X-RAY CT ASSESSMENT OF LUNG FUNCTION AND BIOMECHANICS

Sam Bayat

Univ. Grenoble Alpes, STROBE Laboratory, Inserm UA07, Grenoble, France
Grenoble University Hospital, Dept. of Pulmonology & Clinical Physiology, Grenoble, France

Background

The lung is a complex, over-engineered organ comprising airways, blood vessels and parenchymal tissue. To ensure its main function of gas exchange, the lung constantly undergoes structural deformation through breathing and pulsatile blood flow. The biomechanical properties of viscoelastic respiratory tissues play a crucial role in both normal physiology and in diseases. For example, mechanical ventilation of patients with acute respiratory failure can cause excessive stress and strain and energy dissipation within the parenchyma leading to injury, which significantly contributes to mortality, a condition referred to as Ventilator-Induced Lung Injury (VILI)[1]. The multiscale interaction of all the components that constitute the lung leads to a complex dynamic behaviour where lung function as a whole is not the sum of the behaviour of its individual components. Elucidating the lung microstructure and micromechanics *in vivo* in health and disease remains very challenging. X-ray CT is the state-of the-art modality for imaging lung morphology. In the past decades, elastic image registration methods have been used to assess local lung biomechanics. However, clinical CT is limited in its spatial resolution. Synchrotron phase-contrast and K-edge subtraction CT offer unmatched capabilities in assessing local lung micromechanics and function, respectively. Although these techniques are not yet available in the clinical setting, they promise to further our understanding of lung biomechanics in experimental models.

Recent Advances

We previously introduced an energy-subtractive synchrotron CT technique that allows imaging regional lung function with unequalled spatial resolution in vivo in small animals[2]. More recently, we have developed a synchrotron phase-contrast 4D-µCT technique that allows the *in vivo* assessment of local lung strain under mechanical ventilation in both the parenchyma and blood vessels[3] (Figure 1). In the clinical setting, work is underway to assess local lung biomechanical biomarkers in mechanically-ventilated patients with acute respiratory distress syndrome (ARDS) due to Covid-19, using advanced CT image processing methods, and to study their association with clinical outcome.

Future directions

Synchrotron phase-contrast 4D-µCT is being used to assess lung micromechanics in disease models where it plays a critical role, such as VILI and fibrosis, where better understanding of the consequent lung extracellular matrix alterations and inflammation can offer new therapeutic and preventive opportunities. In the clinical arena, lung biomechanical parameters from patients with ARDS can be used to inform in silico lung models used to personalize mechanical ventilation settings for optimal lung protection, through "offline" simulation.

Sam Bayat is currently Professor of Physiology at the University of Grenoble. He is an MD and obtained his PhD in Biomedical Instrumentation and Modelling at the University of Grenoble in 1998. He was a post-doctoral fellow and Visiting Scientist at the European Synchrotron Radiation Facility in 2003-2004 and invited professor at the University of Geneva in 2015 - 2017. He is chair of the Clinical Respiratory Physiology, Exercise and Functional Imaging group of the European Respiratory Society and member of the European Society of Molecular Imaging and the American and French Physiological Societies. His present research mainly focuses on lung functional imaging and biomechanics. He is an author of over 90 publications in peer- reviewed journals, 4 book chapters and more than 100 contributions to International and National Conferences.

Figures

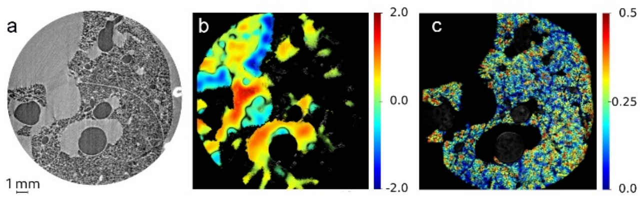

Figure 1: Quantitative mapping of lung tissue biomechanics in a live rat at 6 µm^3 *resolution. Sample X-ray phase-contrast CT image at 42 ms from start of inspiration (**a**); regional strain as a function of time computed within blood vessels (**b**) and airspaces (**c**). Modified from*[3].

References

1. Slutsky, A. S. *et al. N Engl J Med* 369, 2126-36, (2013).
2. Bayat, S. *et al. Front Physiol* 13, 825433, (2022).
3. Cercos-Pita, J.-L. *et al. Scientific Reports* 12, 1-11, (2022).

Acknowledgements

Alberto Bravin, Ludovic Broche, José Luis Cercos-Pita, Richard Deyhle, Luca Fardin, Irma Mahmutovic, Lars E. Olsson, Maciej Orkisz, Gaetano Perchiazzi, Jean-Christophe Richard, Mehdi Shekarnabi.