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Cavitation in ultrasound and shockwave therapy[1]

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Acoustic waves, especially high-intensity ultrasound and shock waves, are used for medical imaging and intra- and extra-corporeal manipulation of cells, tissue, and urinary calculi. Waves are currently used to treat kidney stone disease, plantar fasciitis, and bone nonunion, and they are being investigated as a technique to ablate cancer tumors and mediate drug delivery. In many applications, acoustic waves induce the expansion and collapse of preexisting or newly cavitating bubbles whose presence can either mediate the generation of localized stresses or lead to collateral damage, depending on how effectively they can be controlled. We describe efforts aimed at simulating the collapse of bubbles, both individually and in clusters, with the aim to characterize the induced mechanical stresses and strains. To simulate collapse of one or a few bubbles, compressible Euler and Navier-Stokes simulations of multi-component materials are performed with WENO-based shock and interface capturing schemes. Repetitive insonification generates numerous bubbles that are difficult to resolve numerically. Such clouds are also important in traditional engineering applications such as caveating hydrofoils. Models that incorporate the dynamics of an unresolved dispersed phase consisting of the bubble cloud are also developed. The results of several model problems including bubble collapse near rigid surfaces, bubble collapse near compliant surfaces and in small capillaries are analyzed. The results are processed to determine the potential for micron-sized preexisting gas bubbles to damage capillaries. The translation of the fundamental fluid dynamics into improvements in the design and clinical application of shockwave lithotripters will be discussed.

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