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Quantification of nonlinear shear moduli in transversely isotropic medium: preliminary study *ex vivo* and *in vivo* on muscles

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Background, Motivation and Objective

Acoustoelasticity theory (AET) describes propagation of shear wave (SW) in uniaxially stressed medium and allows to retrieve nonlinear (NL) elastic coefficients of tissues. Regarding clinical diagnosis, studies showed that NL response of material's during mechanical tests is useful for the diagnostic of cancerous tissues. Our hypothesis is that NL parameters can be representative of the state of muscles. In previous work, AET in transverse isotropic medium was developed leading to 9 different configurations (cfigs.) (stress axis vs. fibers axis vs. SW polarization axis vs. SW propagation axis). In this work we propose to use 4 cfigs. (Fig.) to quantify these NL parameters *ex vivo* and *in vivo*.

Statement of Contribution/Methods

Ex vivo experiments were conducted on 4 *ilio psoas* muscles from 2 pigs. During step-by-step mechanical testing, SWS was quantified with a 6 MHz central frequency probe (SL10-2) driven by ultrafast ultrasound (US) device (Mach30, Supersonic Imagine). From the stress (σ) - strain (ϵ) curve obtained with the traction device (Instron 5969), the Young's modulus parallel ($E_{//}$) to fibers was retrieve. Then from 3 different cfigs. (3, 5 and 7), NL coefficients A , H , K were quantified.

In vivo experiments were performed with volunteers on *biceps braachi* after approval of the local ethic committee. Volunteers were seated with the arm fixed to an ergometer in order to control the muscle contraction and σ generated during stretching. By using a dedicated US sequence [1], $E_{//}$ was quantified when the probe was // to fibers axis at rest as well as shear moduli μ_{\perp} and $\mu_{//}$. Then axial ϵ of the muscle and SWS for two cfigs. (3 and 9) were measured every 5° increment of stretching angle, from 90° to 135° of elbow extension. ϵ was retrieved by comparing two US images between two stretching steps and allowed to compute the local σ by applying the Hooke's law. At last since only 2 acquisitions cfigs. are possible *in vivo* a combination (X and Y) of the NL coefficient was calculated and compared with the *ex vivo* data.

Results/Discussion

In *ex vivo* muscle, A , H , K were retrieved thanks to the 3 possible experimentations cfigs. *In vivo*, presented for only one volunteer in Fig., X and Y were retrieved and are in good accordance with them obtained *ex vivo*. This works paves the way to better understand muscle biomechanics and physics during contraction and force production.

