Description for a problem studied at the UK Mathematics-in-Medicine Study Group Southampton 2007
< https://mmsg.mathmos.net/uk/2007/spinal-pressure/ >

# Measuring intra-disc pressures in the spine using MRI images

Dr. Hamid Rassoulian

Medical Physics Group, Southampton University Hospitals NHS Trust

The human spine is made of a series of bones linked together by various tissues such as the muscles, ligaments, nerves, etc. At the interface between the bones additional structures such as discs exist that give flexibility to the spine. The dynamics of spine is conventionally described in terms of the motion segments. Each motion segment is made of two adjacent vertebrae, the intervening disc, and other structures such as ligaments.

Normal wear and tear, through the ageing process, disease, or injury can alter the biomechanical properties of a motion segment and most importantly that of the disc. This can, in turn, result in abnormal deformations of the disc and abnormal loading of other motion segments. A damaged or worn disc can cause pain and disability and has to be surgically managed in the majority of cases.

When patients are diagnosed with disc damage it is usually associated with a long history of back pain, which may have begun years before. It is therefore reasonable to assume that abnormal alterations in the biomechanics of the motion segments may also start at an early stage, but are never detected.

One of the main parameters that indicate disc function is assumed to be the internal pressure or pressure profile inside the disc itself. Because of its composite nature it has not been possible to reach a consensus on how the pressure is distributed within the disc or what the mechanism for its distribution is.

If disc pressure is to be measured invasively it requires an alteration of the very structures that give rise to and/or modify those internal pressures. This is probably the reason for the vastly differing results reported in the literature. An alternative may be to measure the pressure non-invasively making it possible to make such measurements in apparently normal and healthy volunteers.

We aim to examine the potential of measuring or estimating internal pressures of the vertebral disc from MRI (magnetic resonance imaging) images. Based on a basic understanding of how MRI images are generated, it is possible to envisage that a disc, as a self contained container with distributed water molecules inside, can present an image that describes this distribution. Given a change in the structure, the distribution of the water molecules are altered which gives rise to a different image making a diagnosis possible.

Some imaging routines are sensitive to the dynamics of the distribution of the water molecules and we hypothesised that when the disc is pressurised the change in its volume or internal structures can lead to a change in the dynamics of the water molecules leading to a change in the image. This change may serve as the basis to estimate the pressure.

The mathematical challenge is to find relationships between the distribution of the water molecules and the pressure, taking account of the composite nature of the discs' internal structures.

Having a validated method to non-invasively estimate the intra-disc pressures, it is possible to examine the process of ageing and disease and devise new interventions to prevent deterioration of the disc. It is also possible to examine the effect of interventions, for example determine how surgical fixation modifies the disc pressures at the target as well as neighbouring motion segments, or how medication can help or alter.