Measurement of In Vivo Lumbar Intervertebral Disc Pressure During Spinal Manipulation: A Feasibility Study

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This paper presents the first reported measurements of lumbar intervertebral disc pressure in vivo during spinal manipulation. A pressure transducer was inserted into the nucleus pulposus of one normal-appearing lumbar disc in an asymptomatic adult volunteer. Pressures were recorded during several body positions and maneuvers, then during spinal manipulation, and lastly during a repetition of the preintervention body positions. Baseline pressures in the prone and side-lying positions measured 110 kPa and 150 kPa, respectively. During the manipulation, pressure rose to a peak of 890 kPa over 250 ms. Immediately following, pressures in the prone and side-lying positions measured 150 kPa and 165 kPa, respectively. These data do not support the hypotheses that manipulation can reduce a herniation by decreasing intradiscal pressure, or cause a herniation by raising pressure to failure levels. Further work may lead to a better understanding of this treatment method.

Key Words: spine, manometry, human

High-velocity, low-amplitude spinal manipulation (HVLASM) is commonly used in the treatment of low back disorders (Coulter et al., 2002; Wolsko, Eisenberg, Davis, Kessler, & Phillips, 2003). There is some evidence that spinal manipulation is effective in the treatment of low back pain (Assendelft, Morton, Yu, Suttorp, & Shekelle, 2004; Bronfort, Haas, Evans, & Bouter, 2004).

Data on the biomechanical effects of HVLASM have been emerging. Previous investigators have used pressure mats to measure the external loads applied at the contact interface between clinicians and subjects (Herzog, Conway, Kawchuk, Zhang, & Hasler, 1993; Herzog, Kats, & Symons, 2001), inverse dynamics with data obtained from table-mounted force plates and surface electromyography to estimate the loads passing through the lumbar spine (Triano & Schulz, 1997), and magnetic resonance imaging (MRI) to measure gaping of the lumbar zygapophysial joints before and after lumbar HVLASM (Cramer et al., 2002).

However, the biomechanical effects of HVLASM on the lumbar intervertebral disc are largely unknown; thus, the use of HVLASM in patients with lumbar disc pathology has been controversial. A recent systematic review found inconclusive evidence on safety and effectiveness (Lisi, Holmes, & Ammedolias, 2005). Historically, it has been postulated that the loads applied during lumbar HVLASM can reduce a herniated disc (Cyriax, 1953). Based on case reports of adverse effects after lumbar manipulation, others have suggested that such manipulation delivers pathological loads to the disc (Malmivaara & Pohjola, 1982). Preliminary results from cadaveric work suggest that intradiscal pressure may rise or fall during manipulation (Maigne &
Guillon, 2000). Exploring the effects of HVLASM on the lumbar intervertebral disc in vivo may help clarify the indications and contraindications of this intervention in patients with low back pain.

Measurement of lumbar intradiscal pressure emerged as an accepted method for assessing in vivo loading of the lumbar disc in the 1960s and 1970s (Nachemson, 1981; Nachemson & Morris, 1964). Recently, consistent pressure measurements have been obtained from both healthy and degenerated lumbar discs (Sato et al., 1999; Wilke et al., 1999). The purpose of this study was to determine the feasibility of measuring in vivo pressures in normal lumbar discs before, during, and after HVLASM.

### Materials and Methods

#### Study Participants

This study was approved for two human subjects by the institutional review board of the Palmer Center for Chiropractic Research, Davenport, IA. Inclusion criteria were developed to maximize the chances of finding a normal disc and to minimize the likelihood of adverse effects. These criteria were as follows.

1. 25–45 years old.
2. Licensed chiropractor with experience receiving and delivering lumbar side-posture HVLASM.
3. Previous experience observing percutaneous spinal procedures, such as intradiscal pressure measurement, discography, or spinal injection procedures.
4. No significant past or present low back pain (Score of 0/10 on Numeric Rating Scale; Williamson & Hoggart, 2005).
5. No history of chronic pain in any region.
6. No signs of disc degeneration or other significant pathology at the target disc on MRI.
7. No abnormal psychometric testing on the Zung Self-Rating Depression Scale (Zung, 1965) or Modified Somatic Perception Questionnaire (Main, 1983).
8. No bleeding diathesis, no use of aspirin or nonsteroidal antiinflammatory drugs within past 7 days, no anticoagulant medications, no diabetes mellitus, and/or no active infection requiring treatment with antibiotics.
9. Previous experience of receiving lumbar spinal manipulation resulting in an audible cavitation, or "popping," without adverse effects.

Criteria 2 and 3 above were included to ensure that subjects were fully informed of what they would undergo during the procedure.

Informed consent describing the risk of spinal injection procedures and spinal manipulation procedures was obtained from two volunteers: a 41-year-old female, 5'6", 130 lbs; and a 42-year-old male, 5'11", 180 lbs. In both subjects, the L3–4 disc was identified to be without abnormalities on MRI by a radiologist not affiliated with this study.

#### Pressure Sensor

The pressure measurement probe consisted of a flexible catheter with a specially constructed piezo-resistive pressure transducer mounted on the sidewall of a 2.5-mm long, 1.45-mm diameter metal tip (Unisensor AG, Attikon, Switzerland). The transducer had a reported linear pressure range of 0–5 mPa, linearity of ±1.0 mmHg, and thermal drift of 0.1 per mm Hg/°C. The sensor was tested in a custom air pressure chamber pre- and postinsertion and was found to be accurate to within ±0.02 mPa at a pressure of 1 mPa.

The transducer signal was amplified (Mammendorfer Institut für Physik und Medizin, GmbH, Hattenhofen, Germany), read by an analog-to-digital card (DAQCard 1200, National Instruments, Austin, TX), and collected on a laptop computer (Micron Transport VLX) using Labview software (National Instruments, Austin TX). Static pressure measurements were acquired at a rate of 22 Hz and averaged over a minimum of 5 s. Manipulation data were acquired at a sampling rate of 1,000 Hz and smoothed with a moving average over 10 samples.

#### Measurement Procedure

Placement of the transducer was performed by an anesthesiologist with extensive experience with lumbar discography and percutaneous intradiscal procedures. Cefazolin 2 g was administered intravenously 20 min before the procedure. The back was steriley prepped and draped, and strict sterile technique was maintained throughout the procedure. Prior to needle placement, the skin, subcutaneous, and deep muscular tissues along the trajectory of
the needle were infiltrated with 1% lidocaine. A 14-gauge needle with a plastic catheter was placed into the center of the disc using fluoroscopic guidance and a standard extrapedicular approach. The needle was removed, leaving the plastic catheter in the disc, and the pressure probe was inserted through the catheter. The catheter was then withdrawn while the tip of the probe was monitored under fluoroscopic guidance, ensuring that it remained in the nucleus beyond the end of the catheter. The probe was inserted in this manner into the L3–4 disc of each of the two subjects. In the first subject (EC), owing to operator error the probe came out of the disc as the plastic catheter was withdrawn and was not replaced because of concerns about multiple disc punctures. The probe was placed successfully in the second subject (AJL). After the probe was in place, measurements were recorded in the prone and side-lying positions. Pressure was then measured with the subject in a prethrust manipulative position described below. Measurements were then taken during the administration of a high-velocity, low-amplitude thrust also described below. After the thrust, the measurements were repeated in the side-lying and prone positions. Fluoroscopic imaging confirmed that the probe remained within the nucleus throughout this process (Figure 1).

Manipulation Procedure

Spinal manipulation was performed by a chiropractor with extensive experience with HVLASM techniques. Strict sterile technique was maintained throughout the procedure. The particular HVLASM maneuver used in this study was the lumbar mammillary push. The prethrust manipulative position involved the subject lying in the right lateral decubitus position with the left hip and knee flexed. At first, relatively low offsetting forces were applied to bring the spinal region to the end range of passive motion of combined left rotation and left lateral flexion. Thus, the subject’s pelvis was ultimately positioned at approximately a 35° angle to the table surface (Figure 2).

Next, the force of the high-velocity, low-amplitude thrust was generated by an upper extremity thrust and body drop. This procedure has been well described elsewhere (Peterson & Bergmann, 2002; Triano & Schulz, 1997).

Figure 1 — Fluoroscopic images showing the pressure probe positioned in the center of the L3–4 intervertebral disc. The arrowheads indicate the flexible catheter, and the arrow points to the metal tip.
Results

Baseline pressures in the prone and side-lying positions were 110 kPa and 150 kPa, respectively. Pressure rose to 500 kPa when the subject was in the prethrust manipulative position. During the administration of an HVLA thrust, the pressure rose to a peak of 662 kPa over 290 ms. However, this manipulation did not result in joint cavitation, as determined by both the intervening chiropractor and the subject. A second thrust was delivered, resulting in a pressure peak of 890 kPa over 125 ms, and this did cause joint cavitation (Figure 3).

Immediately following the second thrust, pressures in the prone and side-lying positions measured 150 and 165 kPa, respectively. After the procedure, both subjects experienced moderate low back pain that resolved within 48 hr with analgesics. Approximately 16 months following the procedure, neither subject has suffered any recurrent back pain or other adverse effects.

Discussion

To our knowledge, this study presents the first report of in vivo measurement of lumbar intervertebral disc pressure during HVLASM. The measurements we obtained in the prone and side-lying positions are similar to those recently reported for normal lumbar discs in vivo. The 500-kPa pressure seen in the prethrust manipulative position is similar to pressures recently measured for normal subjects sitting upright (550 kPa to 623 kPa); and the peak pressure of 890 kPa during the manipulative thrust is similar to pressures recently measured for normal subjects sitting flexed (830 kPa to 1,133 kPa) (Sato et al., 1999; Wilke et al., 1999). Thus, in the one disc measured in this subject, the pressures during the given HVLASM maneuver were similar to physiologic pressures and unlikely to reduce or cause a herniation.

A increase in pressure of 40 kPa in the prone and 15 kPa in the side-lying positions was seen following the HVLASM procedure. We do not know the duration of this pressure change, since we only took measurements for approximately 12 s in each pre- and postmanipulative position. Since our testing of the device demonstrated measurement error of approximately ±20 kPa on repeated measures, a portion of this change may be artifact. If the manipulation did indeed cause the noted pressure change, the mechanism whereby such change would occur remains speculative.

Concerns for subject safety led us to perform this preliminary study on only two highly informed subjects. We excluded subjects with chronic pain and/or particular psychometric profiles because these factors have been shown to be related to
Figure 3 — Pressure during manipulation: A) Premanipulative positioning (note that this is elevated from the baseline); B) high-velocity, low-amplitude thrust resulting in cavitation; C) release of manipulative positioning and subject’s return to the side-lying position.

There are several limitations to this study, the most significant being the n-of-1 sample size. Data from more subjects are needed to more clearly understand the pressure effects of HVLASM on the lumbar disc.

All measurements were recorded with the sensor oriented in the sagittal plane. We did not attempt to take measurements with the sensor arranged in the transverse plane also; therefore, we could not confirm the presumed isotropic behavior of the disc. However, such perpendicular measurements would not have been technically possible during the phases we were most interested in measuring, the manipulative positioning and thrust.

There was no attempt to determine the location of zygapophysial joint cavitation relative to the disc being measured. It was not our intention to ensure that cavitation occurred at L3–4, but merely to measure pressure at that level while it was being targeted for manipulation. Indeed it is unclear whether single-level audible cavitation can be achieved accurately with HVLASM (Ross, Bereznick, & McGill, 2004) or whether such cavitation is necessary for clinical improvement (Flynn, Fritz, Wainner, & Whitman, 2003). Future work measuring intradiscal pressure changes in the presence or absence of same-level cavitation may be interesting.

This study was limited to the measurement of one manipulative maneuver. Variation in subject positioning and load application with various maneuvers may yield different results. Pressures were recorded from a normal-appearing disc in an asymptomatic subject. Results from diseased discs in symptomatic subjects may be different. Also, current technology does not allow measurement of a disc stress profile (McNally & Adams, 1992) during HVLASM. However, since anomalous stress concentrations seen on profilometry have been shown to predict painful discs (McNally, Shackleford, Goodship, & Mulholland, 1996), such measurement may
be more clinically relevant than the simple pressure measurement we conducted.

Measuring lumbar intervertebral disc pressure in vivo during HVLSM was accomplished successfully. The peak pressures measured during the manipulation positioning and thrust were similar to pressures previously measured for sitting unsupported and sitting flexed, respectively. These data do not support the hypotheses that manipulation can reduce a herniation by decreasing intradiscal pressure or cause a herniation by raising pressure to failure levels. Further work exploring the pressure changes caused by different manipulative positioning and the changes seen in symptomatic subjects may lead to a better understanding of this treatment method.

**References**


