Ultrasound has been widely used in healthcare for diagnostics and some rehabilitation applications. In the past 2 decades, use of ultrasound has gained widespread importance for non-invasive and minimally invasive therapy to treat tumors and other major illnesses. The first FDA approved treatment for uterine fibroids was in 2004. Since then, there have been more FDA approvals for bone metastases, prostate cancer, essential Tremor (Parkinson’s), etc. The number of clinical and preclinical trials have also grown in huge numbers around the world for other treatments include liver and pancreatic cancer, brain tumor, hypertension, glaucoma, breast tumor, depression, coma, etc. Deep brain stimulation (DBS) is an invasive procedure for Parkinson’s tremor that requires extensive surgery while the newly FDA approved (2016) MR-guided Focused Ultrasound (MRgFUS) can treat patients with Parkinson’s tremor in a non-invasive manner.

Focused ultrasound is being currently investigated for tissue ablation, drug delivery, immunomodulation, and radiation. For tissue ablation, there are two main mechanisms that are primarily used – thermal ablation (localized hyperthermia) and histotripsy (acoustic cavitation). Localized hyperthermia relies on increasing the temperature of tissue to implement cell death resulting in ablation. Thermal ablation does require careful treatment protocols to avoid damage to surrounding tissue since there is a temperature gradient through the whole treatment zone. Histotripsy on the other hand is more tissue specific and can cause more localized ablation without damage to surrounding tissue. But, it requires generation of very high negative peak pressures. The understanding of material properties, tissue interaction, and the transducer design can be a challenge for histotripsy applications. For example, frequency compounding is a key technique used to increase the peak negative pressure for histotripsy that allows increase in amplitude of peak negative pressures within a particular frequency band. For transcranial ultrasound treatments, ultrasound has to be applied through the skull at a critical angle to have optimized transmission. Frequency compounding and beamforming are important techniques for transcranial based focused ultrasound treatments.

Along with MRgFUS, ultrasound guided focused ultrasound treatments (USgFUS) are also gaining popularity but so far no treatment has resulted in FDA approval. Combined ultrasonic imaging and therapy transducers are key for visualization of the treatment and assuring minimum deviation from the targeted treatment envelope. The development of combined imaging and therapy transducers is a major challenge.

This presentation will focus on the latest ultrasound-based therapeutic treatments, key aspects of their treatment mechanisms, major challenges, and advances in piezoelectric materials and transducers that have enabled the various focused ultrasound treatment options and also the challenges that we still need to overcome to make HIFU treatments widely available.