Numerical investigation on cavitation induced blood vessel injury during ultrasound treatments

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# Abstract

Cavitation in medical applications is increasingly used for kidney stone structure in shock wave lithotripsy (SWL), drag and gene delivery through encapsulated bubbles, blood brain barrier (BBB) permeability and in high intensity focused ultrasound (HIFU) among others. Despite the beneficial use of cavitation in these procedures, the exact mechanism of the adverse effects that are being reported, such as hemorrhage, still remain unknown. In this work, we present numerical simulations of cavitation induced soft tissue interaction/injury during ultrasound treatments, using an explicit density-based solver (ForestFV) that is able to capture multi-phase, fluid-solid interactions (FSI) in various spatial and temporal scales using an adaptive mesh refinement (AMR) framework for unstructured grids. Namely three different configurations are investigated. In the first cases, a novel tension driven tissue injury mechanism is highlighted for the inertial collapse of attached and detached bubbles on soft tissue. In the next configuration, we demonstrate that the resulting liquid jet from a collapsing bubble can penetrate a blood vessel wall and cause hemorrhage, a typical side effect during high intensity ultrasound. Finally, in the last cases, we present large scale oscillations of bubbles within a capillary the stress development inside the soft tissue wall, as well as the injury potential of stable cavitation to various blood vessels.