Peripherally Inserted Central Catheter Placement Using the Sonic Flashlight

Nikhil B. Amesur, MD, David C. Wang, MD, PhD, Wilson Chang, MD, PhD, David Weiser, BS, Roberta Klatzky, PhD, Gaurav Shukla, BS, and George D. Stetten, MD, PhD

The Sonic Flashlight is an ultrasound (US) device that projects real-time US images into patients with use of a semireflective/transparent mirror. The present study evaluated the feasibility of use of the Sonic Flashlight for clinical peripherally inserted central catheter placements, originally with the mirror located inside a sterile cover \( (n = 15) \), then with the mirror outside \( (n = 1) \). Successful access was obtained in all cases. Results show that this new design improved visibility, as judged subjectively firsthand and in photographs. The study demonstrated the feasibility of the Sonic Flashlight and the new design to help assure sterility without degrading visibility, allowing further clinical trials involving physicians and nurses.

Abbreviation: PICC = peripherally inserted central catheter

PERIPHERALLY inserted central catheters (PICCs) are increasingly being used as a safe alternative to direct placement of central catheters, allowing longer dwell times compared with peripheral intravenous catheters. This makes PICCs the preferred access method for many uses, including long-term chemotherapy, hyperalimentation, repeated administration of blood products, and repeated venous sampling. As superficial antecubital and forearm veins become hard to access after multiple punctures, the upper arm becomes the optimal placement site for PICCs. Cannulation at this location requires ultrasound (US) guidance and is most reliably performed by experienced users. The recent trend in miniaturization of inexpensive US machines has prompted an increase in attempted PICC placement at the bedside, but the success rate remains variable, ranging from 67% to 92% according to three separate studies (1–3). Improving this success rate would help alleviate the bottleneck caused by PICC placement in the interventional radiology suite and reduce the risk posed by transporting patients.

Much of the difficulty in learning conventional US-guided procedures stems from the displaced sense of hand-eye coordination that occurs when the operator looks away from the operating field to see the US display, requiring mental computation of the relationship between the needle and the underlying anatomy. Eliminating this cognitive process could make it easier and faster to learn US-guided vascular access procedures, allowing more PICCs to be placed by bedside personnel instead of by experienced interventionalists in the interventional radiology suite.

To address this difficulty, some researchers have explored methods for viewing the US image, patient, instrument, and operator’s hands in a single environment. Head-mounted display systems have been developed to superimpose the US image within the patient (4–7). These systems track the location of the US transducer relative to the head-mounted display, so the image can be computed and superimposed by the head-mounted display with the correct stereoscopic perspective and location. To the person wearing the head-mounted display, the US image appears within the patient at its actual physical location. Despite their promise, head-mounted display systems have yet to overcome significant obstacles, including lag time, low resolution, limited field of view, significant weight, and expense. In addition, if multiple observers are cooperating in a procedure, each observer requires a separate head-mounted display to see the same in situ US image.

The Sonic Flashlight (Fig 1) uses a novel means to display real-time US images inside the patient without positional tracking or a head-mounted display system (8,9). The Sonic Flashlight...
fixes the relative geometry of the transducer, display, and a half-silvered mirror to produce a virtual image of the US display inside the patient (Fig 2). Looking through the half-silvered mirror, the US image appears to float within the patient, with each pixel of the scan seeming to emanate from its correct anatomic location within the patient. With the Sonic Flashlight, the US image, patient, instrument, and operator’s hands are all merged into a single environment. This makes US-guided interventional procedures as simple as aiming for the US image itself. The Sonic Flashlight display is viewpoint-independent, meaning that users looking through the mirror from any vantage point will see the US image properly registered with the internal anatomy.

Unlike most conventional US displays, which are magnified to permit greater resolution of fine detail, the Sonic Flashlight display cannot be magnified. It is necessary for the Sonic Flashlight to display the US scan at its actual scale so the images of the underlying structures can appear at their correct locations. This lack of magnification can be a disadvantage for some applications involving very small structures. However, for PICC placement purposes, the true anatomic size is sufficient for identification of the underlying anatomy.

The Sonic Flashlight directly addresses many of the head-mounted display–related issues and has been proven effective in cadaveric retrobulbar injection of the eye (10) and cadaveric jugular vein access (11). It has been shown that, compared with conventional US, vascular access in phantoms with the Sonic Flashlight is faster and easier for experienced US users (12), as well as faster to learn for US novices (13). Precise psychophysical experiments have shown particular advantages in using the Sonic Flashlight versus conventional US by reducing errors in judging target location (14,15). The present study describes the first clinical trial in which an experienced interventional radiologist used the device to place PICCs in patients in the interventional radiology suite.

MATERIALS AND METHODS

During 8 years of development, there have been multiple prototypes of the Sonic Flashlight. The first version ready for clinical use employed a 10-MHz US system (model 2000; Terason, Burlington, Massachusetts), the probe of which was fitted with a small flat-panel display (AM550L organic LED; Kodak, Rochester, New York) and a dedicated half-silvered mirror. A standard transparent disposable sterile probe cover (model 9001C0197; Bard Access Systems, Salt Lake City, Utah) was fitted over the Sonic Flashlight to eliminate cross-contamination between patients. For the first 15 patients, the mirror was attached directly to the Sonic Flashlight inside the sterile cover. For the remaining 11 patients, a subsequent design was employed that used a disposable mirror clipped on outside the sterile cover. To avoid variability between US systems, we used the same Terason US probe with its laptop-based display as the conventional US for comparison.

Under institutional review board approval, we recruited 26 subjects among those who had been referred to the interventional radiology department at our institution to have a PICC placed. After obtaining informed consent from each patient, an experienced interventional radiologist scanned the upper arm with both the Sonic Flashlight and...
conventional US. The same radiologist performed the procedures on all subjects. Identification of the basilic vein, brachial veins, and brachial artery were compared and recorded with each modality. If the identifications by both modalities agreed, it was considered a successful identification. If the basilic vein was visualized with the Sonic Flashlight, the Sonic Flashlight was used to guide a needle (21 gauge, 7 cm) into the basilic vein. The basilic vein was favored as it typically is more superficial and does not present with an accompanying artery, reducing the risk of complications related to arterial puncture. If the basilic vein was determined to be an inappropriate target—eg, it was thrombosed—the brachial vein was used instead. If vascular access was unsuccessful after three attempts with the Sonic Flashlight, the radiologist was to revert to the use of conventional US for the procedure (however, this never occurred in the present study). If successful access was gained in the selected vein, the procedure continued as in a standard PICC procedure.

RESULTS

Our first set of clinical trials involved 15 of the 26 patients (16). The vessels were visualized in situ with the Sonic Flashlight. The identities of the vessels were confirmed by comparison with conventional US. The needle was easily aimed and inserted into the basilic or brachial vein in all cases, and the needle tip was visualized at its expected location. Successful access was obtained in all 15 subjects: 13 on the first attempt and two on the second attempt. Therefore, no case had to be converted to conventional US guidance. However, a problem was noted with probe cover, which enveloped the entire Sonic Flashlight device, including the mirror, to ensure sterility. Commercial probe covers currently marketed as “transparent” are not actually designed to prevent all distortion of visible light. Resulting image blurriness was noted as inconvenient during three procedures, even though it did not affect outcome (Fig 3, bottom).

In reviewing the initial trial, it was decided that a redesign of the Sonic Flashlight was required to solve this problem. Accordingly, we created a separate mirror holder that snapped onto the flat-panel display, holding the plastic probe cover flat over the organic LED display. This greatly re-
duced the diffusive effect of the probe cover on the display (Fig. 4). In the process, the mirror was moved entirely outside the cover, eliminating any effect of the cover on the direct line of sight. An optional darkened hood was also added that could be snapped onto the entire apparatus to reduce reflection from ambient light.

The resulting image (Fig. 3, top) shows little or no light-distorting effect. As the mirror and hood are now unprotected by the probe cover, they must be sterilized for each patient. We chose to make them disposable to eliminate any risk of cross-patient contamination.

With this new model, successful access was obtained in the remaining 11 subjects: eight on the first attempt, two on the second, and one on the third. The vessels were visualized in situ with substantially greater clarity, as judged by the radiologist, than in the first set of clinical trials. The identities of the vessels were again confirmed by comparison with conventional US. The needle was easily aimed and inserted into the basilic or conventional US. The needle was easily confirmed by comparison with conventional US guidance by nonradiologists, with the goal of reducing the number of patients who need to be transported to the interventional radiology suite for PICC placement. We also hope to show the utility of the Sonic Flashlight in helping interventional radiologists place catheters in the jugular, subclavian, and femoral veins.

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