Herniated Lumbar Disks: Real-time MR Imaging Evaluation during Continuous Traction[1]

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Purpose: To assess the morphologic changes in herniated lumbar intervertebral disks and surrounding structures during lumbar traction by using real-time magnetic resonance (MR) imaging.

Materials and Methods: This prospective study was approved by the institutional review board, and written informed consent was obtained from all participants. Forty-eight consecutive patients with lumbar disk herniation (13 men and 35 women) were treated with continuous lumbar traction by using a nonmagnetic traction device. Real-time MR imaging of the lumbar spine was performed before the initiation of traction and at 10-minute intervals during 30 minutes of 30 kg of continuous traction. Sagittal and axial MR images were analyzed to determine qualitative changes during lumbar traction. Quantitative changes caused by traction on the lumbar spine were determined by measurement of lumbar vertebral column elongation and the disk reduction ratio.

Results: Continuous traction on herniated lumbar disks and surrounding structures resulted in change in disk shape, disk reduction with opening in the intervertebral disk, reduction of herniated disk volume, separation of the disk and adjoining nerve root, and widening of the facet joint. Both the mean lumbar vertebral column length (elongation of 1.45% after 30 minutes, $P < .001$) and the mean disk reduction ratio (8.57%, 15.24%, and 17.94% after 10, 20, and 30 minutes of traction, respectively) increased with time of traction.

Conclusion: The results of this study demonstrated that the real-time effects of continuous traction on herniated lumbar intervertebral disks and their surrounding structures can be visualized by using MR imaging.

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In clinical practice, lumbar traction is commonly used to treat patients with back pain (1). It can be combined with other physical therapy modalities; however, evidence for the efficacy of lumbar traction as part of physical therapy for the treatment of back pain is conflicting (1–3). The physiologic effects of traction, especially on the cervical vertebrae, have been extensively reported from the 1950s. Traction can stretch ligaments and muscles, elongate the intervertebral space, tighten the posterior longitudinal ligament to generate a centripetal force on the intervertebral disk, enlarge the intervertebral foramina, and separate apophyseal joints (4–7).

Several groups have tried to estimate the mechanical effects of lumbar traction. Some authors (8,9) have shown that lumbar traction has an effect on increasing stature, while others (10,11) used radiographic evaluation to reveal the mechanical effects of lumbar traction on widening the intervertebral foramen and intervertebral space. Several studies have investigated the effect of lumbar traction by using invasive procedures such as intradiskal pressure measurment (12), diskography (13,14), and epidurography (15). Although one study (16) used computed tomography (CT) to investigate the effect of traction on lumbar disk herniation, quantitative analysis of the changes was not performed.

Direct visualization of the lumbar disks would be helpful for evaluating the effect of traction, and magnetic resonance (MR) imaging is the best visualization tool for evaluating the intervertebral disks and surrounding structures. However, it is difficult to perform MR imaging with commercially available traction devices because they usually contain metallic components, which interfere with the MR imaging machine, producing substantial artifacts. In 2002, our team studied the use of MR imaging during cervical traction with a nonmagnetic traction device (17). Even though some investigators (18,19) had previously tried to evaluate the effect of traction, MR imaging evaluation was performed before the treatment session and 3–6 weeks after treatment. To our knowledge, no studies that used MR imaging to evaluate the real-time effect of traction on the spine have been reported.

We designed a nonmagnetic lumbar traction device that can be used in the MR imaging suite without causing degradation of images due to artifact. We aimed to assess the morphologic changes in herniated lumbar intervertebral disks and surrounding structures during lumbar traction by using real-time MR imaging.

Advances in Knowledge

- MR imaging showed that continuous lumbar traction produced changes in herniated lumbar disks and surrounding structures such as a change in disk shape, reduction of herniated disk volume, separation of the disk and adjoining nerve root, and widening of the facet joint.
- MR imaging showed that both the mean lumbar vertebral column length ($P < .001$) and the disk reduction ratio ($P < .001$) increased with continuous lumbar traction.

Implications for Patient Care

- The effect of lumbar traction could be visualized with real-time MR imaging during continuous traction.
- Lumbar traction could elongate the lumbar vertebral column and reduce the volume of the herniated lumbar disk.

Materials and Methods

Patients

Between August 2012 and May 2013, 48 patients (13 men and 35 women) with lower back pain were prospectively enrolled in our study. All of the patients had been given a diagnosis of lumbar disk herniation after lumbar spine CT or MR imaging evaluation. They were recruited from the clinic of the physical medicine and rehabilitation department of a university hospital (Gangnam Severance Hospital, Yonsei University College of Medicine). Exclusion criteria were contraindications to MR imaging, such as the presence of cardiac pacemakers or intracranial clips, and contraindications to lumbar traction, such as instability of the lumbar spine, intervertebral disk inflammation or tumor, uncontrolled hypertension, severe osteoporosis, and pregnancy. Previous back surgery was also an exclusion criterion. Our study was approved by the institutional review board of Gangnam Severance Hospital, and informed consent was obtained from all study participants.

Lumbar Traction Equipment

The lumbar traction device was designed for continuous lumbar traction and was made with a nonmagnetic material compatible with use in MR imaging units (Fig 1). By using a weighted pelvic and chest belt, traction force on the lumbar spine similar to that of conventional continuous traction was achieved. We used 30 kg of traction force because a reduction in the intradiskal pressure in patients treated with 22.7–45.4 kg of traction has previously been documented (12). The equipment consisted of the following four parts: *(a)* weights made from water bottles to generate traction force (attached to a pelvic belt and a chest belt, each carrying 15 kg), *(b)* a pelvic belt to conduct traction force from the weight to the lumbar spine, *(c)* a chest belt to secure the patient's body

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Abbreviation:
HIZ = high-intensity zone

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Conflicts of interest are listed at the end of this article.

on the MR imaging table, and *(d)* frames made of nonmagnetic polyvinyl chloride (PVC) pipes. The frames were designed to be detachable from the floor. Flooring work was required to create a mounting hole for installing the frames of the lumbar traction equipment in the MR imaging laboratory. The construction for placement of the device was performed prior to the installation of a new MR imaging unit. Before the MR imaging examination, patients were instructed to avoid position changes or motion during the entire procedure. A chest belt added to a pelvic belt was applied to prevent the patient from sliding on the examination table. Leg support under bent knees also kept patients from moving.

Figure 1

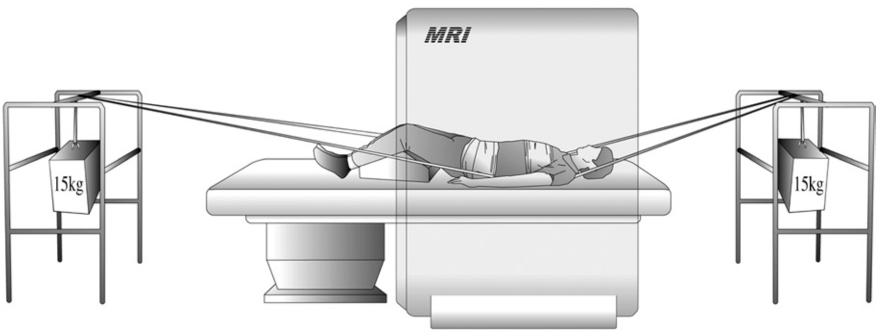

Figure 1: The application of lumbar traction during MR imaging.

MR Imaging

All MR imaging studies were performed by using 3.0-T MR imaging units (Discovery MR750; GE Healthcare, Milwaukee, Wis). With the patient wearing the traction device and placed in the MR imaging unit, standard lumbar spinal sagittal and axial turbo spin-echo T2-weighted images were acquired by using a CTL spine coil (GE Healthcare). The parameters for sagittal turbo spin-echo T2-weighted MR imaging were as follows: repetition time msec/echo time msec, 4683/81; matrix, 384 × 384; field of view, 280 mm; number of signals acquired, two; and echo train length, 22. The acquisition time was 6–7 minutes. The parameters for axial turbo spin-echo T2-weighted MR imaging were as follows: 3011/105; matrix, 320 × 224; field of view, 180 mm; number of signals acquired, five; and echo train length, 16. The acquisition time was 3–4 minutes. The section thicknesses for both the sagittal and axial images were kept as thin as possible (2 mm) to avoid partial volume averaging. Images were first obtained with no weight on the traction device. After 30 kg of weight was added to the traction device, delayed images were obtained after 10, 20, and 30 minutes of continuous lumbar traction.

Image Analysis

For qualitative analysis, three authors (two neuroradiologists [T.S.C. and S.J.A., with 30 and 6 years of experience, respectively] and one physiatrist [H.E.Y., with 5 years of experience]) reviewed sagittal and axial image cuts, analyzing the herniated disk and surrounding structures to identify differences before and after continuous lumbar traction. We regarded the following findings as representing change: differences in intervertebral disk shape, a reduction in the high-intensity zone (HIZ) at the posterior annulus, separation of the disk and adjoining nerve root, and facet joint widening. Changes in disk shape were categorized as subtle or definite. If the retracted posterior margin of the disk showed a reduction in size or loss of convexity only on sagittal images, we defined these changes as subtle. If these changes were observed on both axial and sagittal images, we defined these changes as definite. If a cerebrospinal fluid cleft was newly noted between the disk and adjoining nerve after traction, we regarded this phenomenon as the separation of the disk and adjoining nerve root. We classified the patients whose findings satisfied at least one of the above criteria as being in the positive-finding group and those whose findings did not show any change as being in the negative-finding group. To assist in the visualization of structural changes, identical sagittal-plane cuts obtained prior to traction and obtained after 30 minutes of traction were superimposed by using Adobe Photoshop (Adobe Systems, San Jose, Calif) (Fig 2). With the images that showed patient motion, despite the efforts to prevent position change and motion, we overlapped the images by using the sacrum and coccyx as reference structures.

For quantitative analysis, lumbar vertebral column elongation and the reduction ratio (17) were measured in all patients. As a parameter of lumbar vertebral column elongation, the distance between the anterosuperior border of the L1 vertebral body and the superoposterior point of the S1 vertebral body on magnified sagittal MR images was measured by using the computer console of the MR imaging unit. Each intervertebral disk height was measured at the midline of the vertebra between the superior and inferior endplates. The reduction ratio was calculated with herniated disks, which were defined as disks with disk material that extended beyond the intervertebral disk space. The reduction ratio represented the reducibility of the disk, which was calculated as follows: $[(D - d)/D] \cdot 100$, where D is the distance between the base and the tip of the herniation before traction and d is the same distance during traction (Fig 3). For the quantitative measurement, one author (J.H.P., with 14 years of experience) downloaded the sagittal and axial images of interest (at baseline and at 10, 20, and 30 minutes) without knowledge of patient information and the time of acquisition (ie, whether the image was obtained before traction or after traction). The other three authors (T.S.C., H.E.Y., and S.J.A.) measured the length of the vertebral column and the reduction ratio independently on the images obtained at each of the

Figure 2

Figure 2: Superimposed sagittal MR images obtained before and 30 minutes after traction in a patient in the positive-finding group (left) and a patient in the negative-finding group (right). The two images in each patient were superimposed after the image transparency was adjusted by using Adobe Photoshop. This made identification of the differences between the images obtained at two points in time easier. Left: Notable changes, such as elongation of the overall lumbar vertebral column and a change in intervertebral disk shape, are seen. Right: No distinguishable change is seen in these overlapped images.

Figure 3

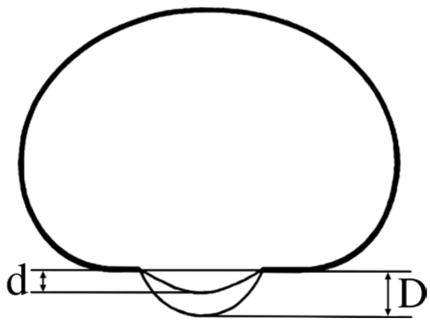

Figure 3: Measurement of the reduction ratio. The reduction ratio was calculated as follows: $[(D - d)/D] \cdot 100\%$. D is the distance between parallel lines drawn at the base and the tip of the herniated disk protrusion before traction, while d is this distance during traction.

three traction times. All observers were blinded to their prior measurements and to the other observers' measurements. To reduce experimenter bias, the observers agreed to and then followed the best measuring technique. The mean value was recorded as the result.

Statistical Analysis

Software (SPSS, version 18.0; SPSS, Chicago, Ill) was used for statistical analysis. An independent t test was used to compare patient characteristics between the positive-finding group and the negative-finding group. A one-way repeated-measures analysis of variance was used to compare lumbar vertebral column elongation, each intervertebral disk height, and the reduction ratio after 0, 10, 20, and 30 minutes of traction. $P < .05$ was considered to indicate a statistically significant difference. Reliability was examined with Fleiss κ values. Interpretation of the strength of agreement determined with the κ values was performed by adopting the criteria of Fleiss, where a κ value greater than 0.75 indicated excellent agreement; a κ value of 0.41–0.75, fair to good agreement; and a κ value of 0–0.40, poor agreement.

Results

Patient Characteristics and Results of Qualitative Analysis

The mean age of all the patients was 39.5 years (range, 22–64 years). The mean ages of the male and female patients were 37.5 years (range, 28–57 years) and 40.2 years (range, 22–64 years), respectively. The mean body weight for all patients was 62.7 kg (range, 44–90 kg). No patient reported having pain or other problems while undergoing traction or MR imaging.

Of the 48 patients, 16 (33.3%) showed structural changes in the herniated disk and surrounding structures during traction and were classified as being in the positive-finding group. Observations included subtle changes in disk shape in 10 patients (Fig 4), reduction of the HIZ at the posterior annulus in five patients (Fig 5), definite changes in disk shape in two patients (Fig 6), separation of the adjoining disk and nerve root in two patients (Fig 7), and widening of facet joints in two patients. For the grouping of patients into the positive- and negative-finding groups, intraobserver and interobserver reliability examined with Fleiss κ values were 0.97 and 0.94, respectively.

The mean body weight was 57.1 kg in the positive-finding group and 65.6 kg in the negative-finding group. As a result, the ratio of traction force to body weight was greater in the patients with changes in the positive-finding group than in the negative-finding group (53.6% and 47.5%, respectively). The mean height was lower in the positive-finding group. Characteristics of the two groups are described in the Table.

Quantitative Analysis of Lumbar Vertebral Column Elongation

The mean length of the lumbar vertebral column of the patients was 165.3 mm before the application of traction and 166.5, 167.3, and 167.7 mm after 10, 20, and 30 minutes of traction, respectively (Fig 8). Compared with the mean vertebral column length before traction, elongation by 1.45% had occurred after 30 minutes of traction—a statistically significant finding ($P < .001$). Elongation occurred between 0 and 10 minutes of traction and between 10 and 20 minutes of traction, and these findings were also statistically significant ($P < .001$). Elongation between 20 and 30 minutes of traction was observed, but this finding was not statistically significant. For the length of the lumbar vertebral column, mean intraclass correlation coefficients were 0.93 for intraobserver reliability and 0.89 for interobserver reliability.

When analyzed only for the positive-finding group (n = 16), the mean length of the lumbar vertebral column changed from 163.9 mm (before traction) to 165.6 mm (10 minutes of traction), 166.6 (20 minutes of traction), and 167.9 mm (30 minutes of traction). Therefore, 30 minutes of traction in the positive-finding group revealed 2.44% vertebral column elongation compared with that before traction—significantly more elongation than that in the negative-finding group (1.09%, P = .007).

Quantitative Analysis of Reduction Ratio

The reduction ratio was calculated after every 10 minutes of traction in all patients. Of the 48 patients, six had two-level disk herniations. One L3-4 intervertebral disk, 17 L4-5 disks, and 30 L5–S1 disks were used in the calculation. Reduction ratios were 8.57%, 15.24%, and 17.94% after 10, 20, and 30 minutes of traction, respectively (Fig 8). For the reduction ratio, mean intraclass correlation coefficients were 0.96 for intraobserver reliability and 0.87 for interobserver reliability.

Figure 4

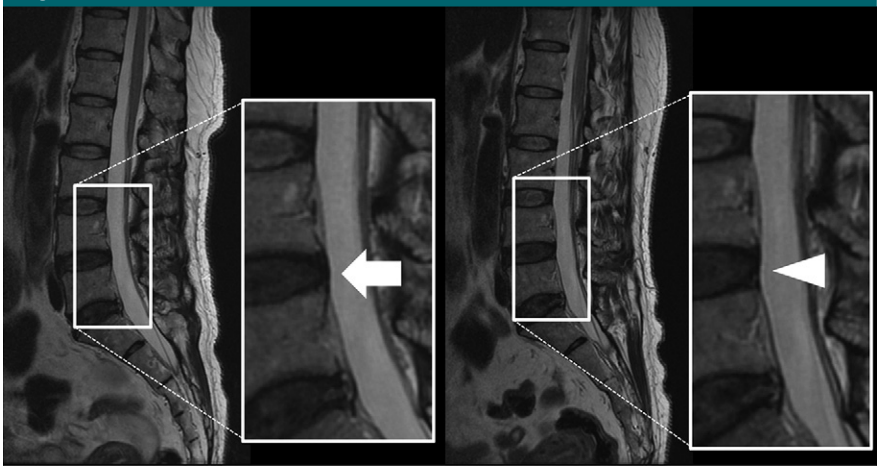

Figure 4: Sagittal MR images show disk shape before traction (left) and 30 minutes after traction (right). The shape of the disk between L4 and L5 is convex before traction (arrow) but has become concave 30 minutes after traction (arrowhead).

Figure 5

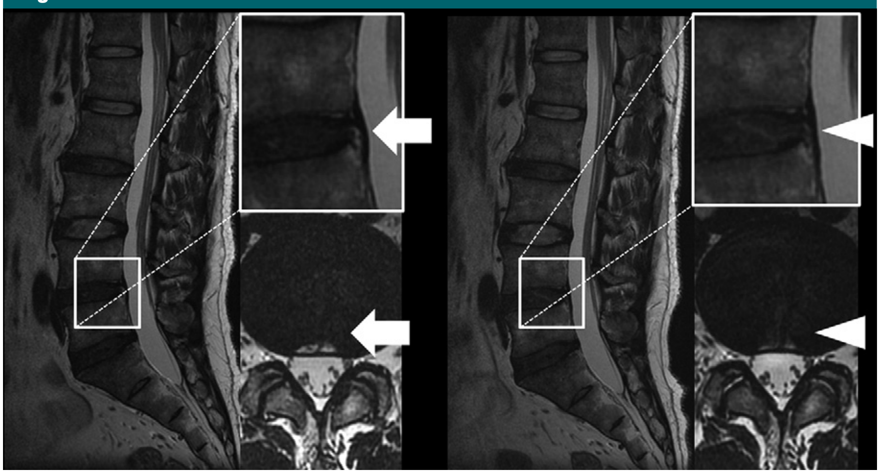

Figure 5: MR images show reduction of the HIZ at the posterior annulus before traction (left) and 30 minutes after traction (right). The HIZ at the posterior annulus is observed, and the disk shape is convex (arrows) prior to traction. The HIZ has been reduced at the posterior annulus 30 minutes after traction and reabsorbed into the nucleus (arrowheads). The convexity of the disk has also disappeared. Reduction of the HIZ is also seen in axial views (lower right images).

Discussion

Our study results demonstrated that MR imaging enables visualization of how sustained lumbar traction affects nuclear protrusions, which was not previously well established in the literature. Whereas some researchers evaluated the lumbar spine in the weight-bearing position by using axial-loading devices to simulate axial compression on the spine during standing (20–22), we found only one study (17) in which MR im aging was used to evaluate the morphologic changes of herniated cervical disks during cervical traction. There are some studies (9,11,14,16) that demonstrated the mechanical effects of lumbar traction

Figure 6

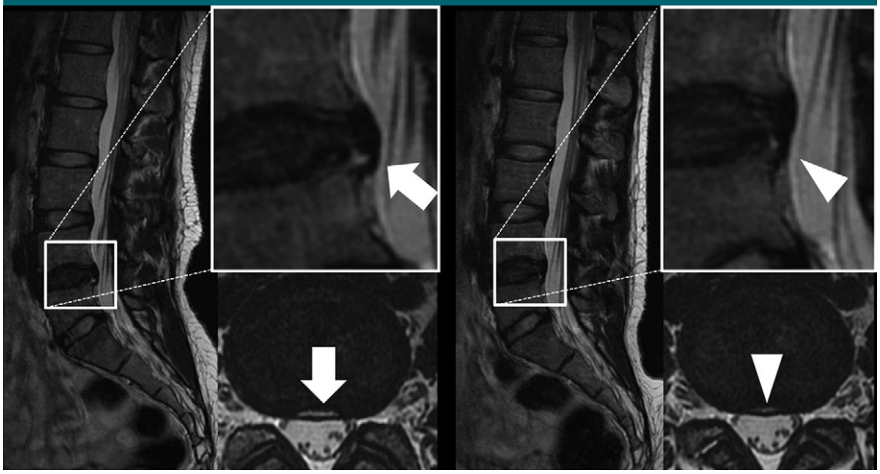

Figure 6: MR images show definite changes in disk shape before traction (left) and 30 minutes after traction (right). The HIZ at the posterior annulus is observed, and the shape of the disk is convex (arrows). The volume of herniated disk material is reduced 30 minutes after traction (arrowheads). Reduction of herniated disk volume is also seen in axial views (lower right images).

Figure 7

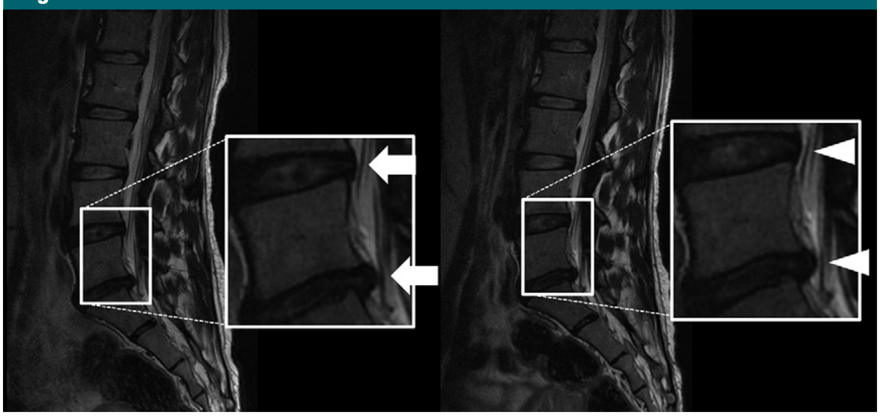

Figure 7: Sagittal MR images of adjoining disk and nerve root before traction (left) and 30 minutes after traction (right). Adjoining disks and nerve roots before the traction (arrows) were separated after 30 minutes of traction. A cerebrospinal fluid cleft was clearly visualized (arrowheads).

Patient Characteristics in Each Group

Characteristic	Positive-Finding Group (n = 16)	Negative-Finding Group (n = 32)	P Value
Age (y)	41.31	38.66	.499
Body weight (kg)	57.13	65.59	.009
Traction force (%)	53.63	47.50	.026
Height (cm)	161.63	166.97	.043
Body mass index (kg/m^2)	22.00	23.44	.136

Note.—An independent t test was used to compare the two groups. Traction force is the ratio of 30 kg of traction force to patient body weight. $P < .05$ was considered to indicate a statistically significant difference.

by using simple radiography, myelography, stature measurement, intradiskal pressure measurement, and CT. However, we found no studies that evaluated the effect of lumbar traction by using real-time MR imaging, which is currently the best imaging modality to show the intervertebral disk and surrounding structures.

If spinal MR imaging could be performed simultaneously with lumbar traction, the changes in intervertebral disks and surrounding structures could be directly evaluated. For real-time MR imaging, a lumbar traction device should be made of nonmagnetic materials and designed so that it does not occupy the space of an MR gantry and coil while still being capable of inducing an adequate traction force. Therefore, we designed a device on a polyvinyl chloride (PVC) frame that could generate traction force by using plastic water bottles.

In our evaluation of the changes in herniated disks during continuous lumbar traction with real-time MR imaging, we observed lumbar vertebral column elongation on sagittal images and a higher reduction ratio on axial images. The length of the lumbar vertebral column elongated from a mean of 165.3 mm before traction to a mean of 167.7 mm after 30 minutes of traction. The percentage of elongation (1.45%) seems slight; however, if the disk portion could be extracted from the total lumbar column length, we believe that the percentage of elongation would be notable. Elongation of the lumbar vertebral column continued throughout the 30 minutes of traction; however, the largest significant increase occurred by 20 minutes, and the difference in elongation length between each 10-minute period became less as time passed.

We reviewed all of the MR images and found changes in disk shape, reduced herniated nucleus pulposus through the torn annulus tract, separation of the adjoining disk and nerve root, and widening of facet joints. These findings suggest that direct reduction effects on lumbar intervertebral disks can be verified with MR imaging performed during traction.

In our study, only 16 (33.3%) of 48 patients showed changes in the

Figure 8

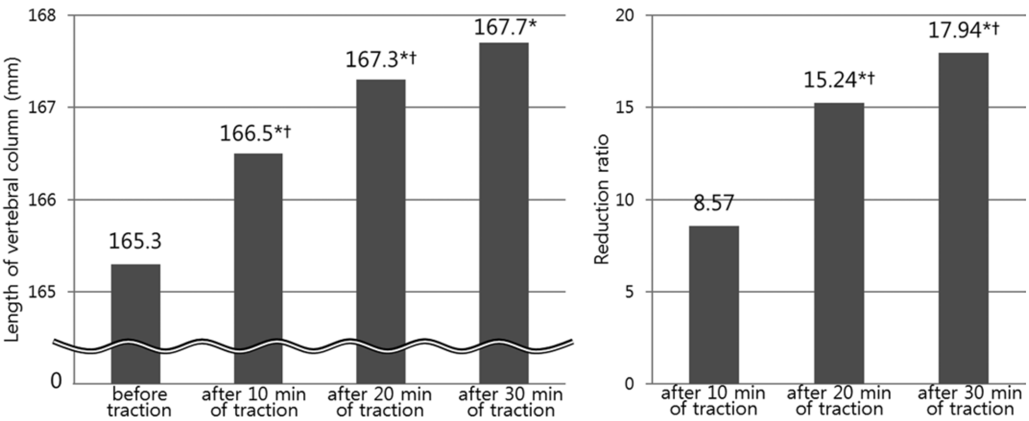

Figure 8: Bar graphs show elongation of lumbar vertebral column (left) and disk reduction ratio (right) in all patients ($n = 48$). $* = P < .001$ compared with before traction. $\dagger = P < .001$, compared with the length 10 minutes earlier. Repeated-measures analysis of variance was used for statistical analysis.

herniated disk and surrounding structures at MR imaging after traction. Patients in this positive-finding group had significantly lower body weight, shorter height, and lower traction force relative to body weight than patients in the negative-finding group. If higher traction force could be applied, we anticipate that the number of responders might increase, the elongation length might be greater, and morphologic changes might be more obvious.

Our study had some limitations. Because this was a pilot study, we concentrated on designing a lumbar traction device that can work effectively in an MR imaging unit. So the lack of a control group is one of the main design flaws. A number of considerations that could overcome these limitations were not included in our study. These considerations include adjusting traction force or angle, the use of a split table that reduces friction between the table and the body, and using more weight to attempt to generate a more effective traction force. Another limitation was that the qualitative assessment of such findings as disk shape, separation of disk and nerve roots, and facet joint widening was performed subjectively. Furthermore, we observed only the effect of short-term traction, but long-term follow-up could provide more information. Observation of the rate of return of pathologic disk configurations after the release of traction may be of interest for future investigations.

In conclusion, our study demonstrated that the real-time effects of continuous traction on herniated lumbar intervertebral disks and their surrounding structures can be visualized by using MR imaging.

Disclosures of Conflicts of Interest: **T.S.C.** disclosed no relevant relationships. **H.E.Y.** disclosed no relevant relationships. **S.J.A.** disclosed no relevant relationships. **J.H.P.** disclosed no relevant relationships.

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Iodinated Contrast Media: A Semantic Somersault

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Editor:

Having been involved with contrast media research (1) and having followed the scientific literature with regard to contrast media since the 1960s–1970s, we have observed that intravascular contrast media based on iodine are nowadays almost invariably designated as iodinated contrast media in the scientific literature (2,3). As an example, when you start to fill in "iodinated" in the search field on the PubMed home page you will get a number of choices for "iodinated contrast." If you put "iodine" in the search field, you get only one choice: "iodine contrast."

The simple question then arises: How is it possible to iodinate a contrast medium that is already saturated with iodine? In the context of contrast media, for example, those used with intravenous urography, computed tomography, and catheter-based angiography and interventions, the term *contrast medium* itself implies that it is based on iodine. Thus, the term *iodinated contrast medium* is tautological. It is the benzene molecule (C_6H_6) that is iodinated by substitution of three iodine atoms for three hydrogen atoms, which results in an iodine or iodine-based contrast medium including replacement of the remaining three hydrogen atoms with side chains containing, for example, hydroxyl groups (OH) to allow for high hydrophilicity of nonionic contrast media.

Contrast media based on gadolinium for magnetic resonance imaging are almost always correctly denoted as gadolinium contrast media. Is it just because the term *gadolinated* is difficult to articulate? Who has heard of bariuminated contrast media? So why overelaborate with the word iodinated for contrast media? So far there exists no iodinated contrast media, and the correct term should simply be *iodine contrast media*. We would appreciate if scientific journals would set a standard for a correct language in this respect.

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Editor's Note

From
Herbert Y. Kressel, MD, Editor, *Radiology*

I thank the authors for their thoughtful comments. As they note, current common terminology for iodine-based contrast media is iodinated contrast material. I suspect this reflects the fact that the benzene molecule has been "iodinated." Moreover, it is shorter, easier to read, and universally understood by our readers than is other suggested terminology. We do not have strict style guidelines for the description and would certainly allow the use of the terms iodine-based or iodine-containing contrast material. Similarly, the preferred terminology for the gadolinium agents is gadolinium-based contrast agents, often abbreviated as GBCAs, or gadolinium chelates. The copy editors inform me that we would accept the term *gadolinated* if used by an author, although we have not encountered such usage. We would not accept the term *gadolinium contrast medium* as it might imply the use of elemental gadolinium, which of course is toxic.

A review of the literature on the terminology used shows wide variability, and our current style approach to this allows for a good deal of flexibility, which is probably a realistic approach in view of the range of common usage patterns.

Errata

Originally published in:
Radiology 2009;252(2):577–586
DOI: 10.1148/radiol.2522081956
Tracheomalacia in Adults with Cystic Fibrosis: Determination of Prevalence and Severity with Dynamic Cine CT
Shaunagh McDermott, Sinead C. Barry, Eoin E. Judge, Susan Collins, Pim A. de Jong, Harm A. W. M. Tiddens, Edward F. McKone, Charles G. Gallagher, and Jonathan D. Dodd

Erratum in:
Radiology 2015;275(3):934
DOI:10.1148/radiol.2015154012
In the author list, the third author should be listed as Eoin **P**. Judge.

Originally published in:
Radiology 2015;275(3):755–762
DOI: 10.1148/radiol.14141400

Herniated Lumbar Disks: Real-time MR Imaging Evaluation during Continuous Traction
Tae-Sub Chung, Hea-Eun Yang, Sung Jun Ahn, and Jung Hyun Park

Erratum in:

Radiology 2015;275(3):935
DOI:10.1148/radiol.2015154011

An early online version of the article was incorrect. Page 760, Figure 6 should appear as follows:

Figure 6