

MR-HIFU

Kullervo Hynynen, Ph.D.

Dept of Med Biophysics, University of Toronto
Sunnybrook Health Sciences Centre, Room S-6-65b,
2075 Bayview Avenue
Toronto, Ontario, Canada, M4N 3M5

High Intensity Focused Ultrasound (HIFU) is a noninvasive method to deliver highly concentrated energy deep in the body and it has been explored for tissue ablation for over half a century. The basic mechanism used for tissue ablation is temperature elevation that results in thermal coagulation of the tissue at the focus. A safe clinical use requires that the focus is guided by an imaging method. Magnetic Resonance Imaging (MRI) provides such features as excellent soft tissue contrast, temperature sensitivity and ability to detect thermally coagulated tissue, that make it well suited for the guidance, control, and monitoring of thermal therapies. The treatment of uterine fibroids with MRI guided HIFU has been approved by the FDA and is on its way to becoming routine. In addition there are several clinical reports demonstrating the feasibility of MR-HIFU for the treatment of brain, breast, bone, liver, and prostate tumors. Pre-clinical testing of endocavity devices shows promise for the treatment of esophageal cancers and potential for cardiac ablation.

There is now an increasing amount of evidence that focused ultrasound exposures have much a wider use than simply thermal ablation of tissues for surgical purposes. It has been shown that low thermal exposure controlled by MRI can be used to locally release therapy agents from temperature sensitive carriers or turn on gene therapy only in the heated tissue volume. Thus MR-HIFU can be used to localize an intervention that can change or cure tissue function.

Animal experiments have shown that HIFU exposures can induce transient and local increase in the cell membrane or blood vessel wall permeability. This may allow localization of the treatment based on imaging information on the anatomy, physiology or function. This potential for delivering large molecules into an image defined location has especially high potential brain where the Blood-Brain barrier (BBB) prevents the diffusion of most therapeutic and imaging agents in to the brain from the blood vessels. MR-HIFU has now been explored by several research groups for the disruption the blood-brain barrier for targeted delivery of molecules such as antibodies and chemotherapeutic agents in the brain. Similarly recent reports have demonstrated that HIFU can stimulate or inhibit neurons thus providing a tool for brain research and potential treatments. Therefore, MRI-HIFU coupled with the development of phased array methods for focusing ultrasound exposures through intact skull may have significant potential in the future clinical patient care.

In this talk the basic principles of MR-HIFU devices will be described and the current status of clinical devices reviewed. Finally, the potential future applications will be summarized and the technology requirements discussed.