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Peripherally Inserted Central Catheter Placement with the Sonic Flashlight: Initial Clinical Trial by Nurses

David Wang, Ph.D.^{2,3}, Nikhil Amesur, M.D.², Gaurav Shukla^{1,2}, Angela Bayless, R.N.², David Weiser¹, Adam Scharl¹, Derek Mockel¹, Christopher Banks, R.N.², Bernadette Mandella, R.N.², Roberta Klatzky, Ph.D.⁴, and George Stetten, M.D., Ph.D.^{1,2,5}

¹Department of Bioengineering, University of Pittsburgh

²Department of Radiology, University of Pittsburgh Medical Center

³Department of Biomedical Engineering, Carnegie Mellon University

⁴Department of Psychology, Carnegie Mellon University

⁵Robotics Institute, Carnegie Mellon University

Abstract

Objective—We describe a case series comprising the first clinical trial by intravenous (IV) team nurses using the Sonic Flashlight for ultrasound guidance of peripherally inserted central catheter (PICC) placement.

Methods—Two IV team nurses with more than 10 years experience placing PICCs and from 3–6 years experience with ultrasound (US) attempted to place PICCs under US guidance in patients requiring long-term IV access. One of two methods of US guidance was used: conventional ultrasound (CUS) (60 patients) or a new device called the Sonic Flashlight (SF) (44 patients). The number of needle punctures required to gain IV access was recorded for each subject.

Results—In both methods, 87% of the cases resulted in successful venous access on the first attempt. The average number of needle sticks per patient was 1.18 for SF-guided procedures, as compared to 1.20 for CUS-guided procedures. No significant difference was found in the distribution of the number of attempts between the two methods. Anecdotal comments by the nurses indicated the comparative ease of use of the SF display, although relatively small scale of the SF image compared to the CUS image was also noted.

Conclusions—We have shown that the Sonic Flashlight is a safe and effective device for guidance of PICC placement in the hands of experienced IV team nurses. The advantage of placing the ultrasound image at its actual location must be balanced against the relatively small scale of the SF image.

Keywords

Ultrasound; Sonic Flashlight; image guided intervention; central catheter; intravenous

Disclosures

A patent and several pending patents on the Sonic Flashlight are held through the University of Pittsburgh by George Stetten, David Wang, and David Weiser.

Introduction

Peripherally inserted central catheters (PICCs) have been used for over two decades to provide a safe and effective means of venous access that is longer term than that provided by regular peripheral lines. Initially inserted in peripheral veins using conventional venipuncture techniques, PICC placement has been further advanced by using ultrasound guidance to access those veins not visible on the skin surface.¹ US guided PICCs have been routinely placed by radiologists in the interventional radiology (IR) suite, but they are increasingly performed at the bedside by specialized intravenous (IV) nurses. This generally avoids the risk and delay of transporting the patient to the IR suite and yields significant financial savings. One analysis in 2005 found that PICC placement at the bedside by a nurse costs between \$150–\$200 as opposed to placement in the IR suite costing \$450–\$3,000.² Most American academic medical centers now employ a team of specialized IV nurses to place PICCs at the bedside, reserving the IR suite for particularly difficult cases. Two advances have made bedside PICC placement by nurses increasingly effective: (1) the modified Seldinger (micro-introducer technique), and (2) ultrasonic image guidance at the bedside using portable scanners. Together, these technologies provide the operator with information about the status of target vessels, reduce tissue trauma, and lower the average number of needle sticks required to achieve venous access.^{3,4} Ultrasound (US) guidance has become the standard of care for PICC placement in both adults and pediatric patients.⁵ US guidance improves the success rate of PICC placement and reduces the time needed to perform the procedure.^{6,7} However, incorporating US into the standard protocol has faced an obstacle, in that it requires learning a new form of hand-eye coordination. The operator must learn to look away from the patient to view the ultrasound screen during the cannulation, rather than looking directly at the patient's arm using external visual landmarks.⁸

The Sonic Flashlight (SF), first reported in this journal in 2001,⁹ is an adaptation to the standard US scanner in which the conventional ultrasound (CUS) display is replaced with a small flat-panel display and a half-silvered mirror mounted directly on the transducer, reflecting the US image into the patient.

The top portion of Figure 1 shows the SF used in the present clinical trial. The three basic components are held rigidly together by a custom plastic frame: the ultrasound transducer, a small flat-panel display, and a half silvered mirror. Looking through the mirror, the projected real-time US image appears to float beneath the skin, in situ, precisely where the scan is being obtained. The effect is something akin to seeing one's reflection in a hallway mirror; it appears to float at a location behind the wall. The fact that the mirror of the SF is semi-transparent permits direct observation of the patient's skin and the exposed portion of the needle superimposed with the reflection of the ultrasound image. The result is a merging of the US image, transducer, needle, operator's hands, and patient's skin into the same field of view, enabling natural perceptually-guided action. In contrast, CUS displaces hand-eye coordination by forcing the operator to look away from the operating field to see the US display. CUS therefore requires time to master special cognitive skills not required with the SF.

The SF has proven effective in cadavers for retrobulbar injection of the eye,¹⁰ jugular vein access,¹¹ and biopsy of targets in the brain.¹² We have shown that, compared to CUS, vascular access in phantoms with the SF is easier to perform and faster to learn for US novices as well as for experienced US users.^{13,14, 15} A number of detailed psychophysical experiments have shown particular advantages in using the SF over CUS, in terms of reducing errors in judging target location.^{16,17} An initial clinical trial was conducted in which an experienced interventional radiologist successfully used the SF to place PICCs in patients in the controlled environment of the IR suite.¹⁸

The present paper describes the first clinical trial by nurses at the patient's bedside. The trial aims to demonstrate (1) that experienced IV team nurses can adapt to the SF quickly and (2) that use of the SF in place of CUS does not compromise safety and reliability.

Materials and Methods

The SF used in this trial (shown in Fig 1) consists of a commercially available 10 MHz US probe (Terason 2000; Teratech, Burlington, Mass), altered by the attachment of a 25×50×2-mm custom half-silvered mirror with 30% reflectance, and a 44×33-mm flat-panel organic light-emitting diode OLED (AM550L; Kodak, Rochester, NY). The OLED display was chosen because it is thin and light and has excellent off-angle viewing quality. The bottom portion of Figure 1 shows the same device with a sterile probe cover pulled over the ultrasound transducer and display. The mirror is held in place on the transducer by a disposable frame, which also presses the transparent probe cover flat over the display to reduce distortion. Thus the ultrasound transducer and display do not require sterilization, and the pre-sterilized mirror-frame assembly can be used once and discarded. The disposable mirror-frame assembly could be very inexpensive; even as a research laboratory, we were able to produce them for about \$10 apiece.

An enactment of the procedure inserting a needle into the upper arm with guidance from the SF is shown in Figure 2. The SF is held by one hand at right angles to the patient's arm producing a cross-sectional image of the target vein. The needle is introduced with the other hand at approximately 45 degrees to the skin, to intersect with the vein in the plane of the US image. The same procedure on a cadaver as shown from the operator's point of view is shown in Fig. 3. Again the Sonic Flashlight is held in one hand and the needle in the other. The half-silvered mirror generates a reflected virtual image of the ultrasound data, showing a cross section of the basilic vein with the needle tip visible within it.

Under IRB approval, two nurses were recruited, each with more than 10 years of experience in placing PICCs as part of the IV team. Nurse #1 had 3 years experience with ultrasound, and Nurse #2 had 6 years experience. Each nurse performed PICC line placements on two groups of patients: Group 1 with CUS and Group 2 with the SF.

Group 1 - In the first group each nurse used CUS for scheduled PICC placement on 30 patients (60 total). The US machine was a commercially available iLook 25 (Sonosite, Inc., Bothell, WA) portable scanner with a 25-mm broadband 10-5 MHz linear array transducer and a standard 12.7 cm color Liquid Crystal Display (LCD). The nurse scanned the patient's upper arm with the CUS scanner to identify a target vein (either basilic, brachial, or cephalic). After preparing the sterile field, the nurse introduced the needle under CUS guidance into the target vein and recorded the number of needle puncture attempts required for successful access. Success was defined as witnessing blood return from the target vessel, whether or not a PICC was successfully placed, since subsequent introduction of the wire did not depend upon ultrasound guidance.

Group 2 – In the second group of patients, the nurses used the SF instead of CUS. Each nurse received a one-hour training session on using the SF with a special vascular phantom (Blue Phantom, Inc., Kirkland, WA). With IRB approval, each nurse then received informed consent from 22 patients (44 total) scheduled for PICC placements. The nurse scanned the patient's upper arm with the SF to identify a target vein (again, either basilic, brachial, or cephalic). After preparing the sterile field, the nurse introduced the needle under SF guidance. As in Group 1, success was defined as witnessing blood return from the target vessel, whether or not a PICC was successfully placed. If successful access was gained in the selected vein using the SF within 3 attempts, the number of attempts was recorded, and the PICC placement continued.

as in Group 1. If venous access was unsuccessful after 3 attempts, the operator was to revert to CUS for additional attempts to carry out the physician's request for PICC placement, but this never actually happened in our trial.

Results

Each of the two nurses used CUS on 30 patients and the SF on 22 for a total of 104 patients. No subjects needed more than three needle sticks in order for the PICC to be placed under either SF or CUS guidance. The results are shown in Table 1. The average number of needle sticks required is comparable for each modality (CUS: 1.20 sticks per patient; SF: 1.18 sticks per patient); 87% of subjects had successful venous access on the first attempt in both modalities. A chi-square test comparing the frequency distributions between modalities shows no significant difference between the two groups ($\chi^2 = 0.392$, $p = .822$). Thus no performance decrement was seen in trained PICC nurses when using the SF for guidance of the PICC procedure, as compared to CUS guidance.

Anecdotally, both nurses expressed the opinion that the SF made the procedure easier, although both also noted that the image was smaller than the nurses were accustomed to seeing. They questioned whether this might lead to ambiguity for less experienced nurses in differentiating the target vein from an adjacent artery. The size of the image displayed by the SF must be the same as that of the scanned anatomy, so that it can be superimposed correctly. Conventional ultrasound displays, by contrast, generally show a magnified image.

Discussion

Our previous study demonstrated that the SF is effective when used by an interventional radiologist in the IR suite. The present study placed the Sonic Flashlight in the hands of nurses at the bedside, yielding needle-stick rates comparable to CUS and generally favorable responses from the nurses. Since the total number of patients (104) was not large enough to permit in-depth statistical analyses, we believe that a larger clinical trial with trained PICC nurses would be of interest. The larger trial may record additional parameters such as procedure duration, which we chose not to measure in the present trial as we did not want to rush the nurse participants. Such a trial may also explore differences based on US experience, as well as technical expertise with catheter placement, comparing learning times between CUS and the SF.

The main potential disadvantage of the SF appears to be the relatively small size of the image it displays. Unlike most CUS displays, which are magnified to permit greater resolution of fine detail, the SF display cannot be magnified; the image must be displayed at the actual scale of the underlying structures for it to be “registered” at the correct location. This lack of magnification could be a disadvantage for some applications involving small features, such as breast tumor biopsy. However, for the purpose of PICC placement, at least in the hands of experienced nurses, the true anatomic size appears sufficient for identification of the target vein. It should also be noted that the CUS display could still be included in the apparatus and consulted at any time during the procedure. On future models, a magnification mode may also be incorporated into the SF display that would temporarily sacrifice the true anatomical relationship of the structures for greater detail in the image.

Given that the SF has shown reduced learning times compared to CUS, we are planning a separate trial with inexperienced US users, including new PICC nurses and first-year residents, who exhibit a significant learning curve when training for vascular access with CUS. The trial would aim to demonstrate reduced time and effort in learning to use US guidance for PICC placement with the SF relative to CUS. The intuitive hand-eye coordination offered by the SF

may facilitate learning by such novice users, not just for PICC placement, but for many other interventional procedures as well. Thus, the SF could help spread the use of US in general to a wider population of health-care providers.

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Figure 1.

Top: The Sonic Flashlight (SF) showing a small organic light-emitting diode (OLED) display and half-silvered mirror attached to the ultrasound probe. **Bottom:** The same device with a sterile probe cover, showing the clip-on disposable mirror-frame assembly shown outside the probe cover.

Figure 2.

Enactment of the basic procedure of needle insertion into deep vein of the arm for peripherally inserted central catheter (PICC) placement using the Sonic Flashlight (SF). The operator holds the SF in one hand while looking down through the half-silvered mirror, guiding the needle into the reflected ultrasound image of the vein. (see Fig. 3 for operator viewpoint)

Figure 3.

Photograph from the operator's point of view for the same procedure shown in Fig. 2 in a cadaver upper using the Sonic Flashlight. The in-situ virtual image is shown in the white box, magnified on the left. The needle tip is visible within the right basilic vein (shown in cross-section as a dark circular area around the bright needle tip). Figure 3 is adapted with permission from Radiology.¹⁵

Table 1

Operator	Modality	1 stick	2 sticks	3 sticks
Nurse 1	Conventional Ultrasound (n=30)	29 (97%)	1 (3%)	0 (0%)
	Sonic Flashlight (n=22)	21 (95%)	0 (0%)	1 (5%)
Nurse 2	Conventional Ultrasound (n=30)	23 (77%)	3 (10%)	4 (13%)
	Sonic Flashlight (n=22)	17 (77%)	4 (18%)	1 (5%)
Total	Conventional Ultrasound (n=60)	52 (87%)	4 (7%)	4 (7%)
	Sonic Flashlight (n=44)	38 (87%)	4 (9%)	2 (5%)