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In-vivo Cervical Intervertebral Disc Characterization by Elastography

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1. Introduction

Intervertebral disc (IVD) plays an important role in spine biomechanics. Its mechanical properties are a determinant aspect of the spine's physiological flexibility; alterations of these properties can be the sign or the cause of a disc disease. Magnetic resonance is currently the reference technique to assess cervical IVD (Gibson et al., 1986); it allows the evaluation of disc's morphology, water and collagen content. However, it is time consuming and difficult to include in clinical routine.

Shear wave elastography is a non-invasive technique to evaluate soft tissue's elasticity (Tanter et al., 2008). It measures the shear waves speed (SWS) in the tissue, which depends on its shear modulus and, under certain hypotheses, on its elastic modulus. It recently started being introduced in clinic for application to tissues such as muscles, prostate, liver and breasts.

Elastography was recently applied in vitro to measure IVD in oxtails; a repeatability of 7 % was determined, and a correlation was observed between SWS and disc stiffness in compression (Vergari et al., 2012. Vergari et al., Submitted). In vivo feasibility in humans, however, remained to be proven. In this study, elastography was applied in vivo to measure cervical intervertebral disc and determine measurement reliability.

2. Methods

Forty-seven healthy subject (21 females, 26 males, average age 37 ± 13 years (range 22-73) volunteered. They signed an informed consent and declared being free from back and neck pain and spinal or disc pathologies. Body mass index (BMI) was calculated as body mass/height². The subject lied down in supine position; elastographic images of the IVD were acquired (Aixplorer, Supersonic Imagine, France) with an 8 MHz linear ultrasonic probe placed transversally at the level of C6-C7 or C7-T1 disc. Three series of six second movies were acquired by one operator. On a subset of 5 subjects (24 ± 2 years old), movies were acquired by 3 operators in order to evaluate the operator-effect. Movie frames were processed with custom software developed in Matlab (Mathworks, Natick, MA, USA) to determine average SWS in a region of interest corresponding to the intervertebral disc. Correlations were analysed with Spearman's rank correlation coefficient ($\alpha = 0.05$), while repeatability and inter-operator reproducibility were determined according to norm ISO 5725-2:1994, which describes methods to determine these two parameters.

3. Results and Discussion

Measurement time was about 10 minutes for each subject, which is compatible with clinical application; Figure 1 shows an example of the images obtained. Global average SWS was 3.0 ± 0.4 m/s, ranging between 2.2 and 3.9 m/s; repeatability was 0.2 m/s (7 % coefficient of variation) while reproducibility was 0.3 m/s (10 %). These repeatability values are similar to those previously obtained in vitro in IVD (7-8 %, Vergari et al., 2012), but also to those obtained in muscles (5-8%, Lacourpaille et al., 2012).

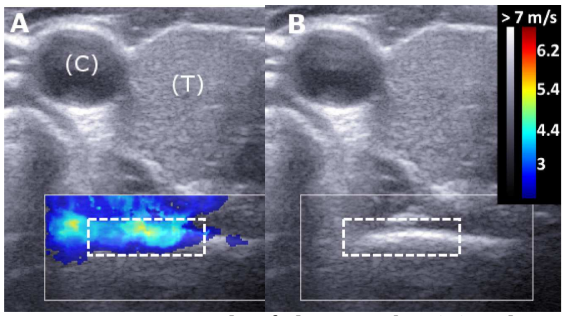

Figure 1. Example of elastographic (A) and ultrasonographic images (B) of IVD annulus fibrosus (dashed rectangle). Colour chart indicates SWS. (C): carotid artery, (T): thyroid.

No significant difference was observed between males and females ($p > 0.05$). A correlation was observed between SWS and BMI (Spearman's rho = -0.41, $p < 0.05$). The correlation with age was expected since it is well-known that IVD characteristics change with age (Lehto et al., 1994); signs of this physiological disc aging can already be detected at 20 years old.

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The correlation with BMI, on the other hand, was not initially expected, but associations between overweight (body mass index $\geqslant$ 25 kg/m^2) and disc degeneration have been previously reported for the lumbar spine (Liuke et al., 2005). However, this correlation could be indirect as BMI was correlated with age.

Two main limitations affect this study. First, subjects were included if free of back pain and known spinal pathologies; the status of their discs, however, was not assessed with other means (e.g., magnetic resonance). Since it has been previously shown that degenerated discs can often be asymptomatic, it is likely that some of the subjects which were included as healthy actually presented, to some extent, degenerated discs. This might alter the correlation shown in Figure 2, which therefore cannot be considered representative of the physiological aging of the disc alone, but also of asymptomatic pathological degradation. Work is currently being performed to do magnetic resonance imaging and elastography of the same subject to determine disc status and elastographic characteristics.

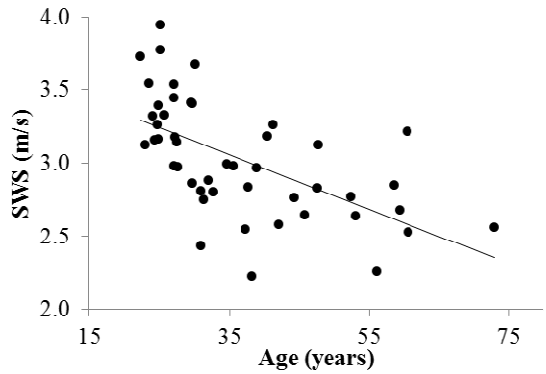

Figure 2. Correlation between SWS and subject age (N = 47, Spearman's rho = -0.68, p $\ll$ 0.05).

The second limitation is due to the fact that the elastographic device does not allow exporting raw data to process series of images, so custom software was developed for semi-automatic processing, which was performed by one operator. Placement of the region of interest on the IVD, in particular, could be operator-dependent. Future automation of data processing should limit this potential source of variability. Results of this study, however, demonstrated that the measurement itself was not operator-dependent.

4. Conclusions

In the present work, feasibility of in vivo characterization of cervical intervertebral disc was determined for the first time. Measurements were repeatable and did not depend on the operator; moreover, an age-effect was detected on SWS in IVD. These results open the way to the exploration of diseased intervertebral disc mechanical properties in vivo.

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