NUMERICAL MODELLING OF SHOCK WAVE INTERACTIONS WITH KIDNEY CELLS

Dongli Li, Robin Cleveland and Antoine Jérusalem

Department of Engineering Sciences, University of Oxford, Parks Road, Oxford, OX1 3PJ,
dongli.li@eng.ox.ac.uk; robin.cleveland@eng.ox.ac.uk; antoine.jerusalem@eng.ox.ac.uk

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Shock waves are used medically for lithotripsy (i.e., fragmenting kidney stones) and the treatment for musculoskeletal indications. Shock waves also show great potential in cancer therapy where they can be used to mechanically destroy tumour cells or enhance sonoporation to effect therapeutic drug delivery. The mechanisms by which shock waves interact with cells are poorly understood. We present a numerical work aimed at understanding the interaction between shock waves and tissue at the cellular level. In lithotripsy, the goal is to minimise soft-tissue injury–an unwanted side-effect from the procedure. For the other therapeutic applications including cancer treatment, the focus is on understanding the associated mechanics and optimising the therapeutic effect on the target cells whilst minimising the impact on healthy cells. This work focuses initially on kidney tissue which has both lithotripsy and cancer applications, however, the model can be extended to other organs. A continuum framework is used here to model the kidney cell with differentiated nucleus, cytoplasm and membrane mechanical properties. The cell is embedded in kidney tissue, and the cell geometry is extracted from fluorescent microscopic images of a Madin Darby canine kidney (MDCK) cell. The pressure loading is a shock wave profile defined from experimental measurements at the focus of a Dornier HM3 lithotriptor. The response of the cell was analysed in terms of the volumetric and deviatoric deformation of different cell components, as well as membrane surface strain. The simulation results predict that shock waves produce a focused pressure on the distal surface of the cell and that the volumetric and deviatoric impedance mismatch, cell geometry and the variations in tissue viscosity are not only affecting the maximum pressure or von Mises stress inside the different cell components, but also their locations.