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Numerical simulation of shock wave generation and focusing in shock wave lithotripsy

Jeffrey Krimmel and Tim Colonius
California Institute of Technology, 1200 E. California Blvd, Pasadena, CA 91125, USA

Shock wave lithotripsy is a procedure where focused shock waves are fired at kidney stones in order to pulverize them. Lithotripters with different source mechanisms and reflector shapes (or lenses) are in clinical use, but prediction of focal region pressure is made difficult by nonlinearity and cavitation. We report on development of a numerical simulation framework aimed at accurate prediction of focal region pressures and bubble dynamics. Shock wave generation and beam focusing are simulated via the Euler equations with MUSCL-type shock-capturing scheme and adaptive mesh refinement (AMR). Electrohydraulic, electromagnetic, and piezoelectric-array lithotripters are modeled with axisymmetric geometries. In the electrohydraulic case, an expanding bubble model simulates spark firing. In the piezoelectric case, a boundary condition prescribing the motion of individual elements is used. Calculated peak pressures and pulse widths agree well with experimental data for the electrohydraulic and electromagnetic lithotripters. For the piezoelectric case, peak pressures are increasingly over-predicted by the model when more elements are fired, and reasons for this discrepancy will be discussed. Finally, we compare the spatial and temporal characteristics of the focal pressure fields for several clinical lithotripters in the context of observed stone comminution efficacy and tissue damage.
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