 100% in both groups, and there were no procedure-related complications. The total radiation dose of bedside PICC at ICU was significantly lower than that of conventional PICC at the intervention clinic (557.9 mGy*cm^2 ± 209.2 vs 985.2 mGy*cm^2 ± 547.6, $P<.001$). The total procedure time was significantly different between the bedside and conventional PICC groups (26.8 minutes ± 3.9 vs 24.1 minutes ± 5.55, $P=.028$). The average patient transfer time to the intervention clinic was 26.6 minutes ± 9.8.

Bedside PICC using portable DR is a safe and effective procedure option to manage ICU patients in daily clinical practice.

Abbreviations: DR = digital radiography, ICU = intensive care unit, PICC = peripherally inserted central catheter, US = ultrasonography.

Keywords: bedside procedure, intensive care unit, peripherally inserted central catheter, portable digital radiography

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1. Introduction

Peripherally inserted central catheters (PICCs) are used in clinical practice for reliable intermediate and long-term venous access, and they are a safe and convenient way to administer various medications such as antibiotics and parenteral nutrition.[1,2] PICC has advantages over the traditional venous accesses: lower rates of complications such as pneumothorax, hemothorax, catheter-related infection, and the elimination of unnecessary discomfort caused by the regular exchange of peripheral intravenous lines.[3,4]

ICU patients are particularly required to maintain stable and long-term venous access pathways, such as PICC, to be used by multiple clinical staff members for a variety of uses including intravenous fluids, antibiotics, and total parenteral nutrition. However, it is difficult to transfer ICU patients to intervention clinics to perform PICC because of the difficulties in transporting various life-support devices. In previous studies, blind ultrasonography (US)-guided bedside PICC has not shown favorable results because of catheter tip malposition and procedure-related complications.[5,6] To date, there have been few studies on optimal established placement techniques of PICC for critically ill patients.

For this study, we decided to use a portable digital radiography (DR) system during the procedure to achieve successful PICC in

ICU patients. With technical advances, recent portable DR systems can generate lower radiation doses and provide images by real-time acquisition and postprocessing.[7–9] We hypothesized that portable DR-guided PICC could be helpful in reducing catheter tip malposition by ensuring the adequate location of the guide wire tip during the procedure. The purpose of this study is to investigate the clinical efficacy of bedside PICC using a portable DR system in ICU patients.

2. Methods

2.1. Patients

We retrospectively reviewed the electronic medical records of 65 ICU patients who underwent PICC insertion from May 2016 to May 2017 in our institution. The patient group comprised 35 males (53.8%) and 30 females (46.2%) of mean age ± standard deviation (SD) of 69.8 ± 13.2 years with a range of 35 to 92 years. Of these patients, 45 underwent bedside PICC using portable DR in the ICU because of their complex and unstable clinical situations, with ventilator care or extracorporeal membrane oxygenation (ECMO) treatment. The other 20 patients were transferred to the intervention clinic and underwent fluoroscopy-guided PICC. We reviewed the electronic medical records available for each patient for clinical presentation, transfer time, procedure time, and exposed radiation dose. The institutional review boards approved this study, and informed consent was waived owing to the retrospective nature of the study.

2.2. Technical details of PICC placement

All procedures were performed by one interventional radiologist with 4 years of experience in PICC placement. Fluoroscopy-guided PICC was performed in the intervention clinic using a low-dose X-ray system (Allura Clarity, Philips Healthcare, The Netherlands) and US guidance (EPIQ, Philips) with a 5- to 18-MHz linear-array transducer. Bedside PICC was performed using portable DR (DRX-Revolution, Carestream Health, NY) and US guidance (EPIQ, Philips) with a 5- to 12-MHz linear-array transducer. Turbo-Ject Power-Injectable PICC (Cook, Bloomington, IN) and Power Injectable Pro-PICC (Medcomp, Harleysville, PA) devices, of 5-F dual lumen or 6-F triple lumen, were used for all patients.

2.2.1. Fluoroscopy-guided PICC. Although the choice of the puncture side and site was at the operator's discretion, in our routine practice, the selection was initially based on vein diameter; the preferred side was the right arm, but if the vessel was too small to puncture or not observable on ultrasound, we performed PICC in the left arm. The puncture site was 6 to 10 cm above the antecubital fossa through the basilic or brachial vein. We punctured the target vein with a microneedle (21 gauge) under B-mode duplex US. Then, we inserted a micro-guide wire (0.018 inches). The guide wire course and position were controlled by fluoroscopy, and to estimate catheter length for optimal tip position, the guide wire was placed either more than or <1 cm into the cavoatrial junction (CAJ). We used the exposed centimeter of the guide wire at the skin site to set the length of the catheter and prepared the measured catheter length using sterile scissors. The standard peel-away introducer was also inserted into the vein. After the inner sheath was removed, we advanced the catheter through the guide wire. When the desired advancement was achieved, the sheath was removed by splitting and peeled away. We immediately checked the final catheter tip using fluoroscopy. The puncture site was dressed using a catheter stabilization device.

2.2.2. Bedside PICC using portable DR. To use the portable DR, before surgical draping we put the detector under the patient's body at chest level; we always used a disposable surgical drape for this procedure (Fig. 1). We then followed the same protocol as that for the fluoroscopy-guided PICC. When the guide wire was inserted, we routinely advanced the wire 40 cm along and then took portable chest X-ray. We checked the guide wire tip and calculated the distance between the tip and the CAJ; we also prepared the catheter at the calculated length. Finally, the catheter tip position was established using one more portable chest X-rays (Fig. 2).

While inserting the PICC, we rotated the patient's head toward the insertion site and tilted the chin to the chest to minimize tip malposition.[10–12] However, if the guide wire tip was located in the jugular vein or the tip of the wire was not visible in chest X-ray, the guide wire tip was altered and an ultrasound control of the jugular vein was performed to check the guide wire in the SVC direction. Immediately following successful placement, we obtained another chest X-ray.

2.3. Endpoints

The primary endpoint of this study was the clinical success rate, which was defined by the absence of procedure-related complications such as infection until either the 14th day or the date of death, whichever came first. We also measured technical success depending on the adaptive position of the catheter tip on immediate portable chest PA as the secondary endpoint.

2.4. Statistical analysis

We tested the data for normal distributions using a Kolmogorov–Smirnov test; we compared normally distributed variables using an independent t test and expressed them as mean ± SD. We performed group comparisons of categorical variables using the χ^2 test or, for small cell values, Fisher's exact test. We performed all statistical analyses using the IBM SPSS 24.0 software package (SPSS, Armonk, NY), with $P<.05$ considered to indicate a statistically significant difference.

3. Results

The clinical and procedural details including the demographics, underlying diseases, indications, transfer time, procedure time, and radiation doses used for all patients are summarized in Table 1. There were no significant differences between the 2 groups in terms of demographics, underlying disease, or indication for catheter placement. Technical and clinical success rates of 100% were achieved in both groups. There were no procedure-related complications, such as PICC-associated bloodstream infections, in either group.

The radiation dose was significantly lower in patients with bedside PICC than in patients with fluoroscopy-guided PICC: 557.9 ± 209.2 mGycm^2 versus 985.2 ± 547.6 mGycm^2 ($P<.001$). However, bedside PICC also required significantly longer procedure time than fluoroscopy-guided PICC: 26.8 ± 3.9 minutes versus 24.1 ± 5.6 minutes ($P=.028$) (Table 1). The average patient transfer time to the intervention clinic was 26.6 ± 9.8 minutes for fluoroscopy-guided PICC.

Figure 1. Preparing the bedside peripherally inserted central catheter in the intensive care unit using portable digital radiography.

4. Discussion

The PICC method, first introduced in 1975, was designed to resolve the complications of long-term central venous plastic catheters in peripheral vessels.[13] In comparison with conventional central venous catheter, PICC has a low incidence of complications such as pneumothorax, hemothorax, and infection. PICC is also advantageous because it does not require changing every 2 to 3 days, as does the peripheral venous catheter.[3,4] For these reasons, PICC has emerged as a viable alternative to traditional venous access and has seen increased usage. PICC is particularly necessary for ICU patients because they are hospitalized for long periods and need to receive many therapeutic drugs intravenously.[14,15]

However, there are many difficulties in transporting ICU patients to intervention clinics to perform PICC because they have various life support devices at their bedsides such as ventilators and extracorporeal membrane oxygenation. In addition, transferring ICU patients brings potential risks such as lack of oxygen, disconnecting support devices, or the sudden deterioration of patients' conditions, requiring first aid. To solve these problems, a number of researchers conducted studies with blind US-guided bedside PICC and reported findings in the literature.[6,16] Although previous researchers suggested blind US-guided bedside PICC as an option for ICU patients, this technique did not show favorable outcomes and was associated with the serious complication of catheter tip malpositioning.[5] Therefore, for the present study, we decided to investigate the clinical usefulness of portable DR-guided bedside PICC as an option in ICU patients in terms of reducing procedure time, potential risks from transporting patients, and procedure-related complications. We also compared the results with conventional fluoroscopy-guided PICC in the intervention clinic. In this study, the average transfer time was about 26 minutes, which was similar to the procedure times with both techniques. This result showed that the patients' transportation could be a time-consuming process to perform PICC for ICU patients. Therefore, we believe that bedside PICC using portable DR can be a viable option for ICU patients to simplify overall process with preprocedural time-saving and decrease potential risks related to patient transportation.

In the previous study, the most significant problem with bedside PICC was malpositioning of the catheter tip[17]; even minor malpositioning can increase the risk of complications such as thrombosis, arrhythmia, cardiac tamponade, and catheter malfunction.[18–21] To reduce tip malpositioning, a new device called an electromagnetic positioning system has been developed,[22] but

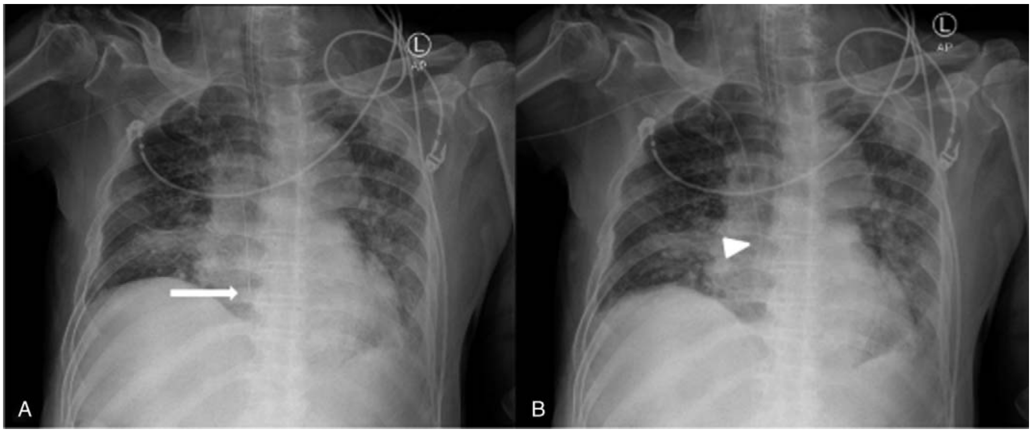

Figure 2. A 69-year-old man with lobar pneumonia: (A) portable chest X-ray image with a fixed guidewire length of 40 cm, and (B) portable chest X-ray image after correcting the length and inserting catheter. The tip of the catheter (arrowhead) is positioned at the cavoatrial junction correctly compared with the tip of the guidewire (arrow).

it is not suitable for clinical practice in terms of cost-effectiveness or access. Therefore, we devised a simple technical approach using a portable DR system. Recently, developed portable DR systems use flat panel detectors, which generate lower radiation doses while maintaining imaging quality comparable to previous film transistor detectors. In addition, portable DR can repeatedly reproduce images through real-time acquisition and postprocessing.[7–9] By taking advantage of this system and taking additional chest X-rays in the middle of the procedure, we were able to solve the catheter tip malposition problem. In addition, the average radiation dose for bedside PICC using portable DR was significantly lower than that for fluoroscopy-guided PICC in the present study. Therefore, the bedside PICC can be a useful option for managing the ICU patients with its benefits such as reducing radiation exposure and decreasing procedure-related complications.

Table 1

Comparison of clinical and procedural details according to type of procedure.

Patient characteristics	Fluoroscopy guided PICC (n = 20)	Bedside PICC (n = 45)	*P*
Demographics			
Sex			.902
Male, n (%)	11 (31.4)	24 (68.6)	
Female, n (%)	9 (30)	21 (70)	
Age, y, mean ± SD	65.6 ± 14.1	71.7 ± 12.4	.083
Underlying disease, n (%)			.761
Internal medicine	11 (29.7)	26 (70.3)	
Neurology	6 (28.6)	16 (71.4)	
Surgery	3 (42.9)	3 (57.1)	
Indications, n (%)			.134
Venous access	5 (17.9)	23 (82.1)	
Total parenteral nutrition	2 (33.3)	4 (66.7)	
Long term antibiotic administration	13 (41.9)	18 (58.1)	
Radiation dose, mGycm^2, mean ± SD	985.2 ± 547.6	557.9 ± 209.2	<0.001
Procedure time, min, mean ± SD	24.1 ± 5.6	26.8 ± 3.9	.028

Data in parentheses are percentages of each item. PICC = peripherally inserted central catheter.

In this study, we also found that the procedure time for bedside PICC using portable DR was significantly longer than that of fluoroscopy-guided PICC, although the difference in mean values was small. This difference may have been due to the time-consuming factors of bedside PICC as follows: the immobile nature of the patients, efforts to sort out the various devices or peripheral venous catheters with therapeutic drugs, and the need for additional time for X-rays. Although this procedure takes more time due to these factors, it can be a more efficient alternative for ICU patients considering the time to transport patients to the intervention clinic and the clinical risks associated with doing so. In addition, it is possible that the procedure time can be shorter if the operator is familiar with this technique.

Several limitations of this study should be considered when interpreting the results. First, our study was a retrospective examination of a small number of patients. Second, we derived the results for this study from a single interventional radiologist. Third, this study was conducted in a single institution. However, there are differences in operating teams, equipments and ICU setups according to institutions for performing PICC. Thus, our study had a weakness for generalization. Lastly, although none occurred in the present study, it is impossible to confirm central venous stenosis by ultrasound alone, and this may lead to failure of the PICC procedure. These issues need further evaluation in future studies.

In conclusion, we suggest that bedside PICC using portable DR can be safe, effective and convenient, therefore, it can be helpful for managing immobile or critical patients in daily clinical practice. We expect that a future study with a larger patient population, multiple practitioners different DR systems would help validate our results.

Author contributions

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