Ultrasound-based shear wave MRE for the biomechanical characterization of complex soft tissues
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Background, Motivation and Objective
Magnetic Resonance Elastography (MRE) and Ultrasound-based dynamic Elasticity Imaging are both based on the measurement of the mechanical properties by investigating shear wave propagation in biological soft tissues [1,2]. Even though these techniques have potential complementary strengths, their combination has been rarely investigated [3,4]. The purpose of this study is to develop an ultrasound-based shear wave MRE approach, which combines localized harmonic shear waves generated by Acoustic Radiation Force (ARF) with MRE shear wave imaging. An innovative reconstruction process is used for the identification of the mechanical properties and application to fibrous tissues.

Statement of Contribution/Methods
A 256-elements MR-compatible focused ultrasound transducer driven at 1 MHz (Imasonic France) immersed in degassed water generates harmonic shear waves (100 or 200 Hz) (figure A). The shear wave propagation is observed in a (X,Y) plane orthogonal to the axial direction Z of the transducer using a spoiled gradient echo sequence with motion-sensitizing gradients in a 1.5T MRI scanner (Siemens Germany). The Green formalism and an automatic differentiation approach are used in a quantitative gradient method for shear wave inversion and reconstruction of the stiffness profile in anisotropic media (shear modulus $\mu$ as a function of the spatial direction $\theta$).

Results/Discussion
The protocol is successively applied to a transverse isotropic hydrogel phantom [5] and to an ex vivo beef muscle (figures B and C, respectively). The profiles (blue squares) are consistent with a theoretical transverse isotropic distribution (orange lines) [6] and allows identifying the anisotropic stiffness tensor. The mechanical identification using the gradient method benefits from the advantages of both ARF and MRE methods. While the use of ARF makes the generation of the shear waves controlled, the use of MRE allows for 3D characterization with isotropic resolution and quality. Although the Ultrasound-based shear wave MRE protocol is applied for anisotropy, its extension to further complex properties will be considered, such as viscoelasticity.


Figure. Harmonic shear waves are generated by a 1MHz ultrasound localized transducer in the tissue (A). The shear wave propagation is imaged using an MRE sequence and the stiffness profile is reconstructed using an identification process in a transverse isotropic hydrogel phantom (B) and in an ex vivo beef muscle (C).