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Boundary integral simulations of a red blood cell squeezing through a submicron slit under prescribed inlet and outlet pressures[1]

ZHANGLI PENG, HUIJIE LU, University of Notre Dame, ALEXIS MOREAU, EMMANUELE HELFER, ANNE CHARRIER, ANNIE VIALLAT, CNRS Aix Marseille University, France — We developed a boundary integral formulation to simulate a red blood cell (RBC) squeezing through a submicron slit under prescribed inlet and outlet pressures. The main application of this computational study is to investigate splenic filtrations of RBCs and the corresponding in vitro mimicking microfluidic devices, during which RBCs regularly pass through inter-endothelial slits with a width less than 1.0 micrometer. The diseased and old RBCs are damaged or destroyed in this mechanical filtration process. We first derived the boundary integral equations of a RBC immersed in a confined domain with prescribed inlet and outlet pressures. A multiscale model is applied to calculate forces from the RBC membrane, and it is coupled to boundary integral equations to simulate the fluid-structure interaction. After multi-step verifications and validations against analytical and experimental results, we systematically investigated the effects of pressure drop, volume-to-surface-area ratio, internal viscosity, and membrane stiffness on RBC deformation and internal stress. We found that spectrins of RBCs could be stretched by more than 2.5 times under high hydrodynamic pressure and that the bilayer tension could be more than 500 pN/um, which might be large enough to open mechanosensitive channels but too small to rupture the bilayer. On the other hand, we found that the bilayer-cytoskeletal dissociation stress is too low to induce bilayer vesiculation.

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Huijie Lu
University of Notre Dame

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