Image guidance of Focused Ultrasound

Ultrasound can be focused to interact with tissues and deliver drugs deep within the body, without damage to overlying tissues. Image guidance is important for targeting therapy, ensuring treatment and safety, and for assessing therapy. Ultrasound imaging, magnetic resonance imaging, optical imaging, and PET are all being developed and evaluated for these tasks. This presentation will describe some current research areas in the image guidance of focused ultrasound.

For tissue ablation, it is critically important to monitor tissue temperature. This is possible with both ultrasound imaging and MRI. A current research area concerns thermal ablations of moving organs, such as the liver and kidneys. We have developed a method for FUS ablation of abdominal organs including real-time MR thermometry, organ and transducer tracking, and beam steering.

There are a number of methods under investigation for the visualization of ablated tissue. Both ultrasound-based and MR-based acoustic radiation force imaging (ARFI) methods are potential candidates. ARFI relies on tissue displacement by the ultrasound beam, which is related to the tissue stiffness. Evaluating the change in tissue stiffness provides the spatial extent of the thermal ablation. Other evaluative imaging includes contrast enhanced MRI, which visualizes disruption of perfusion, and diffusion-weighted MRI, which demonstrates a 30% decrease in ADC in the ablated tissue.

The displacement visualized with ARFI is also proportional to the ultrasound intensity. Therefore, visualization of the focal spot can be done without a significant temperature rise. In the MR-guided neurosurgical applications of focused ultrasound, this could allow the focal spot to be visualized more safely than with a small temperature rise required for MR thermometry visualization. In addition, it provides a means for image feedback when correcting phase aberrations from the skull.

For drug delivery, image monitoring of delivery is being developed with MRI, PET, and optical imaging. Blood-brain barrier opening can be detected with uptake of a gadolinium contrast agent on MR-images. Investigators at UC Davis have shown that the drug shell can be visualized with PET, while the contents are visualized with optical imaging, to enable visualization of the drug release.

Learning Objectives

1. Understand the basis for acoustic radiation force imaging and its applications
2. Understand the current research in the image guidance of focused ultrasound