Purpose: Histotripsy is an exciting new mechanism for ablating tissue in that it completely emulsifies tissue, leaving nothing behind but a liquid-like slurry. Although clinical applications of this approach are still to be tested, it offers high promise for the use of High Intensity Focused Ultrasound (HIFU) for therapy. Accordingly to the conventional approach, short (microsecond-length) pulses of very high amplitude ultrasound are used to induce intense cavitation, which mechanically disrupts the tissue. We have developed an approach that involves longer (millisecond-length) pulses. These high amplitude pulses develop into shock waves that induce superheated boiling in the tissue, resulting in very efficient tissue emulsification.
Methods. Experiments have been undertaken in a variety of tissues and tissue phantoms; we particularly prefer transparent tissue mimicking materials that permit high-speed photography. Histotripsy lesions (essentially holes in tissue) were generated in these materials under acoustic exposures that have been reported in clinical applications. Imaging modalities include MR, ultrasound, and high-speed photography.
Results. When ultrasound imaging is used to examine HIFU-induced, thermal-lesion formation, the appearance of hyperechogenicity often occurs. Although this hyperechogenicity has typically been associated with the occurrence of cavitation, we have determined that cavitation seldom generates enough backscatter to be detectable; rather, hyperechogenicity is more often associated with boiling. In particular, we have observed that when the HIFU intensity is sufficiently high that shock formation occurs, boiling can occur in milliseconds. The appearance of a hyperechoic echo is an accurate focus monitoring technique. Modeling, using weak shock theory, supports this occurrence of boiling. The time-to-boil can accurately be predicted by modeling and is very reproducible.
Conclusions: Histotripsy can be generated by shock-wave-induced boiling, an approach that offers many attractive features.