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Shape optimisation for faster washout in recirculating flows[1]
JESSICA WILLIAMS, Massachusetts Institute of Technology, FLORIAN WECHSUNG, New York University, BENJAMIN TURNEY, SARAH WATERS, DEREK MOULTON, University of Oxford — How to design an optimal biomedical device to minimise trapping of undesirable biological solutes/debris is a pertinent but complex question. We address this challenge, deriving particular motivation from *ureteroscopy*, a minimally invasive surgical procedure for the removal of kidney stones by irrigating dust-like stone fragments with a saline solution.
We represent the renal pelvis as a 2D cavity and model fluid flow with the steady, incompressible Navier–Stokes equations. Within this modelling framework, the presence of vortices – which arise as a result of flow symmetry breaking – has previously been linked to long washout times of kidney stone dust; modelled via advection and diffusion of a passive tracer.
For a given flow field $\mathbf{u}$, vortices are characterised by regions where $\det \nabla \mathbf{u} > \mathbf{0}$. Thus, integrating a smooth form of $\max(0, \det \nabla \mathbf{u})$ over the domain provides an objective to minimise recirculation zones. We employ adjoint-based shape optimisation to identify ureteroscope tip geometries that reduce this objective. We show that a reduction in the vortex objective correlates with a reduction in washout time, and hence determine tip shapes which result in reduced washout times.

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