Progress Towards a Clinically Useful Sonic Flashlight

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ABSTRACT: We have demonstrated a new method of displaying ultrasound images *in situ* within the patient, using a half-silvered mirror attached to the ultrasound transducer. The mirror reflects the ultrasound image from a flat-panel monitor (also attached to the transducer) so that the virtual image occupies its actual location within the patient. The observer sees the ultrasound image merged with a direct view of the patient. Since the merger is independent of viewer location, it generates the stereoscopic illusion that the ultrasound image is actually emitted from within the patient. Natural hand-eye coordination can be used to aim directly at the image through the patient's skin, giving an intuitive ability to guide invasive procedures such as needle biopsy or insertion of catheters. The system requires no tracking or head mounted apparatus, and several observers can share in the perception, facilitating collaboration and instruction.

We believe the sonic flashlight could have a broad impact on the interventional diagnosis and treatment of disease. We review our progress to date in developing a series of prototype devices. Responding to feedback from our clinical collaborators, we have upgraded all elements of the apparatus and implemented a new generation of the system that is smaller, lighter, and more easily manipulated. Miniaturization of commercially available ultrasound scanners will, we believe, soon make possible a pocket-sized device that could be carried by the individual medical practitioner much as a stethoscope is carried today. We have improved performance as we gain a better understanding of the optical parameters of the system, and are taking advantage of recent advances in display technology. We have demonstrated *in situ* visualization of vasculature of the neck in a human volunteer, the anatomy of the eye in a cadaver, and the pericardial space in a live porcine heart. Our present emphasis is on developing the application of vascular line placement.

In addition to the "full-scale" sonic flashlight described above, we aim to extend the basic concept to remote procedures at different scales, in particular to real-time in vivo tomographic microscopic imaging modalities such as optical coherence tomography (OCT) and ultrasound backscatter microscopy (USB). We have constructed a working prototype using a mechanically linked system to magnify ultrasound-guided manipulation by a factor of four, and developed plans for magnified guidance systems for epidermal and catheter-based operation. Such systems would operate in vivo by providing a robotic linkage between a miniature "slave" effector operating in the scanned field (e.g. skin, bladder epithelium, tissue culture), and a scaled-up model or "master" effector held by the operator. The model effector would be visually merged with a magnified virtual image from the scanner, giving the operator, holding the model effector, the ability to interact naturally with the virtual image in real time.