Fact and Fiction of Disc Reduction: A Literature Review

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Abstract: This article reviews research on the effects of manipulation, traction, and McKenzie exercises on the position of herniated nuclear material in lumbar intervertebral discs. Conclusions based on this research are discussed as well as clinical relevance and avenues for future research.

Key Words: Disc, Herniation, Manipulation, Traction, McKenzie

Introduction

"Disc herniation" is a collective term, describing a process in which the rupture of anular fibers allows for a displacement of the nucleus pulposus within the intervertebral space, most commonly in a posterior or posterolateral direction[1]. Weber[1] subdivides disc herniations into three categories: protruded, extruded, and sequestered. He visualizes a protrusion as a bulging disc with the anular wall still intact and an extrusion as a disc in which the nucleus pulposus has penetrated the outer anular fibers. With a sequestration, one or more fragments of the nucleus have broken free from the herniated mass and have escaped into the spinal canal.

All nociceptively innervated structures are theoretically a source of pain if afflicted by an appropriate disease or disorder[2]. Because the periphery of the disc is nociceptively innervated, the degenerative and/or traumatic process of disc herniation may produce discogenic pain by excessive mechanical strain on the outer anular fibers[2]. Inflammatory products following trauma to these anular fibers may cause pain by chemical irritation of the nociceptive nerve fibers[2]. Disc herniation can also cause compression of nociceptively innervated extradiscal structures, such as the posterior longitudinal ligament, the dural sleeves of the nerve roots, and possibly the dural covering of the spinal cord [2].

Disc herniation can also cause radicular pain. Dorsal root ganglia have been shown to be sensitive to mechanical compression[2] (normal nerve roots are not sensitive to such compression[2]). However, the venous system of the nerve root is very vulnerable: even minor compression may lead to edema formation, resulting in intraneural inflammation and making the nerve root highly mechanosensitive[1]. Penetration of the outer anular fibers may also release endogenous chemicals from within the disc, thus increasing nerve hyperexcitability and susceptibility to compression[1]; these chemicals may also cause pain by chemical irritation of any other nociceptively

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innervated structures with which they come into contact[2].

The goal of physical therapy with disc herniation (as with any other disease or dysfunction) is to restore or maximize patient function. Disc herniation is hypothesized to result in the patient's symptoms by mechanical or chemical irritation of discal and extradiscal structures. Decreasing the mechanical component by restoring the displaced nuclear material to its normal, or a more normal, place within the disc is one possible method for decreasing symptoms and restoring function. Physical therapists use several interventions in the treatment of disc protrusion or extrusion, justifying these choices by stating these interventions may alter the position of nuclear material. This article reviews research on the ability of the physical therapist to affect nuclear position in the lumbar spine by manipulation, traction, and McKenzie exercises. To establish the effect of such interventions on nuclear position research uses imaging techniques that give information on that nuclear position pre- and post-intervention, such as epidurography, discography, CT scan and MRI. I will also discuss possible conclusions drawn from these research findings, the relevance of these conclusions for physical therapy practice, and suggestions for future research.

Manipulation

Spinal (thrust) manipulation can be a combination of movements along any of the six degrees of freedom a vertebra has for motion[3]. Most literature, however, deals with rotatory manipulation. In this type of manipulation, emphasis is placed on a transverse plane rotation; however, this does not exclude other translation or rotation from taking place.

Wilson and Ilfeld[5] used a regional rotatory manipulation on 13 patients with disc herniation at L4-L5 or L5-S1 that had been confirmed on a myelogram. Immediately after the manipulation, a repeat myelogram was done; this showed no change in herniation in 12 patients and an increase in one. During subsequent surgery, the anulus of this one patient was found to be intact. The authors stated that it is unlikely that an extrusion can be reduced by manipulation, but despite the findings in their patient with the larger herniation, manipulation may be beneficial in patients with a protruded disc with a still intact posterior anulus.

Zhao and Feng[4] studied the effects of conservative treatment with segmental spinal manipulation on herniation size and location using repeated CT images in 22 patients with multi-level and 39 patients with single level herniations. No changes were found in size and position on CT with naked-eye examination in a total of 86 motion segments, nor in volume with a computerized evaluation system in 27 patients with 38 affected segments. The authors hypothesized that studies that show reduced herniation following manipulation may be flawed as a result of the natural shrinkage of the extruded tissue over time, as a result of different planes for pre- and post-intervention imaging, and even because forceful manipulation may progress an extrusion to a sequestration with migration of disc fragments out of the plane of the post-intervention CT image.

In a case study Zhao and Feng[6] describe the treatment of a 12 year old girl with a herniation of L5-S1, confirmed by both CT and MRI. Despite treatment with segmental rotatory manipulation of the affected motion segment and despite full functional recovery, no changes on CT scan 4 and 10.5 months after the initial onset of complaints were apparent.

One hypothesis regarding the effect of rotatory manipulation on the location of the herniated nuclear material of an extrusion is that rotation may create a negative intradiscal pressure that may "suck in" the herniation[4]. Rotation leads to tensile stresses in the anular fibers restricting this motion. This tensile stress is transmitted to the nucleus contained within these fibers, resulting in increased intradiscal pressure. This was confirmed by Nachemson[7] during in vivo measurements of intradiscal pressure: rotation led to increased intradiscal pressure in the L3-L4 disc when added to trunk flexion with weights. This increased pressure may very well lead to further extrusion of nuclear material through the anular tears.

One might assume that tension generated in the outer still intact anular fibers may affect the position of the nuclear material of a disc protrusion. Wilson and Ilfeld[5] reported on one patient with a larger herniation after manipulation. Contradicting their assumption that rotatory manipulation may be helpful in reducing nuclear material in case of an intact anulus, as stated previously, this patient was found on subsequent surgery to have an intact anular wall.

In conclusion, based on the research reviewed, there is no proof to support the hypothesis that rotatory manipulation will restore normal nucleus position in either disc protrusion, or extrusion; nor is there evidence to support a differential effect of manipulation on protrusion versus extrusion. In fact, rotatory manipulation may well lead to further nuclear displacement. In the case of a protrusion, tensile strain to anular fibers as a result of rotation may further weaken the containment of the nucleus. The increased intradiscal pressure associated with rotatory manipulation may well lead to an increased displacement of the nucleus in the case of disc extrusion.

Traction

Traction can be applied to the lumbar spine manually or mechanically; in a supine, prone or inverted position; in different degrees of trunk flexion or extension; with constant or intermittent force application; and using a conventional table or a split-table. All applicable studies used constant traction in a supine or prone position on a conventional surface.

Mathews[8] subjected two patients with disc protrusions confirmed on epidurography to 120 lbs of continuous lumbar traction while they lay prone on a conventional table. A 46 year old female with protrusions between L1 and L4 no longer showed any sign of disc protrusion on epidurography after 38 minutes of traction; repeat epidurography showed returning defects after 14 minutes. Twenty days later symptoms recurred and the epidurography showed disc protrusions similar to the first study. The second patient, a 67 year old male, had a protrusion at L3-L4, which was reduced after four minutes of traction and even further reduced after 20 minutes of traction. Ten minutes after release of the traction, the protrusions were shown to have returned to 2/3 of their original size.

Gupta and Ramarao[10] treated 14 patients with intervertebral disc prolapse confirmed by epidurography with 10 to 15 days of continuous bed traction. Traction of 60 to 80 lbs was applied through the thighs with adhesive plaster and the foot of the bed raised 9 to 12 inches. Patients received a 15 to 20 minute rest period from traction every 3 to 4 hours. On a repeat epidurography after 10 to 15 days of this traction treatment, 8 patients showed a return to normal on a P/A study and 11 returned to normal on a lateral study.

Onel et al[9] studied the effects of 15 minutes of traction at 45 kg in a supine position with the legs in semiflexion on 30 patients with a disc herniation confirmed on CT scan. The patient group consisted of 18 men and 12 women between ages 20 and 40. CT scans were taken before traction and after 15 minutes of continuous traction. Of the 14 patients with a median herniation, 11 showed regression of the herniation, 2 showed an increase, and 1 showed no change. Six out of 9 patients with a posterolateral herniation showed a decrease, while 3 showed no change. Of the seven patients with a lateral herniation 4 decreased and 3 remained the same.

Traction is hypothesized to affect the position of herniated nuclear material in two ways. Traction may create a negative intradiscal pressure or even a central vacuum inside the disc, which may cause a central migration of the herniated nuclear material[3,8,9]. This hypothesis is strengthened by Nachemson's findings[7]: 500 Newtons of traction in supine reduce the L3-L4 intradiscal pressure to zero. It is also suggested that traction will lead to tensioning of the posterior longitudinal ligament (PLL), which will then exert an anteriorly directed force on a disc herniation underneath this ligament[9]. Onel et al[9] stated that the very moderate result of traction on reducing lateral herniations supports the role of the PLL pushing back herniations, as these lateral herniations are not covered by this ligament. This rationale for using traction is also supported by Harrington et al[11], who found that traction results in an anteriorly directed force generated by the PLL at the mid-body level of L1. Although not directly applicable to the scenario of affecting a disc herniation at mid-disc level, at least this study showed the generation of an anteriorly directed force in the PLL by traction. We should remember that the PLL is wider at the level of the disc than at the level of the vertebral body; it also stands off several millimeters from the posterior surface of the vertebral body but is intimately connected to the disc[11]. This may lead us to assume that traction leads to a greater anteriorly directed force at disc level than at mid-body level under the same traction forces.

Mathews[8]' study showed a temporary displacement of herniated material in two patients, both during and after traction; however, it is not clear if this was the result of the traction or the result of the prone position, the effect of which is discussed below. Interestingly enough, both of these patients complained of pain radiating down the lateral aspect of the leg to the lateral ankle and lateral foot, indicating a possible L5 nerve root problem. No herniations were shown at L4-L5 or L5-S1 in either patient, however, which gives this study less external validity to justify traction as a treatment for radiculopathy resulting from mechanical compression by a disc herniation. The study by Gupta and Ramarao[10] used a form of traction that is no longer in use. It also lacked a control group showing the value of traction, bedrest and, of course, natural progression over just bedrest and natural progression. The Onel et al[9] study showed regression of herniated material during traction but did not provide information on whether this reduction was maintained after traction.

In conclusion, some evidence exists that continuous lumbar traction can temporarily influence the location of herniated nuclear material. If mechanical compression is indeed a source of pain in patients with disc herniation, traction could have at least a temporary effect on these patients' symptoms. Based on the studies reviewed, no differentiation can be made regarding the effect of traction on protruded versus extruded discs.

McKenzie exercises

McKenzie exercises[12] are passive and active exercises in beginning, middle and end-range of trunk flexion, in extension, and in a combination of sidebending and rotation called side-gliding. The exercises are performed weightbearing or non-weightbearing and are chosen for their ability to "centralize" the patient's symtoms. McKenzie defines centralization as " the situation in which pain arising from the spine and felt laterally from the midline or distally, is reduced and transferred to a more central or near midline position when certain movements are performed"[12]. According to McKenzie, centralization only occurs in what he calls the derangement syndrome, which is defined as " the situation in which the normal resting position of the articular surfaces is disturbed as a result of the change in the position of the fluid nucleus between these surfaces". This definition equates the derangement syndrome with a disc herniation. McKenzie's conceptual model behind treatment of the herniated disc is that in the case of an intact anular wall during spine segment motion, the nucleus will move away from the side of compression loading, i.e., the nucleus will move towards the convexity. Simply put, with anular fibers present to exert force on the nucleus during flexion, the nucleus will move posteriorly and during extension the nucleus will move anteriorly.

There appears to be agreement on the behavior of the anulus during flexion and extension of the lumbar spine[3,12-14]. With flexion, the tangential strain (circumferential stretching) in the posterior anulus increases, flattening the posterior part of the disc; anteriorly there is an increase in the disc bulge. During extension, the posterior disc shows an increased bulge with tightening and flattening of the anterior anular fibers. There is less agreement on the effect of movement on the position of the nucleus.

Shah et al[13] attached metal foil strain gauges at six sites on the L4-L5 disc of six cadaveric L3-L5 spine segments to measure radial bulging of the disc and tangential strain of the disc wall. The spines came from four males and two females, aged 16 to 41. Lateral and A/P radiographs and discography were used to ensure undamaged spines with normal discs. The spines were loaded with central axial loading as well as both anterior and posterior offset loading (to simulate flexion and extension). Posterior offset loading that simulated extension increased the bulge of the posterior disc wall and produced maximal tangential strain at the anterior disc surface; anterior offset loading simulating flexion increased the disc bulge anteriorly and lead to maximal tangential strain posteriorly. Central axial loading resulted in both tangential strain and in a radial bulge being maximal at the posterolateral surface of the disc. The authors hypothesized that both bulge and strain were maximal posteriorly with central axial loading could be explained by the nucleus being positioned slightly posteriorly in the disc or by anisotropy of the elastic constants of the anulus. They state, however, that both these hypotheses would result in a simultaneous increase or decrease of bulging and tangential strain at the same site with offset loading, which is contrary to the experimental findings. They suggested an alternative explanation of a nucleus that moves towards the convexity during spine motion, resulting in increased tension in the anular fibers in the direction towards which the nucleus moves, and reduced tension of anular fibers with a resulting increased bulging on the opposite side of the disc. Discography with visualization of the nuclear cavity in three further postmortem studies showed nuclear movement with anterior and posterior offset loading. The authors suggested further research on the movement of the nucleus, especially in aging or degenerated spines where increased interaction of proteoglycans with collagen may limit normal nuclear movement.

Gill et al[15] studied the effects of repeated extension motions on discographic dye patterns of 54 cadaveric lumbar motion segments. Of these 54 discs, 15 were categorized as normal or slightly degenerated, 22 as moderately degenerated, and 17 as severely degenerated. Series of 30, 90, and 270 repetitions of compression and extension within physiologic force limits were performed. Extension led to increased leaking of dye in 43% of the studied discs, increased anular bulging in 31%, movement of dye into the vertebra in 37%, and changes in the shape of the dye pattern in 35%. No changes in the dye patterns could be visualized in the normal discs. In abnormal discs, however, the change in dye patterns was more significant and correlated with the amount of degeneration. The authors did not find nuclear movement as a result of repeated extensions, and they suggested that favorable clinical results of repeated extension exercises may be the result of chemical changes rather than changes in the position of the nucleus. They did find that in degenerated discs, extension can lead to extravasation of dye out of the nuclear cavity through the defects in the anulus. They stated that the clinical relevance of this extravasation is unclear.

Injection of radiopaque fluid into the nucleus, as with discography, alters the stiffness of the disc and may influence the mechanical response of the disc to movement. To prevent this from affecting their study, Krag et al[16] placed seven metal markers in 11 lumbar and thoracic motion segments, all of which showed no evidence of significant structural abnormalities. These segments were then loaded by a combination of a forward flexion moment, an axial compression force, and an anterior shear force. This simulated flexion load caused a posterior migration of the markers in the nucleus pulposus. The authors suggested a load-redistribution function for this observed movement of the nucleus, which they stated may be negatively affected by changes occuring with aging and degeneration.

Schnebel et al [17] used digitization to study the movement of the posterior and anterior boundaries of intradiscal dye in response to changing from a supine knee-to-chest to a prone press-up position in 35 patients (mean age 37). Discography was done on 30 L5-S1 segments, 35 L4-L5 segments, and 35 L3-L4 segments. Of these discs, 47 had an abnormal morphology and 53 were normal. A statistically significant ($p<0.05$) movement of the posterior aspect of the nuclear contrast agent occurred in normal discs, both regional (L3-S1), and on the individual segments. At L3-L4, the dye moved anteriorly 0.8 mm, at L4-L5 2.2 mm, and at L5-S1 2.9 mm. The anterior boundary only moved significantly anteriorly at L4-L5, but there was a significant anterior movement of 1.1 mm in the three segments combined. The only significant movement ($p<0.05$) in the degenerated discs was a 1.4 mm posterior displacement of the posterior aspect of the dye at L5-S1 with extension. The authors noted that using discography to predict nuclear position may be inaccurate in abnormal discs, as the contrast medium may enter anular tears that may or may not contain part of the nucleus. They suspect that the posterior movement found with extension in the L5-S1 degenerated segment represented dye rather than nuclear movement. The increased pressure in the nucleus as a result of the injection with contrast medium may also have influenced the effort spent by the patients during the experiment and may, therefore, not be representative of an actual physical therapy regimen. The authors concluded that it is unlikely that the clinical results of flexion or extension exercises are the result of changes in nuclear position, but that they may be related to gate control mechanisms, disc hydration, and/or neural tissue relaxation.

Beattie et al[18] noted that data from cadaver studies may not be applicable to living subjects due to changes in fluid content of the discs and the absence of intra-abdominal pressure and muscle tension post-mortem. They evaluated the movement of the posterior and anterior margin of the nucleus in 20 females between 20 and 30 years old using T2-weighted MRI. The subjects were positioned supine with knees and hips flexed to 30 degrees followed by a supine position with knees and hips extended lying on a 5 cm diameter soft lumbar roll. They found significant anterior movement of the posterior margin of the nucleus pulposus in 12 L5-S1, 18 L4-L5, and 20 L3-L4 healthy discs when going from flexion to extension ($p<0.0001$-0.0005). They found few changes in shape and location of the nucleus in subjects with an abnormal nucleus. In four of eight subjects with degenerative discs, the anulus was found to bulge posteriorly with extension. Based on their findings that the nucleus appears to move differently in degenerated and non-degenerated motion segments, the authors questioned whether nuclear movement can be used to explain the effects of extension exercises in individuals with degenerative disc disease.

Fennell et al[19] reported on MR images of four lumbar discs in neutral, flexed, and extended postures of three volunteers. With flexion, both the anterior and posterior margins of all discs moved posteriorly, with the exception of two possibly degenerative L4-L5 discs where the anterior margin moved anteriorly. With extension, both margins moved anteriorly. Correlation between anterior and posterior margin movement and flexion-extension angle was found to be significant.

Studies based on visual observation of the movement of the nucleus on MR images may be flawed because of difficulties in determining boundaries between the nucleus and the anulus. The pixel intensity of T2-weighted MR images is directly related to relative tissue hydration. Brault et al[20] studied the movement of the point of maximal pixel intensity, representing a point somewhere in the center of the nucleus, in ten male subjects (age 21-38 years), when they were subsequently placed in a supine lumbar extension and flexion position. Of the 50 discs studied, 41 were classified as normal, 9 as somewhat degenerated. The change in position of the point of maximal pixel intensity was found to be significant at L1-L2 ($p<0.02$), at L2-L3 ($p<0.02$), at L3-L4 ($p<0.04$), and at L1-S1 combined ($p<0.00$), with the nucleus moving posteriorly when changing from an extension to a flexion position. No equation was found that described the distribution of pixel intensities in abnormal discs and, therefore, no general conclusions on nuclear movement in abnormal discs were made in this study.

The main hypothesis behind using repeated or sustained extensions to reduce posterior or posterolateral disc herniations is that an intact posterior anulus will exert an anteriorly directed force on a moveable nucleus. The resulting anterior displacement of the nucleus should lead to decreased mechanical stimulation of discal and extradiscal nociceptors. In the McKenzie concept patients who do not "centralize" are hypothesized to either lack an intact hydrostatic mechanism or to no longer have discs in which the anulus contains and affects the position of the nucleus[12,21]. So, even according to McKenzie, extension exercises are only indicated in patients with disc protrusions. Patients with disc extrusion and sequestration lack an intact hydrostatic mechanism and an intact posterior anular wall; therefore, the position of nuclear material cannot be affected by extension exercises[21].

All of the research studies reviewed with the exception of that by Gill et al[15] support anterior movement of the nucleus with extension and/or posterior movement of the nucleus with flexion in normal discs. Schnebel et al[17] found posterior movement of the dye used in discography with extension in degenerated discs. Gill et al[15] found extravasation of dye into the epidural space with repeated extension. This extravasation was found to increase with increasing disc degeneration. It is unclear whether this extravasation means that repeated extension movements can lead to further extrusion of already extruded nuclear material[15], but Schnebel et al[17] suspect that the observed discographic changes are dye movement only. The research reviewed does not allow us to use the model of anterior nuclear movement as a result of extension to justify the McKenzie approach with degenerated or herniated discs. As all in vivo studies were done in a non-weightbearing position, no generalization can be made to partial or full weightbearing exercises. With all studies reviewed investigating sagittal plane motion, no conclusions can be made regarding frontal plane movements.

Clinical relevance

Based on the literature reviewed, there is no proof that rotatory manipulation will affect the position of herniated nuclear material in a positive way. Nor is there evidence that such manipulation has a differential effect on a protrusion versus an extrusion. It may, in fact, be contra-indicated in the case of both disc protrusion and extrusion, as it may lead to further displacement of the nucleus.

Continuous traction may at least lead to a temporary reduction in the size of disc herniation, possibly as a result of a negative intradiscal pressure that "sucks" herniated material back in and/or as a result of an anteriorly directed force generated by the PLL. There again is no evidence for a differential effect of traction on a protrusion versus an extrusion.

Research does show movement of the nucleus anteriorly with extension and posteriorly with flexion in non-degenerated discs. There is no proof that similar movement occurs in degenerated discs, so the research reviewed does not validate the McKenzie approach for the treatment of herniated discs. It is unclear whether extension can lead to further posterior displacement and extrusion of nuclear material. Shnebel et al[17] suggested that the clinical results of the McKenzie approach may be related to activating gate control mechanisms, neural tissue relaxation, and increased disc hydration. In support of the theory of neural tissue relaxation, Schnebel et al[22] showed that extension decreases nerve root tension. Magnusson et al[23] supported the theory of increased disc hydration by showing that hyperextension allowed for more disc hydration after prolonged sitting than did recovery in a prone position alone. They hypothesized that the facets may provide for a fulcrum in hyperextension allowing tension to be applied to the disc, unloading the disc, and increasing imbibition. Increased disc hydration reduces posterior bulging[3,14], possibly reducing mechanical stimulation of nerve roots and other extradiscal tissues.

Future research

The research used for this review article deals with the question whether manipulation, traction or McKenzie exercises can affect nuclear position. The question these researchers attempted to answer was not necessarily if this change in position had an effect on clinical results. The assumption, however, was that altering the position of the nucleus would decrease nociceptive afferent information; none of the papers investigated changes in the chemical environment of the discal and extradiscal structures as a possible cause for observed clinical effects. Another assumption was that the observed disc herniations were, indeed, the cause of the patients' symptoms; none of the articles reviewed considered the concept of asymptomatic disc herniations.

Assuming that the disc herniation can cause our patients' symptoms and assuming that mechanical stimulation of nociceptors as a result of changes in nuclear position is at least partially responsible for the reported problems, it appears necessary for future research to define a symptomatic disc versus an asymptomatic disc rather than distinguishing between degenerated and non-degenerated discs. It is clear that a degenerated disc does not show the same movement of the nucleus with repeated extension as a non-degenerated disc. But how much does a disc have to degenerate to become symptomatic? A disc may be minimally degenerated yet symptomatic, and still respond to repeated extension as would a non-degenerated disc, validating McKenzie's conceptual model discussed earlier. Similarly, it may respond differently to traction and manipulation.

We might assume that the presence or absence of an intact outer anulus will have a mechanical effect when using the interventions researched. In order to establish the differential effect of the interventions on a protruded versus an extruded disc, it would be helpful to establish what type of herniation we are dealing with. Of course, it would be of interest to the clinician to establish signs and symtoms for a protrusion versus an extrusion, if such a differential effect exists.

Keeping all these suggestions in mind, future research into the McKenzie method should research the effect of in vivo weigthbearing exercises, as all in vivo studies reviewed were non-weightbearing. A study of the frontal plane motions and their effect on nuclear position would be helpful. It would be very interesting to find out whether further extrusion, as hypothesized with rotatory manipulation[4] and observed with repeated extension[15], is indeed dye or nuclear material. Most importantly, observed effects of nuclear position should be correlated to clinical results. Future studies should use a better research design to increase internal and external validity. Much research remains to be done on the effect of our interventions on symptomatic disc herniation.

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