Intervertebral Disc Modeling

The intervertebral disc (DIV) is an heterogeneous complex structure which ensures the spine mobility and allows an homogeneous repartition of the mechanical strains exerted on the vertebral bodies. These characteristics are du to a high level of the water content and to the high molecular weight of specific macro molecules named proteoglycans(PG). PG are electro negative and they attract the water molecules: they so generate the osmotic pressure in the disc which counterbalances the hydraulic pressure resulting from mechanical loading.
The water content and the presence and quantity of PG in the DIV decrease with a natural process throughout life. However this degenerative process is much faster in some patients
Although genetic and biological factors are also involved in the DIV degeneration, mechanical factors are recognized as having a significant rôle.
A 2-D finite element model for the intervertebral disc in which quadriphasic theory is coupled to the transport of solutes involved in cellular nutrition was developed for investigating the main mechanical factors contributing to disc degeneration. Degeneration is generally considered to result from chronic disc cell nutrition insufficiency, which prevents the cells from renewing the extracellular matrix and thus leads to the loss of proteoglycans. Hence, the osmotic power of the disc is decreased, causing osmomechanical impairments. Cellular metabolism depends strongly on the oxygen, lactate and glucose concentrations and on pH in the disc. To study the diffusion of these solutes in a mechanically or osmotically loaded disc, the osmomechanical and diffusive effects have to be coupled. The intervertebral disc was modeled using a plane strain formulation at the equilibrium state under physiological conditions after a long rest period (called unloaded state). The correlations between solute distribution and various properties of healthy and degenerated discs have been investigated. The numerical simulation showed that solute distribution in the disc depends very little on the elastic modulus or the proteoglycan concentration but greatly on the porosity, diffusion coefficient and endplate diffusion area. The intervertebral disc was then submitted to a diurnal loading / nocturnal unloading cycle and the first study is continued with the analysis of the influence of his nycthemeral cycle. Dependence relations were highlighted between nutrient concentration, cell metabolism rate and disc loading. This coupled model therefore opens new perspectives for investigating intervertebral disc degeneration mechanisms.

Objective :

The present DIV model must be improve including the mechanical non linearities and the relationship between the intra discal pH and the cellular population. Experimental setup (RMI spectroscopy and swelling tests) will be also carry out to validate the numerical results.

This research will be conducted in collaboration with Sylvie Wendling-Mansuy of the «Groupe Interdisciplinaire de Biomécanique Ostéoarticulaire (GIBO) de l'Institut des Sciences du Mouvement (ISM)- CNRS UMR 6152», Pr Patrick Tropiano of the «Service de Chirurgie du Rachis de l'Hôpital Nord de Marseille (APHM)», The «Centre d'Enseignement et de Recherche Chirurgicale, CERC, de l'APHM» and with Benoît Giannesini of the «Centre de Résonance Magnétique Biologique et Médicale (CRMBM) UMR 6612 CNRS, Université de la Méditerranée».

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