Peripherally Inserted Central Catheter Placement With the Sonic Flashlight

Initial Clinical Trial by Nurses

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Objective. We describe a case series constituting the first clinical trial by intravenous (IV) team nurses using the sonic flashlight (SF) for ultrasound guidance of peripherally inserted central catheter (PICC) placement. ***Methods.*** Two IV team nurses with more than 10 years of experience with placing PICCs and 3 to 6 years of experience with ultrasound attempted to place PICCs under ultrasound guidance in patients requiring long-term IV access. One of two methods of ultrasound guidance was used: conventional ultrasound (CUS; 60 patients) or a new device called the SF (44 patients). The number of needle punctures required to gain IV access was recorded for each patient. ***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 compared with 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 the relatively small scale of the SF image compared with the CUS image was also noted. ***Conclusions.*** We have shown that the SF 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. ***Key words:*** central catheter; image-guided intervention; intravenous; sonic flashlight; ultrasound.

Abbreviations

CUS, conventional ultrasound; IR, interventional radiology; IV, intravenous; OLED, organic light-emitting diode; PICC, peripherally inserted central catheter; SF, sonic flashlight

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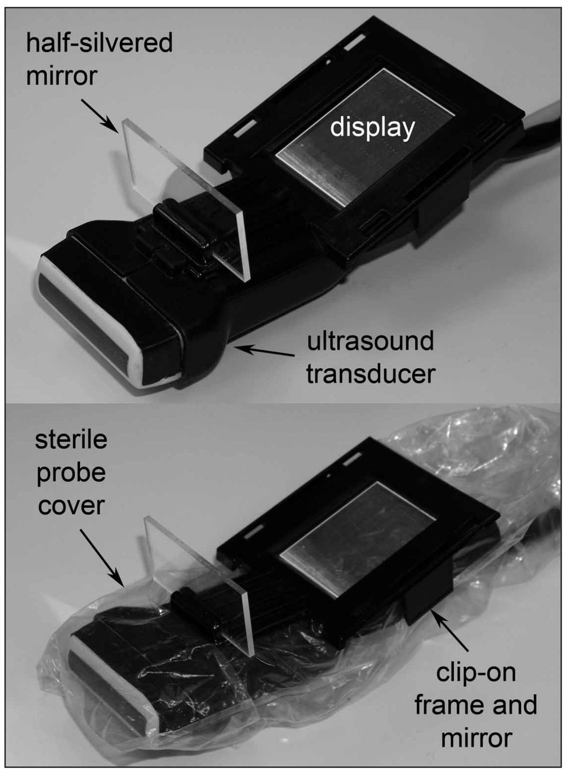
Peripherally inserted central catheters (PICCs) have been used for more than 2 decades to provide a safe and effective means of venous access that is longer term than that provided by regular peripheral lines. Initially inserted in peripheral veins by conventional venipuncture techniques, PICC placement has been further advanced by using ultrasound guidance to access those veins not visible on the skin surface.[1] Ultrasound-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 considerable financial savings. One analysis in 2005 found that PICC placement at the bedside by a nurse costs between $150 and $200, as opposed to placement in the IR suite, costing $450 to $3000.[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 (microintroducer technique) and (2) ultrasound image guidance at the bedside with 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 guidance has become the standard of care for PICC placement in both adult and pediatric patients.[5] Ultrasound guidance improves the success rate of PICC placement and reduces the time needed to perform the procedure.[6,7] However, incorporating ultrasound imaging 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 ultrasound 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 ultrasound image into the patient.

The top portion of Figure 1 shows the SF used in this clinical trial. The 3 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 ultrasound 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 semitransparent 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 ultrasound 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 ultrasound display. Conventional ultrasound 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 with CUS, vascular access in phantoms with the SF is easier to perform and faster to learn for ultrasound novices as well as for experienced ultrasound users.[13–15] A number of detailed psychophysical experiments have shown particular advantages in using the SF over CUS in terms of reducing errors in judging the 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]

Figure 1. Top, Sonic flashlight showing a small OLED display and half-silvered mirror attached to the ultrasound probe. Bottom, Same device with a sterile probe cover showing the clip-on disposable mirror-frame assembly outside the probe cover.



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

Materials and Methods

The SF used in this trial (Figure 1) consists of a commercially available 10-MHz ultrasound probe (Terason 2000; Teratech, Burlington, MA), 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 presterilized mirror-frame assembly can be used once and discarded. The disposable mirror-frame assembly could be very inexpensive; even in a research laboratory, we were able to produce them for about $10 apiece.

An enactment of the procedure of 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° to the skin to intersect with the vein in the plane of the ultrasound image. The same procedure on a cadaver as seen from the operator's point of view is shown in Figure 3. Again, the SF 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 Institutional Review Board approval, 2 nurses were recruited, each with more than 10 years of experience in placing PICCs as part of

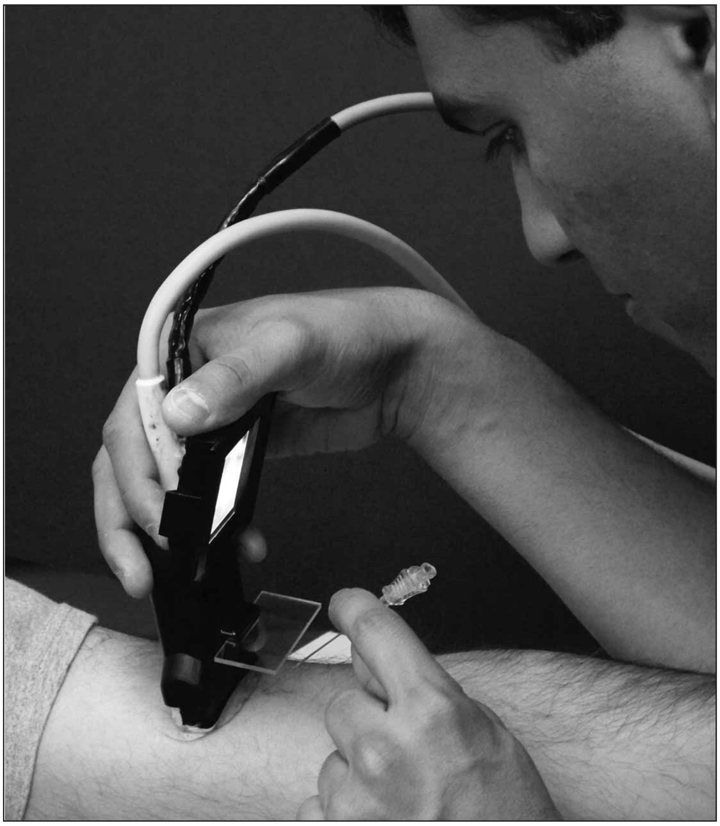
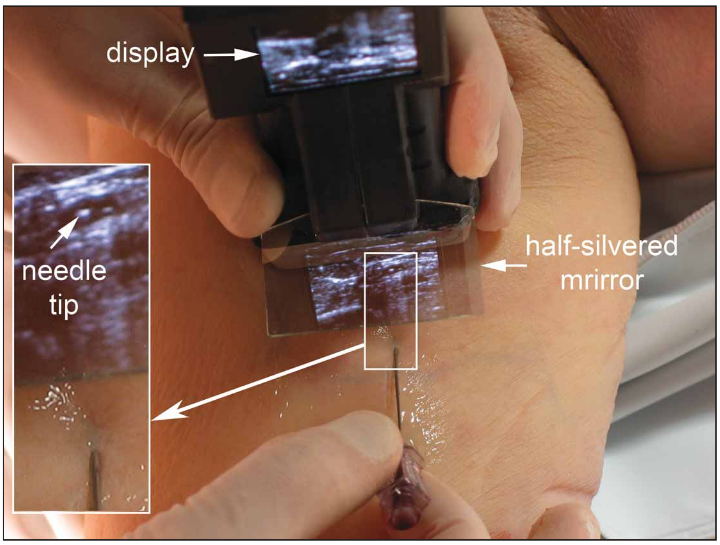


Figure 2. Enactment of the basic procedure of needle insertion into a deep vein of the arm for PICC placement using the SF. The operator holds the SF in one hand while looking down through the half-silvered mirror, guiding the needle into the reflected ultrasound image of the vein (see Figure 3 for operator viewpoint).

Figure 3. Operator's point of view for the same procedure shown in Figure 2 in a cadaver upper arm using the SF. 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). Adapted with permission from *Radiology*.[15]



the IV team. Nurse 1 had 3 years of experience with ultrasound, and nurse 2 had 6 years of experience. Each nurse performed PICC line placements on 2 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 ultrasound machine was a commercially available iLook 25 portable scanner (Sonosite, Inc, Bothell, WA) with a 25-mm broadband 10–5 MHz linear array transducer and a standard 12.7-cm color liquid crystal display. 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 a PICC was successfully placed, because subsequent introduction of the wire did not depend on ultrasound guidance.

Group 2

In the second group, the nurses used the SF instead of CUS. Each nurse received a 1-hour training session on using the SF with a special vascular phantom (Blue Phantom, Inc, Kirkland, WA). With Institutional Review Board 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 2 nurses used CUS on 30 patients and the SF on 22 for a total of 104 patients. No patients needed more than 3 needle sticks 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 was comparable for each modality (CUS, 1.20 sticks per patient; SF, 1.18 sticks per patient); 87% of patients had successful venous access on the first attempt with both modalities. A χ^2 test comparing the frequency distributions between modalities showed 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 compared with 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 showed that the SF was effective when used by an interventional radiologist in the IR suite. This study placed the SF in the hands of nurses at the bedside, yielding needle stick rates comparable with those of CUS and generally favorable responses from the nurses. Because the total number of patients (104) was not large enough to permit in-depth statistical analyses, we think 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 this trial because we did not want to rush the nurse participants. Such a trial may also explore differences based on ultrasound experience as well as technical expertise with catheter placement, comparing learning times between CUS and the SF.

Table 1. Cases Requiring 1, 2, or 3 Sticks for Successful Needle Placement With CUS Versus the SF

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

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 anatomic relationship of the structures for greater detail in the image.

Given that the SF has shown reduced learning times compared with CUS, we are planning a separate trial with inexperienced ultrasound users, including new PICC nurses and first-year residents, who have a considerable learning curve when training for vascular access with CUS. The trial would aim to show reduced time and effort in learning to use ultrasound 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 ultrasound in general to a wider population of health care providers.

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