

HOW RELIABLE IS LUMBAR INTERVERTEBRAL STRESS PROFILOMETRY?

Ralph E. Gay, Brice Ilharreborde, Kristin D. Zhao, Jonathan Bridges, and Kai-Nan An

Biomechanics Laboratory, Division of Orthopedic Research,
Mayo Clinic College of Medicine, Rochester, MN 55905 USA
E-mail: rgay@mayo.edu

INTRODUCTION

Stress measurements in the intervertebral disc have been limited primarily to measuring hydrostatic nuclear pressure with strain gauge techniques and catheter systems. McNally and colleagues developed a technique to measure the distribution of stress in both the nuclear and annular regions. The transducer (OrthoAR Series, Medical Measurements Incorporated, Hackensack, New Jersey) was embedded into the side of a 1.3 mm diameter steel needle which was pulled through the disc at a constant rate producing a “stress profile”. Nuclear pressure measurements were found to be repeatable to $\pm 1\%$ in all directions (no anisotropy). (McNally 1992) A subsequent study examined the validity of the measures in the anisotropic annulus and concluded that the compressive *force* acting on the disc was proportional to the compressive *stress* perpendicular to the transducer membrane. (McMillan 1996) That study also reported that stress profiles (distance vs. stress curves) varied by less than 20% when large numbers of profiles were recorded on the same disc. Several investigators have now used intradiscal stress profilometry under differing load conditions, but no additional reports of the reliability of this technique have been published. *The objective of this study* was to determine the reliability of stress measurements obtained with the stress profilometry technique in cadaveric lumbar nucleus pulposus and annulus fibrosis during 5 loading conditions (simulating 2

postural loads and 3 distraction therapies). Because negative nuclear pressures could be expected during distracted conditions we also sought to determine the accuracy of the transducer in the potential negative range.

METHODS

Four fresh frozen human lumbar motion segments of varied degenerative grade were potted in PMMA using a standard technique. A custom testing apparatus was used that allowed application of simultaneous pure moments and axial compression or distraction. Forces and moments were measured with a 6 DOF load cell (JR3, Woodland, CA, USA). The transducer was calibrated and tested for negative pressure in a custom pressure chamber. After a preload of 300 N for 30 minutes, a 1.3-mm spinal needle was introduced into the anterior annulus at the mid-sagittal line, midway between the vertebral endplates and advanced through the posterior outer annulus under fluoroscopic guidance. The needle was removed and the pressure transducer, mounted on a 1.27mm diameter blunt needle, was introduced into the needle track. The transducer, oriented in the horizontal plane to measure vertical stress, was withdrawn at a constant rate of 2 mm/second using a cable and pulley driven by a stepper motor. After 5 repetitions, the transducer was oriented vertically to measure horizontal stresses and 5 more repetitions performed. This process was repeated on each motion segment during 5 conditions in the following order: 1) non-

weight bearing or lying (300 N compression), 2) weight bearing or standing (500 N compression), 3) distraction alone (90 N), 4) distraction combined with flexion (5 Nm) and 5) distraction combined with extension (5 Nm). Discs were then sectioned and graded for degeneration with the scale of Adams (1=normal, 4=severe). (Adams 1996) Profiles were partitioned into nucleus, posterior and anterior annulus regions. Variability (reliability) of the measures was determined using within-specimen coefficients of variation (CV) as a percent.

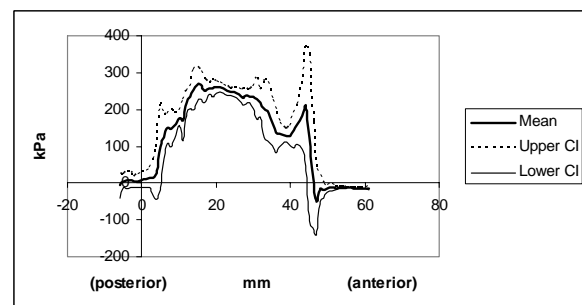
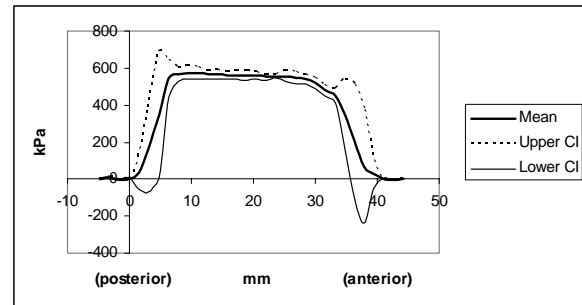
RESULTS

Vertical profiles were more variable than horizontal profiles and contained more stress peaks. To obtain a conservative estimate of reliability, only CVs of vertical profiles were analyzed. Representative mean vertical stress profiles with 95% confidence intervals for a grade 1 and a grade 3 disc under 500 N compression are shown in figures 1 and 2. CVs were generally smaller for compression conditions than for distraction conditions. Within-specimen CV of nuclear stress during compression ranged from 1.6 to 37.2%. The range for the anterior annulus was 3.9 to 67.4% and for posterior annulus 2.3 to 25.5%. CVs for distraction conditions were often > 100% (standard deviation > mean of measurements) because stress was often near 0. The single motion segment with no degenerative change on visual inspection had the most reliable measures.

SUMMARY/CONCLUSIONS

The reliability of intradiscal stress profilometry measures is dependent upon test condition and, to some extent, the amount of disc degeneration. Reliability is acceptable for use in studies evaluating within-specimen changes when sample size

and test conditions are appropriately considered.



Figures 1 and 2. Representative mean vertical stress profiles (mean of 5 sequential profiles) and 95% confidence intervals for grade 1 (fig 1, top) and grade 3 (fig 2, bottom) discs under 500 N compression.

REFERENCES

- Adams MA, McNally DS, Dolan P. (1996) 'Stress' distributions inside intervertebral discs: The effects of age and degeneration. *J Bone Joint Surg Br.* 78:965-972.
- McMillan DW et al. (1996) Stress distributions inside intervertebral discs: the validity of experimental 'stress profilometry'. *J Eng Med (H)* 210, 81-7.
- McNally DS, Adams MA. (1992) Internal intervertebral disc mechanics as revealed by stress profilometry. *Spine.* 17, 66-73.