In vivo mechanical characterization of cervical intervertebral disc by shear wave elastography: a preliminary study

Claudio Vergari[1], Philippe Rouch[1], Dominique Bonneau[1], Guillaume Dubois[1], Jean Dubousset[1], Mickael Tanter[2], Jean-Luc Gennisson[2], Wafa Skalli[1]

[1]Arts et Métiers ParisTech, LBM, 151 bd de l'hôpital, 75013 Paris, France ;
[2]Institut Langevin, Ondes et Images, ESPCI ParisTech, CNRS UMR7587, INSERM U979, Paris, France

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 [1; 2]; however, while it allows the evaluation of disc's morphology, it currently gives no information on its mechanical properties.

Shear wave elastography is a recently developed technique to quantitatively determine mechanical properties of soft tissues [3]. It is ultrasound-based, fast and completely non-invasive, and it has already been successfully applied to organs such as breasts, liver and muscles. Preliminary *in-vitro* measurements in animal samples showed good repeatability and significant correlations between shear wave speed and disc's mechanical properties, which were measured by direct mechanical testing.

The present study represents the first *in vivo* application of shear wave elastography in humans. The aim of this study was to assess repeatability of shear wave elastography in healthy subjects and to start building a database of reference shear wave speeds.

Twenty-nine healthy subjects (13 women, 16 males, Table 1) volunteered in this study. Body mass index (BMI) was calculated; then, three series of six elastographic images of the C6-C7 or C7-T1 disc were acquired (Figure 1 and 2) with an Aixplorer (SuperSonic Imagine, Aix en Provence, France), using an 8 MHz linear probe.

Average shear wave speed was 2.9 ± 0.4 m/s (Table 1), with no significant difference between females and females ($p > 0.05$). Measurement precision, which was evaluated according to norm ISO 5725-2:1994, was 0.23 m/s, corresponding to 7.5 % in coefficient of variation. Correlations were observed between shear wave speed and both age (Spearman's rho = -0.75, $p < 0,01$) and BMI (Spearman's rho = -0.49 $p < 0.01$).

A decrease of shear wave speed with age corresponds to a decrease in IVD elastic modulus; this was expected, since mechanical properties of the disc are known to decrease with age and degeneration [4], although the apparent stiffness of the functional unit can increase because of disc thinning.

The results of this study are still preliminary, and it is still necessary to broaden the subject cohort to include patients with disc diseases and spine deformities. However, these results are encouraging, and they open the way for routine non-invasive characterisation of cervical IVD mechanical properties.

References

1. Watanabe A, Benneker LM, Boesch C, Watanabe T, Obata T, S.E. A (2007) Classification of Intervertebral Disk Degeneration with Axial T2 Mapping. American Journal of Roentgenology 189:936-942
2. Gibson MJ, Buckley J, Mawhinney R, Mulholland RC, Worthington BS (1986) Magnetic resonance imaging and discography in the diagnosis of disc degeneration. A comparative study of 50 discs. J Bone Joint Surg Br 68:369-373
3. Tanter M, Bercoff J, Athanasiou A, et al. (2008) Quantitative Assessment of Breast Lesion Viscoelasticity: Initial Clinical Results Using Supersonic Shear Imaging. Ultrasound Med Biol 34:1373-1386
4. Acaroglu ER, Iatridis JC, Setton LA, Foster RJ, Mow VC, Weidenbaum M (1995) Degeneration and aging affect the tensile behavior of human lumbar anulus fibrosus. Spine 20:2690-2701

Table 1. Subjects characteristics (n = 29) and main results

	Âge	Weight (kg)	Height (cm)	Body mass index (kg/m²)	Shear wave speed (m/s)
Global average (± SD)	35.5 ± 11.5	71.9 ± 13.9	174.1 ± 8.3	23.7 ± 3.9	2.9 ± 0.4
Average males	33.4 ± 10.6	79.7 ± 12.8	179.8 ± 6.6	24.8 ± 4.4	3.0 ± 0.5
Average females	38.1 ± 12.4	62.3 ± 8.1	167.2 ± 3.6	22.3 ± 2.8	2.9 ± 0.4