REFINING THE SONIC FLASHLIGHT FOR INTERVENTIONAL PROCEDURES

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ABSTRACT

Ultrasound (US) is often used in interventional procedures such as accessing blood vessels, performing biopsies, and placing drains. The Sonic Flashlight (SF) is a handheld device that uses a mirror to reflect a real-time US image into the body, making that body part appear translucent. The latest generation handheld SF has been improved to the point where it can be applied to procedures involving fine structures such as vasculature and small tumors. We have dramatically decreased the size, weight, and display lag-time, while increasing resolution. With these improvements, the operator can now clearly visualize and discriminate between small structures. We believe that this version of the SF is ready for clinical trials.

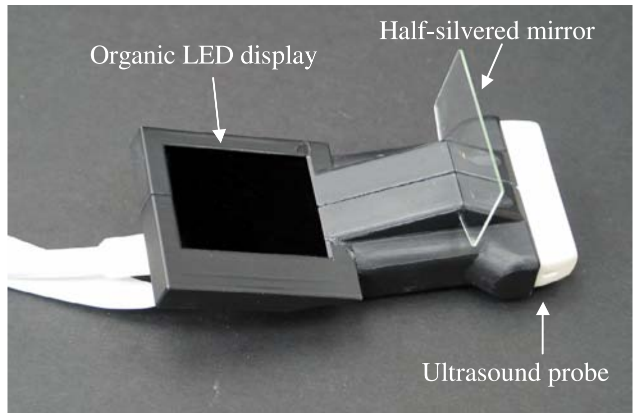

Figure 1. The Sonic Flashlight incorporates a Terason 10Mhz linear probe, a 54.8mm (diagonal) OLED display, and a 20 x 50mm 30% reflective mirror.

1. INTRODUCTION

In most interventional US guided procedures, the US transducer is held in one hand to visualize a target below the surface of the skin, while the other hand guides a needle into the target. Much of the difficulty in learning US-guided procedures stems from the displaced sense of hand-eye coordination that occurs when the operator has to look away from the operating field to see the display. This difficulty is one of the chief reasons why US guidance has not reached widespread adoption outside radiology.

The SF is based on Real-Time Tomographic Reflection (RTTR). It is a novel way to more naturally merge real-time US images into the perceptual real world, without using positional tracking or a head mounted display system [1-3]. The SF fixes the relative geometry of the transducer, display, and a half-silvered mirror that the operator looks through to produce a virtual image of the US inside the patient. Each pixel of the US image appears to emanate from the correct location within the patient, thus obviating the need for a traditional US monitor. Using the SF, the US image, the patient, the instrument, and the operator's hands are all merged into one environment.

2. SONIC FLASHLIGHT DEVELOPMENTS

The SF consists of 3 major components: a display, an US machine, and a half-silvered mirror. The SF works by capturing real-time US images from the scanner, applying an affine transform to those images, and displaying them on the SF display [1]. Previous versions of the SF have lacked the resolution to be useful in procedures involving small structures such as peripheral vessels. The most recent version of the SF has been refined to incorporate a higher resolution scanner into a much smaller, more ergonomic device (Figure 1).

The SF display has five requirements: it must be lightweight, bright, have excellent off angle viewing, high pixel density, and excellent gray-scale and/or color display. For the latest handheld SF, a 54.8mm (diagonal) organic light emitting diode (OLED) display (AM550L, Kodak, Rochester, NY) was selected. This display improves upon the previous SF display in all aspects. It weighs only 8 grams, is bright, offers excellent off-angle viewing, high pixel-density (0.084 x 0.151mm dot pitch), and displays 24-bit color.

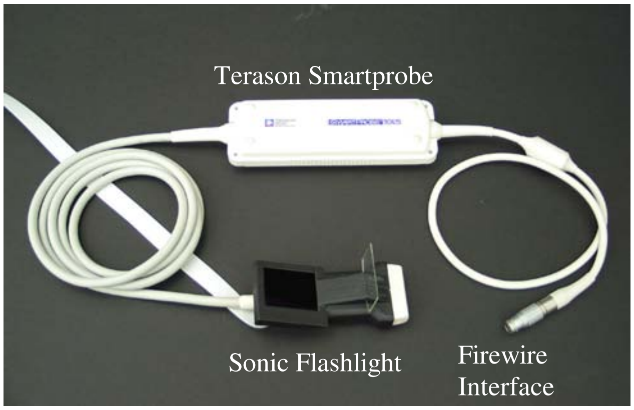

Figure 2. The Sonic Flashlight built around the Terason Smartprobe ultrasound machine, using a 10Mhz linear probe. The ultrasound machine interfaces with a laptop computer via an IEEE 1394 Firewire interface.

The latest SF is built around a Terason (Burlington, MA) US system with a 10 MHz linear probe. Compared to the previous US system (Pie Medical, 50S Tringa), the Terason US system (TUS) offers a number of advantages, including native digital output, 10 MHz (vs. 7 MHz), and a linear array probe. Figure 2 shows the SF built around the TUS. Before adapting it for the SF, the Terason system consists of a SmartProbe that interfaces with a laptop computer via IEEE 1394 Firewire. The laptop monitor displays the US images. To adapt the Terason system for the SF, we used Terason's Software Development Kit, which allows our SF software direct access to the raw digital data captured by the probe. Therefore the SF US image always remains in the digital domain.

This is distinctly different from previous versions of the SF. Most CUS machines only have an analog video output. In all previous versions of the SF, this analog image exited the US machine and then was converted to a digital signal by a video capture board before being affine transformed and sent to the SF display. The US image switched from digital to analog, and back to digital again, which introduced noise and lag time into the system. These problems are eliminated by the TUS.

3. CLINICAL APPLICATIONS OF THE SONIC FLASHLIGHT

US is increasingly being used to guide vascular access procedures. The most common access points include the brachial, basilic, and cephalic veins of the arm, and the internal jugular veins and subclavian veins centrally. In figures 3 and 4, the veins and arteries are visualized using the SF in both cross-section and in longitude section. The vessels are easily located within the body below the surface of the skin. We are optimistic that guiding a

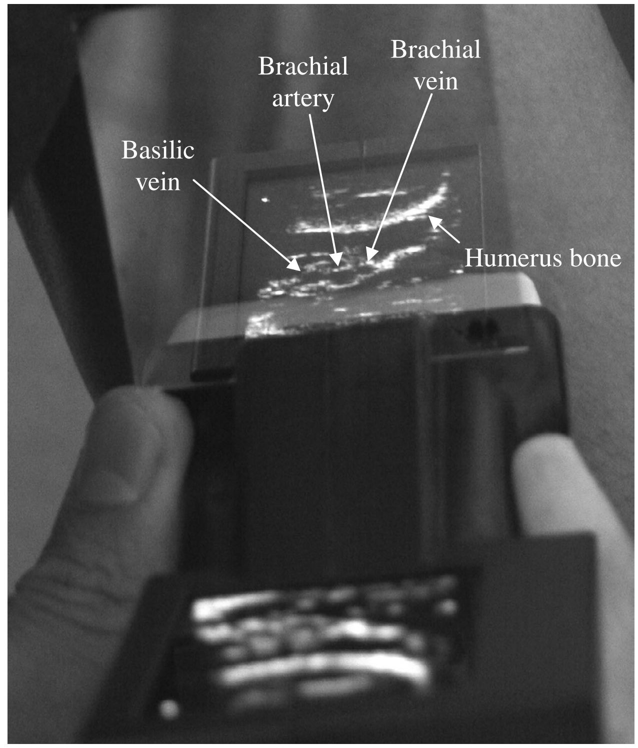

Figure 3. Using the Sonic Flashlight to visualize the internal anatomy of the upper arm. The artery and veins of the upper arm are clearly visible.

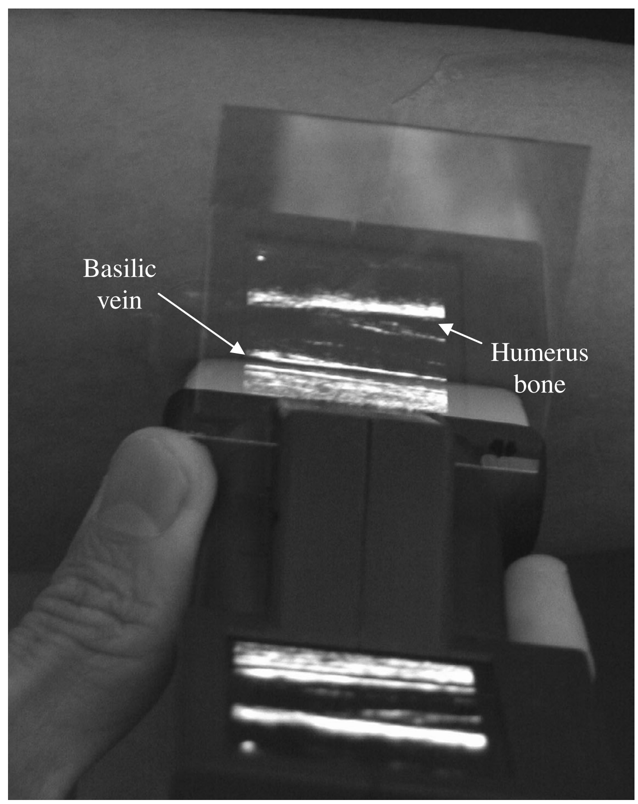

Figure 4. A longitude section of the upper arm, visualizing the basilic vein and humerus.

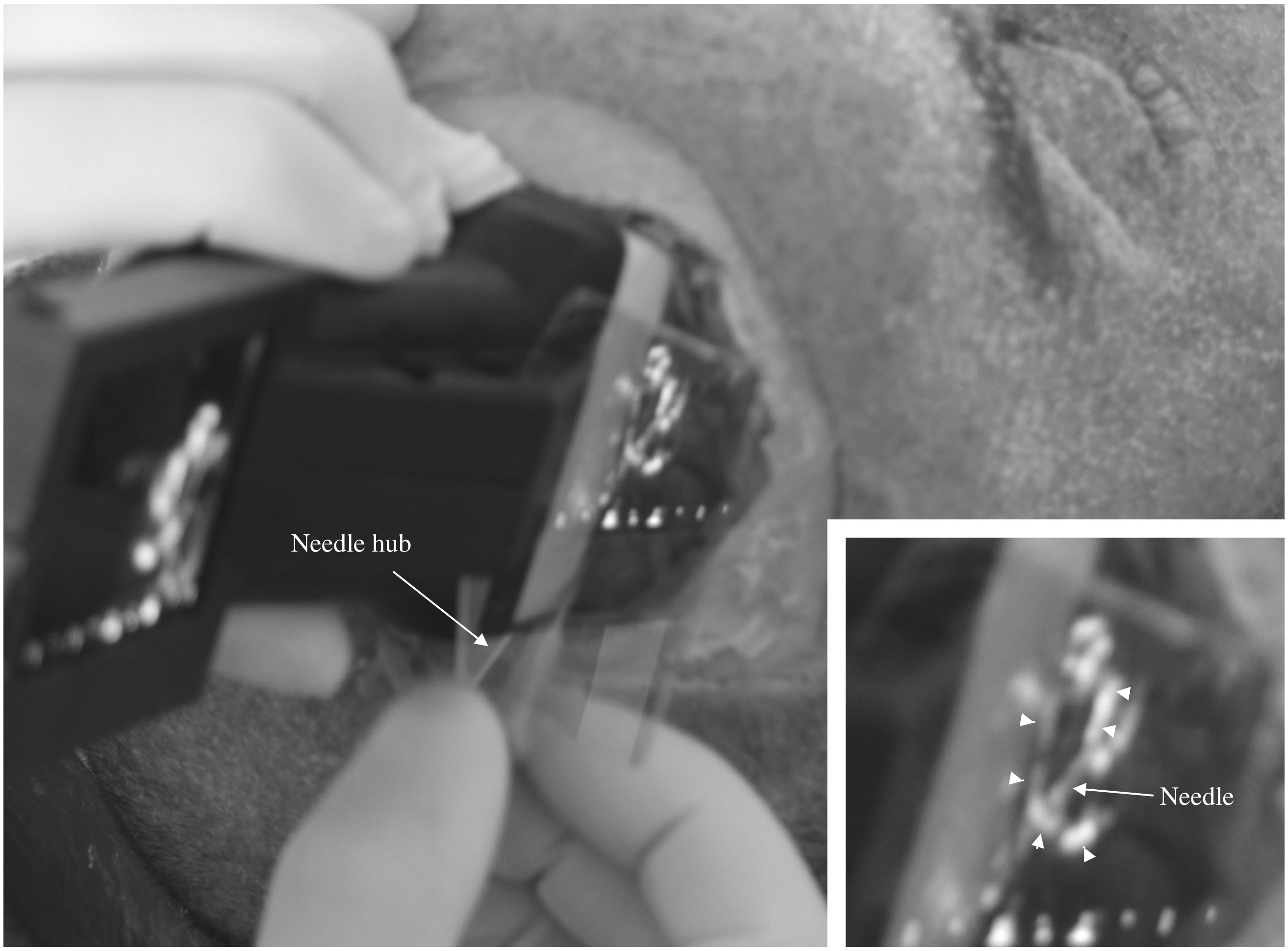

Figure 5. Using the Sonic Flashlight to guide a needle into a simulated tumor within a cadaver brain. The neurosurgeon operates the Sonic Flashlight with his left hand, while guiding a needle with his right hand, intentionally passing through both walls of the simulated tumor. The arrowheads indicate the walls of the simulated tumor. According to user, even his first attempt at this procedure using the Sonic Flashlight was easy and intuitive.

needle into one of these veins or arteries will be as simple as aiming at the image within the arm.

We have previously conducted a pilot study showing that novice users perform vascular access in phantoms significantly faster using the SF compared to conventional US guidance [4]. A more thorough IRB approved study is currently underway comparing the performance of nurses performing vascular access in phantoms using the SF vs. conventional US guidance.

Tumor biopsy and intra-operative localization are other applications where the SF may be particularly well suited. Unlike interventional radiologists, many of the physicians performing these procedures have not had extensive US training. They often find US guidance non-intuitive and difficult and therefore do not use it even when it has the potential to greatly improve accuracy and patient safety. Figure 5 illustrates a simulated US-guided intra-operative procedure, where a neurosurgeon, unfamiliar with ultrasound guidance, guided a needle into a simulated tumor implanted within a cadaver brain. The simulated tumor was a 10mm water-filled latex balloon placed approximately 10mm below the surface of the brain. In contrast to CUS guidance, the operator found the SF easy and intuitive to use for US guide procedures. We have also previously shown in another cadaver study in which the SF was used to guide a retrobulbar injection, a common ophthalmologic procedure [5].

4. CONCLUSION

The improvements made to the SF have resulted in a device that is clinically usable. The increases in scanning and display resolution have made it possible to guide procedures involving fine structures such as blood vessels. Additional work is currently underway to further improve the ergonomics and increase the SF's capabilities. One of these improvements will be the addition of Doppler information to the display, which may aid in vascular access procedures. We believe the SF may have a broad impact on US guidance and we envision widespread use especially by the health-care professional who currently does not use ultrasound. A future version of the SF could be collapsible and small enough to fit into the clinician's pocket, much like a stethoscope or palm-pilot does today.

5. REFERENCES

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