Lumbar Intervertebral Disc Herniation Following Experimental Intradiscal Pressure Increase*

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Summary

An experimental biomechanical model of overload and rupture of the annulus fibrosus (AF) and lumbar disc herniation was achieved by increasing intradiscal pressure while keeping disc height constant in 69 motion segments at the L4–L5 level excised from cadaveric spines. The experiments were made on 53 specimens in neutral posture and on 16 specimens in flexion posture.

The values found for the rupture intradiscal pressure (RIP) ranged from 750 to 1300 kPa for neutral posture and the maximum RIP in anterior flexion was 1177 kPa.

The degree of disc degeneration was assessed by vertebral transcorporeal discography (previous to experiment) and by sectioning the intervertebral disc after the experiment.

The herniated lumbar intervertebral disc model by intradiscal pressure increase makes possible these assertions:

- The correlation between the degree of AF degeneration and the RIP is significant: the maximum RIP corresponds to a non-degenerated AF and the less RIP can tear only a degenerated AF; so disc herniation only occurs to discs with torn AF.
- AF breaking is more often paramedian, left or right. The place of AF breaking was paramedian in 70.3% cases, median in 9.45% cases and posterolateral in 20.25% cases.

Keywords: Rupture intradiscal pressure; transcorporeal discography; disc herniation.

Introduction

Disc degeneration affects the biomechanical behaviour of all vertebral components and induces spinal segment changes with the deterioration of general spinal behaviour.

In 1959 Nachemson was the first to report results concerning the determination of intradiscal pressure on fresh spinal specimens. Subsequently, the intradiscal pressure was measured in vivo with a special transducer (Nachemson and Morris, 1964) and afterwards the lumbar intradiscal pressure was determined for different types of loading (Nachemson and Elfstrom, 1970).

In order to understand the disc degeneration by tears showing up, followed by annulus ruptures and herniation of the nucleus pulposus, it is important to know the intradiscal pressure at failure of the annulus fibrosus.

Such a measurement can not be performed in living humans and for this reason we conceived an experimental model allowing the measurement of the rupture intradiscal pressure in the AF. We isolated the L4–L5 spinal segments, which were subjected to measurement.

Earlier experimental studies on disc herniation were performed with different combined loading modes, resulting in intradiscal pressure increases as one of the parameters. Therefore we decided to design an experimental study with intradiscal pressure increases as the only experimental parameter.

Materials and Methods

From the L1–L5 lumbar segments, removed from 113 cadavers between 21 and 71 years old without spinal deformities, 69 motion segments of the L4–L5 level were used. The distribution was:

- 16 cases in the 21 to 30 year age group
- 15 cases in the 31 to 40 year age group
- 21 cases in the 41 to 50 year age group
- 9 cases in the 51 to 60 year age group
- 8 cases in the 61 to 70 year age group

The device used for fixing the motion segment, increasing intradiscal pressure and measuring the value producing the annular failure is shown in Fig. 1.

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After measuring the pressure at which the AF fails, the disc was sectioned transversally and:
- The circumferences and the outer and inner diameters of the AF were measured.
- The location of annulus tears was shown.
- The aspect of the nucleus pulposus and the degree of annular degeneration were macroscopically assessed, by identifying the annular circumferential and/or radial tears.

In view of the RIP found in the experiment and the discal dimensions measured, the following parameters were worked out:
- the maximum tangential stress withstood by the AF
- the force that produces the failure of the AF.

**Specimen Preparation**

After removing the vertebral segments L1–L5 from cadaveric spines, the motion segment L4 vertebra/L4–L5 intervertebral disc/ L5 vertebra was used in the experiment. The procedure was performed on motion segments with intact neural arches.

The degree of the disc degeneration was assessed by transcorporeal discography previous to the experiment (Fig. 2) and after the experiment the disc is sectioned and the annular tears and the failure are evaluated.

The discography was performed after drilling the L5 vertebra through the inferior end-plate and before setting the device for increasing intradiscal pressure and was performed in all cases in the neutral position. The exploration was achieved with omnipaque 300 mg/ml, using 0.5–1 ml for each disc. The nuclear, central space of the disc, considered as an extended nuclear cavity, was denoted NC and the radial tears occurring in approximately half the annular width are denoted RT (Tables 1 and 2).

Some motion segments were excluded:
- discs with annular tears up to the periphery were excluded from the analysis – the RIP was so small that AF broke immediately;
- the great narrowing discs were excluded from the experiment because they became homogenous fibrous and very hard (RIP was over 14.75 atm).

**Device for Measuring the Rupture Intradiscal Pressure (RIP)**

The device is relatively simple and can be used for fixing the motion segment, increasing and measuring the intradiscal pressure.

The device consists of a source of pressure, with a manometer graduated in kgf/cm$^2$ up to 16 atm and connected to a tube with 2 mm diameter and 1.5 mm width of the outer wall, which is introduced into the DIV through a tunnel drilled in the body of the subjacent vertebra.

The system intradiscal tube-vertebra is tightened between the tunnel drilled through the vertebra and the tubular rod; at the level of the vertebral cartilage end-plate, tight rubber gaskets and a rubber sleeve are applied; everything is then fixed with a metal collar around the vertebral body through which the rod is introduced. The other vertebral body is also fixed posterolaterally to the pedicles with a metal collar, without injuring them; three vertical fastening rods (one placed anteriorly and two posterolaterally) attach this vertebral body to the first collar.

To exemplify the procedure: the motion segment is reversed; at the geometrical center of the inferior plate of L5 vertebra a tunnel with a diameter of approximately 4.5 mm is drilled up to the discal space, then the rod is introduced and tightened inside. Rapid adhesive and dental cement are applied, then the rubber gasket, fastened by a ring with a screw and finally the rubber sleeve, which is tightened to the vertebral body by the metallic collar. The second collar (incomplete and with fastening pedicular jaws, for attachment inside of the spinal canal) is fixed on the L4 vertebral body and tightened with the three rods: the anterior medial one and the two lateral ones.

The increase in pressure was achieved by means of an electric compressor, which can theoretically increase the air pressure up to 16 atm within 5.5 min; practically one can obtain 14.75 atm within 5 min; the connection between the experimental device and the compressor was made by copper tubes of 10 mm diameter.