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Numerical model of the human trachea based on layer specific material models: application to healthy, diseased and stented trachea.

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Tracheomalacia and tracheal stenosis are two main types of tracheal disorders which severely affect breathing. Numerical simulations help understand the intricate changes that occur in the tissue's mechanical behavior, which is critical for developing synthetic prosthesis for instance. However, in order to perform accurate simulations, we need an accurate representation of the tissue's geometry, the in-vivo boundary conditions, and its mechanical response. Although the first two conditions are generally met to a satisfactory extent, there is a pressing need to improve the representative material models [1]. In addressing that gap, this study will focus on acquiring layer specific material models from experiments and incorporate them into finite element models for understanding mechanics of the trachea.

Relevant hyperelastic strain energy density models were identified for each component of the trachea following biaxial tension testing ($n = 3$). Apart from the cartilage, all other tissue components exhibited a non-linear anisotropic mechanical response. The cartilage was therefore represented with a Neo-Hookean solid. The anisotropy exhibited by other components was represented by a Holzapfel model [2], with planar collagen fiber dispersions inducing the anisotropy. In the next step, the finite element model of the trachea was generated using CT-scan images of a human subject. The images were processed in Mimics (Materialize, Leuven, Belgium), using the advanced image-processing modules to segment the trachea and render a 3-d mesh for numerical simulations.

Preliminary results show that the cartilage is the stiffest component of the trachea, hence largely governs its mechanical behavior. The proposed material models for each tissue component showed good agreement w.r.t. the inversely identified material parameters. Using this information in conjunction with the developed mesh, the numerical simulations will analyze the biomechanics of the trachea under several conditions.

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