



HAL
open science

How magnetic resonance elastography (MRE) could provide biomechanical property to complete computed tomography (CT) scan lung diagnostic?

M K Chakouch, P Pouletaut, F Charleux, S F Bensamoun

► To cite this version:

M K Chakouch, P Pouletaut, F Charleux, S F Bensamoun. How magnetic resonance elastography (MRE) could provide biomechanical property to complete computed tomography (CT) scan lung diagnostic?. 48ème congrès de la Société de Biomécanique, Société de Biomécanique, Oct 2023, Grenoble, France. hal-04156906

HAL Id: hal-04156906

<https://hal.science/hal-04156906>

Submitted on 10 Jul 2023

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Public Domain

How magnetic resonance elastography (MRE) could provide biomechanical property to complete computed tomography (CT) scan lung diagnostic?

M.K. Chakouch^a, P. Pouletaut^a, F. Charleux^b, S.F. Bensamoun^{a*}

^a Sorbonne University, Université de Technologie de Compiègne, UMR CNRS 7338 Biomechanics and Bioengineering, Compiègne, France

^b ACRIM-Polyclinique Saint Côme, Radiologie Médicale, Compiègne, France

1. Introduction

Currently, the detection of pulmonary fibrosis is performed with computed tomography (CT) scan that uses radiation. From this test, subjective morphological data, with inter and intra operator variability, is obtained (Chassagnon et al. 2018). There is an important need to objectively and non-invasively quantify pulmonary fibrosis to better observe the effect of treatment and undertake the follow-up of disease. Thus, one alternative is Magnetic Resonance Elastography (MRE) that is a non-invasive technique, based on the application of motion encoding gradients (MEG) to estimate the shear modulus parameter, allowing the quantification of the biomechanical properties of different soft tissues. Other MRE parameters such as the damping ratio, the attenuation, etc. have been correlated to the physiological and structural properties of the tissue, demonstrating that additional MRE markers could provide complementary information. While the liver is the first organ approved for clinical MRE test (Pouletaut et al. 2023), additional MRE research protocols are extensively developed for the brain, kidney, prostate, muscle (Debernard et al. 2011; Chakouch et al. 2022). The COVID-19 pandemic has spurred research in the characterization of the lung tissue (Chakouch et al. 2022). Thus, the purpose of the study is to combine different imaging techniques to demonstrate the relevant biomechanical property that can be provided by MRE test.

2. Methods

2.1 Computed Tomography (CT) scan

Patients (N=10) had a CT scan to monitor a cough, the impacts of tobacco, asbestos, etc. Lung CT

images have been acquired with multi-detector row on General Electric (GE) machine (Figures 1A-1B).

Patients were examined during a single breath-hold and the following parameters were applied for the thoracic CT acquisition: FOV: 43 x 43 cm²; matrix: 512 x 512; voxel size: 0.84 x 0.84 x 0.625 mm³; slice thickness: 0.625 mm; 100 - 140 kV according to the patient's weight. A radiologist read all CT acquisitions.

2.2 Magnetic Resonance Elastography (MRE)

MRE tests were performed, at the same slice level as the CT scan, by using spin-echo echo-planar imaging (SE-EPI) sequence on a 1.5 T MRI GE machine to obtain 4 axial slices of the lungs.

The scan time was 22 s at breath-hold. A round pneumatic driver, used for MRE liver (Leclerc et al. 2013), was placed on the right lung. It is connected to a plastic tube where an air pressure is induced at a frequency of 50 Hz using an acoustic speaker system.

The MRE pulse sequence including a motion-encoding gradient, which oscillated in the Z direction, was used to image the displacement of the shear waves. The phase images were recorded with the following parameters: FOV: 48 x 48 cm²; TR: 250 ms; slice thickness: 15 mm; number of axial slices: 4; voxel size: 3.75 x 3.75 x 15 mm³; matrix: 128 x 128; 4 phase offsets.

To measure the lung biomechanical properties different steps are followed: 1) a region of interest is drawn to select only the right lung to avoid the heart motion, 2) the apparent lung shear modulus is calculated from the phase images using multi-model direct inversion (MMDI) and a specific post-processing (Silva et al. 2015), and then 3) corrected with the cartography of the density hereafter described.

2.3 Lung density

The shear modulus being proportional to the density, a cartography of lung density for each patient is necessary to obtain a true cartography of the shear modulus (Figures 1C-1D).

MRI was performed at breath-hold, at the same slice level as the CT scan, with a fast gradient recalled echo (GRE) sequence (Holverda et al. 2011) and a TR: 15 ms, from which the initial signal of the lung was estimated. Then, the lung density was obtained in reference to a Gadolinium-doped water phantom (Figures 1C-1D) placed on the chest. The MRI acquisition is realized with: FOV: 48 x 48 cm²; voxel size: 7.5 x 7.5 x 15 mm³; matrix: 64 x 64; slice thickness: 15 mm; and flip angle: 10°.

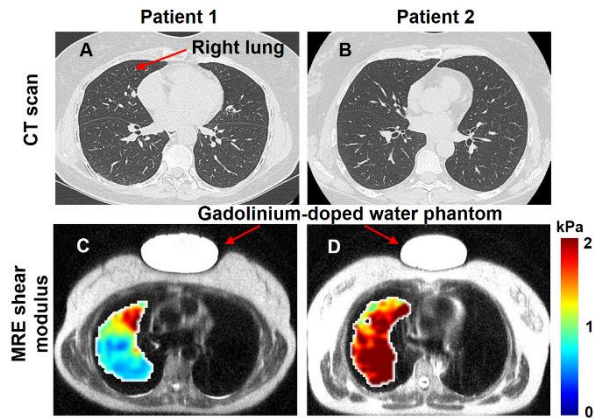


Figure 1: Example of two patients among the cohort with lung axial CT scans (A-B) and MRE shear modulus cartographies (C-D) of the right lungs. Red arrows show the localization of the gadolinium-doped water phantom.

3. Results and discussion

Figures 1A and 1B show an example of CT scan results obtained for two patients with unknown lung disease. No detectable solid mass or any other lung disease was identified on both CT scans, leading to the conclusion that the two patients have healthy lungs.

The figures 1C and 1D show the results of the true MRE cartographies of the shear modulus tests obtained for the two patients. The mean shear modulus for patient 1 and patient 2 are 1.15 ± 0.58 kPa and 2.40 ± 0.82 kPa, respectively. The value obtained for patient 1 is in agreement with the literature for healthy lung (Fakhouri et al. 2022). However, patient 2 revealed a higher shear modulus indicating a pathological biomechanical property of the tissue.

To summarize, the CT scans for both patients had healthy structural properties but the MRE tests have highlighted different biomechanical behaviors. This result shows possible benefits of the MRE tests which can provide complementary information to better diagnose the lung tissue.

4. Conclusions

This study has showed that MRE test could become a non-invasive lung diagnostic tool, allowing the quantification of the lung shear modulus, a potential biomechanical marker of lung disease. In perspective, the CT scan parameters could be correlated to the MRE parameters to predict the evolution of the lung disease. In addition, MRE protocol must be further enhance for the biomechanical characterization of the both right and left lungs. The present study shows the potential interest of MR elastography in the regular care of lung disease and paves the way for other lung applications.

Acknowledgements

This work was supported by the European React'EU recovery plan.

References

- Chakouch M, Charleux F, Pouletaut P, Bensamoun SF. 2022. MR elastography of the human lung. *State of the Art in Bioengineering*. 2(1).
- Chassagnon G, Martin C, Burgel PR, Hubert D, Fajac I, Paragios N, Zacharaki EI, Legmann P, Coste J, Revel MP. 2018. An automated computed tomography score for the cystic fibrosis lung. *European Radiology*. 28(12):5111-5120.
- Debernard L, Robert L, Charleux F, Bensamoun SF. 2011. Characterization of muscle architecture in children and adults using magnetic resonance elastography and ultrasound techniques. *Journal of Biomechanics*. 44(3):397-401.
- Fakhouri F, Kannengiesser S, Pfeuffer J, Gokun Y, d Kolipaka A. 2022. Free - breathing MR elastography of the lungs: An in vivo study. *Magnetic Resonance in Medicine*. 87(1):236-248.
- Holverda S, Theilmann RJ, Sá RC, Arai TJ, Hall ET, Dubowitz DJ, Prisk GK, Hopkins SR. 2011. Measuring lung water: Ex vivo validation of multi-image gradient echo MRI. *Journal of Magnetic Resonance Imaging*. 34(1):220-224.
- Leclerc GE, Charleux F, Robert L, Ho Ba Tho MC, Rhein C, Latrive JP, Bensamoun SF. 2013. Analysis of liver viscosity behavior as a function of multifrequency magnetic resonance elastography (MMRE) postprocessing. *Journal of Magnetic Resonance Imaging*. 38(2):422-428.
- Pouletaut P, Boussida S, Ternifi R, Miette V, Audière S, Fournier C, Sandrin L, Charleux F, Bensamoun SF. 2023. Impact of Hepatic Iron Overload in the Evaluation of Steatosis and Fibrosis in Patients With Nonalcoholic Fatty Liver Disease Using Vibration Controlled Transient Elastography (VCTE) and MR Imaging Techniques: a Clinical Study. *Innovation and Research in BioMedical engineering (IRBM)*. 44(3):100750.
- Silva AM, Grimm RC, Glaser KJ, Fu Y, Wu T, Ehman RL, Silva AC. 2015. Magnetic resonance elastography: evaluation of new inversion algorithm and quantitative analysis method. *Abdominal Imaging*. 40(4):810-817.

Keywords: lung; biomechanical properties; magnetic resonance elastography; computed tomography; shear modulus.

***Corresponding author. Email:** sabine.bensamoun@utc.fr