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A biomechanical model of the asthmatic airway

When asthmatics come in contact with agonists (e.g. cold air, chemicals or dust), the smooth muscle in the walls of their lung airways contracts, causing wheezing and other breathing difficulties. Over long periods there is also substantial thickening of the muscular airway wall. Mathematical modelling has significant potential to offer insights into the interactions between the signalling pathways that initiate smooth muscle contraction, the mechanical action of cross-bridges within smooth muscle that leads to contraction of the airway and surrounding tissue, and the longer-term impact of wall remodelling on airway function. Here we address some of the mechanical aspects of this problem by modelling an airway as a two-layer annulus in plane strain. The inner layer, representing the airway wall, is modelled as a nonlinear incompressible fibre-reinforced material. The outer layer, representing the surrounding parenchyma, is modelled as a linear compressible viscoelastic material. Airway deformations are induced either by imposing external stresses or via active forces generated in the inner muscular layer. When passively inflated, the airway wall exhibits strain-stiffening and creep. The model reveals differences in patterns of deformation depending on whether inflation is driven by stresses on the inner or outer boundary (reflecting differences between artificial and natural ventilation). The model also shows significant stress gradients across thickened airway walls. Initial results coupling wall and muscle mechanics will also be discussed.