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PERSONALIZED PULMONARY POROMECHANICS IN HEALTH AND IDIOPATHIC PULMONARY FIBROSIS

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Lung biomechanics has been extensively studied by physiologists, experimentally as well as theoretically, laying the ground for our current fundamental understanding of the relationship between function and mechanical behavior. However, many questions remain, notably in the intricate coupling between the multiple parenchymal constituents. These fundamental questions represent real clinical challenges, as pulmonary diseases are an important health burden. Interstitial lung diseases, for instance, affect several million people globally. Idiopathic Pulmonary Fibrosis (IPF), notably, a progressive form of interstitial lung disease where some alveolar septa get thicker and stiffer while others get completely damaged, remains poorly understood, poorly diagnosed, and poorly treated. We recently developed a model of the lungs at the breathing time scale and the organ space scale, where the “solid” phase is composed of both tissue and blood while the fluid phase is the air. Several pulmonary-specific hypotheses have been formulated, notably that the end-inhalation and end-exhalation states are in static equilibrium. Moreover, specific boundary conditions are imposed on the lungs themselves, modeling the effect of diaphragm-induced loading and rib cage: a pressure applied on lung surface representing pleural pressure, and a frictionless contact with the moving thorax. Moreover, the constitutive behavior allows to reproduce the volumetric response of lungs to a change of pressure as observed in experimental data. The proposed model can be personalized using clinical data. From two 3D CT-scans, acquired at end-exhalation and at end-inhalation, we obtain a personalized geometry through image segmentation, a personalized porosity, personalized motion & boundary conditions through image registration. Such data allow also to personalize regional mechanical parameters by minimizing the discrepancy between measured and computed motion. We will present results based on control and patient data. Notably, we will show that the model and estimation procedure can quantify the regional tissue stiffening induced by idiopathic pulmonary fibrosis. Our results illustrate how our pulmonary poromechanical model can be used as a diagnosis tool in the clinic when it is personalized to a patient using clinical data acquired in standard protocols.

References

- [1] Chapelle D & Moireau P (2014). General coupling of porous flows and hyperelastic formulations—From thermodynamics principles to energy balance and compatible time schemes. *European Journal of Mechanics Part B: Fluids*, 46, 82–96. <https://doi.org/10.1016/j.euromechflu.2014.02.009>
- [2] Fetita C, Kim Y-W, Tarando S R & Brillet P-Y (2019). Image biomarkers for quantitative analysis of idiopathic interstitial pneumonia. In H. K. Hahn & K. Mori (Eds.), *Medical Imaging 2019: Computer-Aided Diagnosis* (p. 44). SPIE. <https://doi.org/10.1117/12.2511847>
- [3] Genet M, Stoeck C T, von Deuster C, Lee L C & Kozerke, S. (2018). Equilibrated Warping: Finite Element Image Registration with Finite Strain Equilibrium Gap Regularization. *Medical Image Analysis*, 50, 1–22. <https://doi.org/10.1016/j.media.2018.07.007>
- [4] Nunes H, Schubel K, Piver D, Magois E, Feuillet S, Uzunhan Y, Carton Z, Tazi A, Levy P, Brillet P-Y, Nicholson A G, Kambouchner M & Valeyre D (2015). Nonspecific interstitial pneumonia: Survival is influenced by the underlying cause. *European Respiratory Journal*, 45(3), 746–755. <https://doi.org/10.1183/09031936.00148613>
- [5] Patte C, Genet M, Fetita C, Brillet P-Y & Chapelle D (2019). Mécanique pulmonaire personnalisée: Modélisation et estimation—Application à la fibrose pulmonaire. 15ème Colloque National En Calcul de Structures (CSMA). <https://hal.archives-ouvertes.fr/hal-02068920>
- [6] Patte C, Genet M & Chapelle D. A quasistatic poromechanical model of the lungs. In *Revision at Biomechanics and Modeling in Mechanobiology*.