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Abbreviation:
HCD = herniated cervical disk

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Reducibility of Cervical Disk Herniation: Evaluation at MR Imaging during Cervical Traction with a Nonmagnetic Traction Device[1]

The authors evaluated the reducibility of cervical disk herniation at magnetic resonance (MR) imaging performed with the patient in cervical traction. After the acquisition of neutral-state images, cervical traction images were obtained in 29 patients and seven healthy volunteers while they wore a portable intermittent traction device. During traction, all volunteers and 21 patients had a substantial increase in the length of the cervical vertebral column. The disk herniation was completely resolved in three patients and partially reduced in 18. The reducibility of cervical disk herniation can be evaluated at MR imaging performed during cervical traction.

Cervical traction has been applied widely to relieve neck pain from muscle spasm or nerve compression in rehabilitation medicine settings (1,2). Continuous or intermittent traction has been regarded as an effective treatment for herniated cervical disks (HCDs) because it facilitates widening of the disk spaces (3,4). The traction induces pain relief and regression of the herniated disks. Several reports (5–7) have described the regression of herniated disks either spontaneously or within the treatment period.

Widening of disk space during traction has been demonstrated mostly on radiographs (1). Radiography does not yield direct images of the herniated disk, however; radiographs show only the changes in vertebral bone structures. Direct visualization of the cervical disk would be very helpful for evaluating the reducibility of disk herniation during traction, and magnetic resonance (MR) imaging is the best examination for evaluation of intervertebral disk problems. To our knowledge, however, a device that enables visualization of the cervical disk during traction and is applicable to MR imaging has not been available before now. Although a portable traction device for cervical fractures has been reported on, the report was in the form of a technical note regarding a portable traction device that can be used with myelography or computed tomography (CT) (8). The study was not applicable to MR imaging because the metallic composition of the described traction device produced substantial artifacts.

We have designed a portable intermittent traction device made of nonmagnetic materials that do not affect MR imaging. The purpose of our study was to evaluate the reducibility of cervical disk herniation at MR imaging performed with the patient in cervical traction.

Materials and Methods

For 19 months, from June 1999 to November 2000, a total of 29 patients who consecutively received a diagnosis of HCD on the basis of findings at previously performed cervical CT or MR imaging and seven healthy volunteers were examined at cervical spinal MR imaging. The healthy volunteers were selected from a group of young persons during two stages: First, a rehabilitation physician (S.W.K.) selected young (ie, aged 18–40 years) healthy volunteers if they had none of the following symptoms or signs: pain, stiffness, tenderness, fracture, dislocation, neurologic signs such as decreased or absent deep tendon reflexes, weakness, sensory deficits, or muscular signs such as decreased range of motion or point tenderness. Next, the selected volunteers underwent T2-weighted MR imaging while in a neutral (ie, nontraction) state, and if either a degenerative change in or a herniation of a disk was detected, the subject was excluded. Finally, the selected volunteers underwent MR imaging while wearing the inflated traction device.

The patient group consisted of 10 men and 19 women, who ranged in age from 25 to 62 years (mean age, 44.4 years). The healthy volunteer group consisted of one man and six women, who ranged in age from 19 to 37 years (mean age, 26 years). The MR imaging examinations were performed after informed consent had been obtained from all patients and volunteers, as was required by the institutional review board of Yonsei University College of Medicine, YongDong Severance Hospital.

Traction Device

The traction device (Fig 1) was originally designed for portable intermittent use to accommodate a patient's daily activities during traction. It is also constructed of a nonmagnetic material (Airtrac 101; Airtrac MSI, Seoul, Korea) that is compatible to MR imaging units. The traction device consists of three main parts: *(a)* a shoulder cover for the base of the device, *(b)* an accordion-shaped middle component that can be expanded by means of air inflation, and *(c)* mandible supports for effective transmission of traction. When the device is inflated with air, the accordion-shaped middle component stretches and has a traction effect on the neck. The anterior portion of the middle component is fixed with a band to maintain a flexion posture of the neck. We used 30 pounds of traction force: The pressure to the internal space was 0.4 kgf/cm^2. Immediately after the procedure, we asked the volunteers and patients if they had experienced any pain or other discomfort during inflation of the traction device or during imaging.

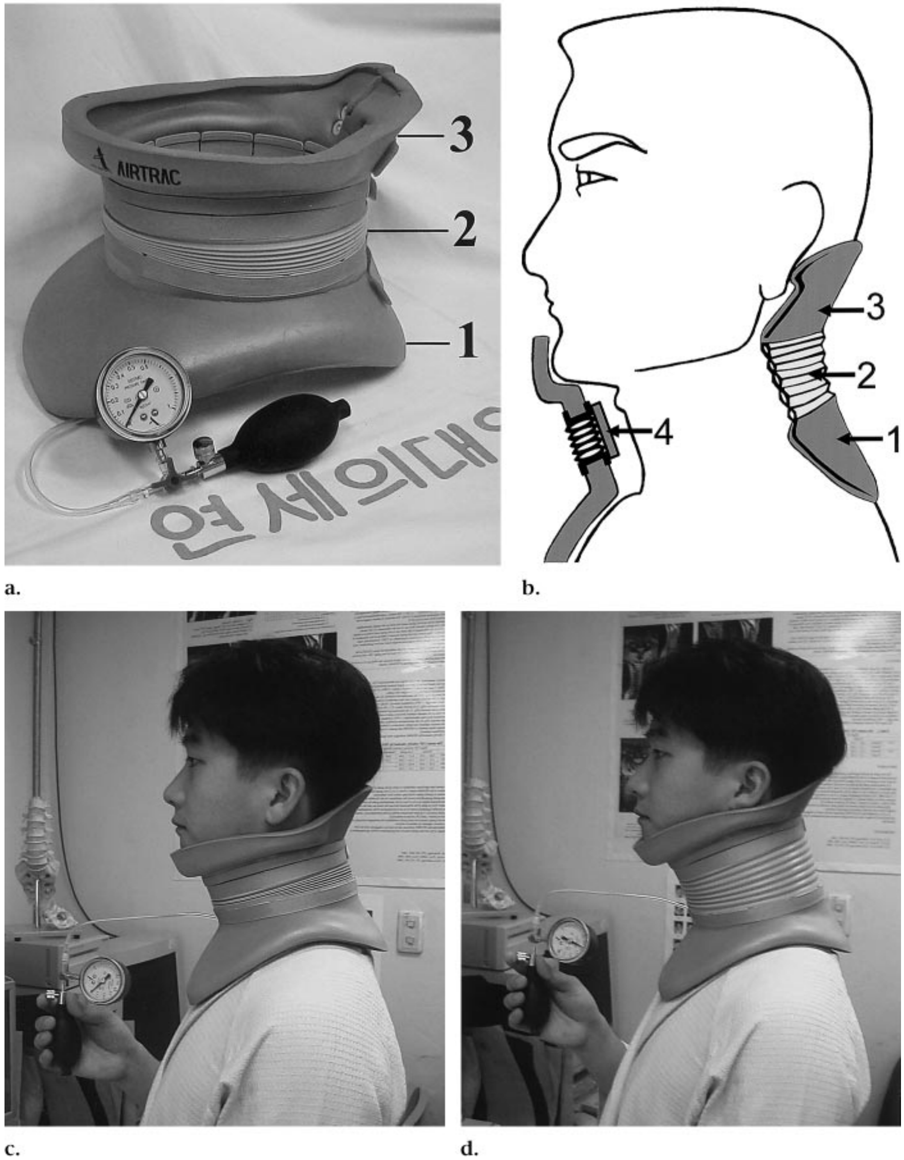


Figure 1. Cervical traction device used on a healthy volunteer. **(a, b)** The traction device consists of a shoulder cover at the base of the device *(1),* an accordion-shaped middle component that is expanded by means of air inflation *(2),* and mandible supports for effective transmission of traction *(3).* In **b**, the anterior portion *(4)* of the middle component is fixed with a band to maintain a flexion posture of the neck. **(c, d)** When the device is inflated with air, the accordion-shaped middle component stretches to have a traction effect on the neck.

MR Imaging

All MR imaging studies were performed by using a 1.5-T MR system (Vision; Siemens, Erlangen, Germany) with 25-mT/m gradient capability. With the patient wearing the traction device, standard cervical spinal MR images were acquired with sagittal turbo spin-echo T2-weighted and transverse two-dimensional fast low-angle shot sequences by using a standard spine circular polarization array coil. The parameters for sagittal turbo spin-echo T2-weighted MR imaging were 4,000/128 (repetition time msec/echo time msec), a 138×256 matrix, a 156×250-mm field of view, and nine images of 3-mm section thickness obtained during an acquisition time of 52 seconds. The parameters for transverse two-dimensional fast low-angle shot MR imaging were 550/12, a 30° flip angle, a 112×256 matrix, a 125×200-mm field of view, and nine images of 3-mm section thickness obtained during an acquisition time of 2 minutes 5 seconds. We reduced the matrix number to less than that used to obtain standard MR images, to minimize the acquisition time and motion artifacts.

First, neutral-state images were obtained during deflation of the traction device. Then, traction-state images were obtained 10 minutes after inflation with an external air tube to allow time for the traction effect on the normal or herniated disk. The patients and volunteers were monitored with closed-circuit television surveillance and could communicate by means of microphone to prevent unexpected emergency situations during traction.

TABLE 1
Increased Length of Cervical Vertebral Column during Traction

Column Elongation	Volunteers (n = 7) No. of Subjects	Volunteers (n = 7) Elongation Length (mm)*	Patients (n = 29) No. of Subjects	Patients (n = 29) Elongation Length (mm)*
Substantially increased length	7	1.93	21	2.19†
Minimally increased length	0	· · ·	8	0.44‡

* Data are mean lengths of elongation of the cervical vertebral column.
† Length of elongation not significantly different from that in healthy volunteers (P = .971).
‡ Significantly shorter length of elongation compared with that in healthy volunteers (P < .001).

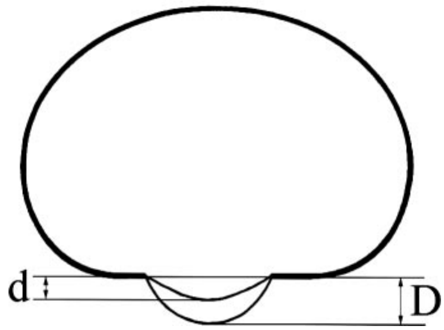


Figure 2. Measurement of reduction ratio. Reduction ratio was calculated as follows: $[(D - d)/D] \times 100$. D is the distance between two parallel lines—one line drawn at the base of the herniated disk particle and the other drawn at the tip—in the neutral state, and d is this distance in the traction state.

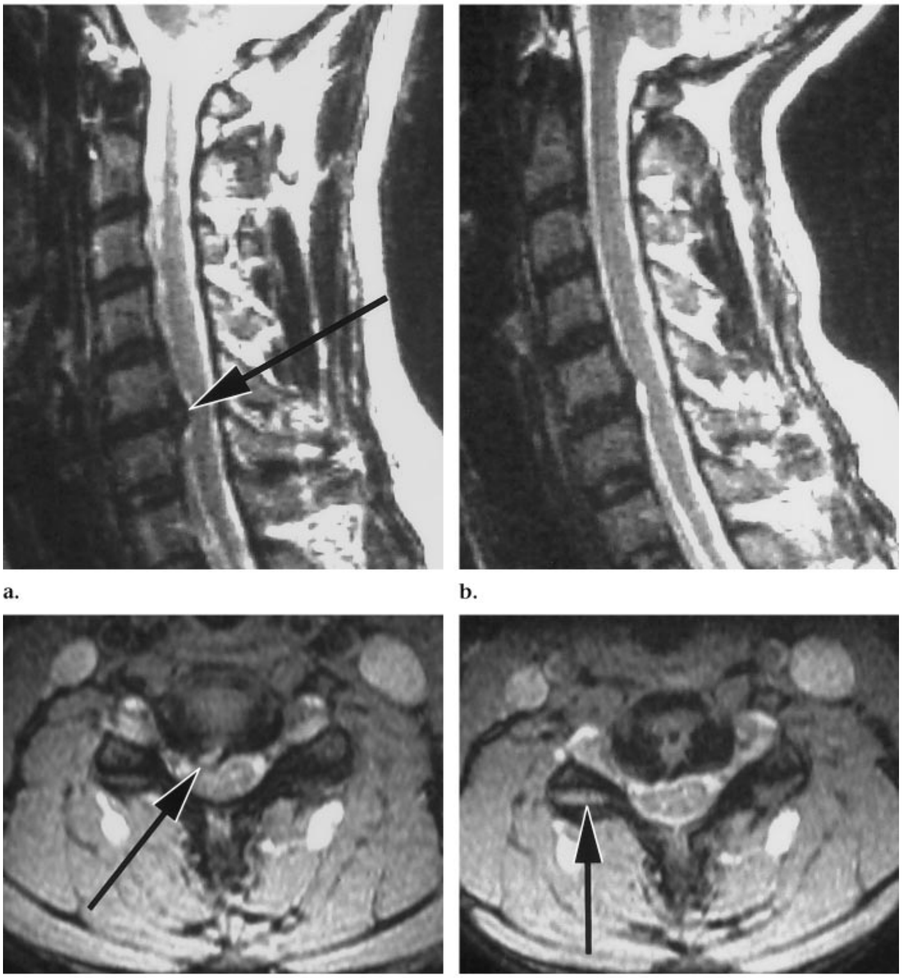


Figure 3. **(a, b)** Sagittal (4,000/128) and **(c, d)** transverse (two-dimensional fast low-angle shot sequence, 550/12, 30° flip angle) MR images depict a completely resolved cervical disk herniation after traction. **(a, c)** Neutral-state MR images show extrinsic compression of the dural sac and spinal cord at the C5-6 cervical disk level due to an HCD (arrow). **(b, d)** Traction-state MR images show reduction of the cervical disk herniation and the residual deformed spinal cord. Widening of the right-side facet joint space (arrow in **d**) is seen on the transverse traction-state image.

Image Analysis

As a parameter of cervical vertebral column elongation, the distance between the middle point of the superior border of the C1 anterior arch and the inferoposterior point of the C7 vertebral body on magnified sagittal MR images was measured by using the computer console of the MR imaging unit (Vision). We did not use the odontoid process as the superior landmark because exact localization of the odontoid process tip could have been difficult sometimes owing to a patient's tilting or rapid position change during traction. Measurements of cervical vertebral column elongation were obtained by two neuroradiologists (T.S.C., Y.J.L.) separately and blindly. The neuroradiologists were not informed of the patients' clinical information.

The reducibility of cervical disk herniation was evaluated in the patient group. Complete resolution of the herniation was defined as a result in which the disk was completely inside the annulus margin without a residual herniated disk particle. Partial reduction was defined as a more than 50% volume reduction in the herniated disk particle with some residual tissue. The reduction ratio was calculated as follows: $[(D - d)/D] \times 100$, where D is the distance between two parallel lines—one line drawn at the base of the herniated disk particle and the other drawn at the tip—in the neutral state and d is this distance in the traction state (Fig 2).

Whether there was widening of the facet joints or intervertebral foramen during traction was determined in the patients and healthy volunteers. Retraction of the posterior margin of the disk during traction, as depicted on sagittal MR images, also was evaluated in the volunteers and patients. If the retracted posterior margin of the disk passed an imaginary line drawn from the posterior margins of two adjacent vertebral bodies, we defined this phenomenon as dimpling.

The two radiologists evaluated the pre- and posttraction images side by side, without knowledge of the patients' clinical information. The radiologists reviewed the images simultaneously, and results were recorded when they reached a consensus.

Statistical Analysis

The extent of cervical vertebral column elongation in the patients during traction was compared with that in the healthy volunteers. Statistical analysis was performed by using computer software (SPSS; SPSS, Chicago, Ill and Excel 2000; Microsoft Korea, Seoul, Korea). The Mann-Whitney *U* test was used to analyze our study data, and a *P* value of less than .05 was considered to indicate a statistically significant difference.

Results

The MR images obtained in the seven healthy volunteers during traction showed that the length of the cervical vertebral column had increased by 0–3 mm (mean length increase, 1.93 mm). Of the 29 patients, 21 (72%) had complete resolution or partial reduction of the cervical disk herniation and an elongation of the cervical vertebral column of 0–7 mm (mean length increase, 2.19 mm), which was not significantly different from that in the volunteers ($P = .917$). Eight patients had minimal elongation of the cervical vertebral column (mean length increase, 0.44 mm), which was significantly shorter than that in the healthy volunteers ($P < .001$) (Table 1). No patient reported having pain or any other discomfort during either traction device inflation or MR imaging.

Of the 29 patients, who had a total of 40 HCDs, 19 had an HCD at one cervical disk level, nine had HCDs at two levels, and one had HCDs at three levels. There were 15 HCDs each at the C5–6 and C6-7 cervical disk levels. There were five HCDs at the C3-4 level, three at the C4-5 level, and two at the C7-T1 level. In the patient with HCDs at three levels, the herniation at one level was reduced but the herniations at the two remaining levels were not. In the nine patients with HCDs at two levels (total of 18 levels), the herniations were reduced at 13 levels and not reduced at five levels. Of the 19 patients with HCDs at one level, 13 had reduced herniations and six did not.

Disk herniation was completely resolved in three (10%) of the 29 patients (Fig 3) and partially reduced in 18 (62%) (Fig 4). Eight of the 29 patients had minimal elongation of the cervical vertebral column during traction (mean length increase, 0.44 mm; range, 0–1.5 mm), however, and no reduction of the disk herniation. The length of elongation of the cervical vertebral column during traction in this group was significantly shorter

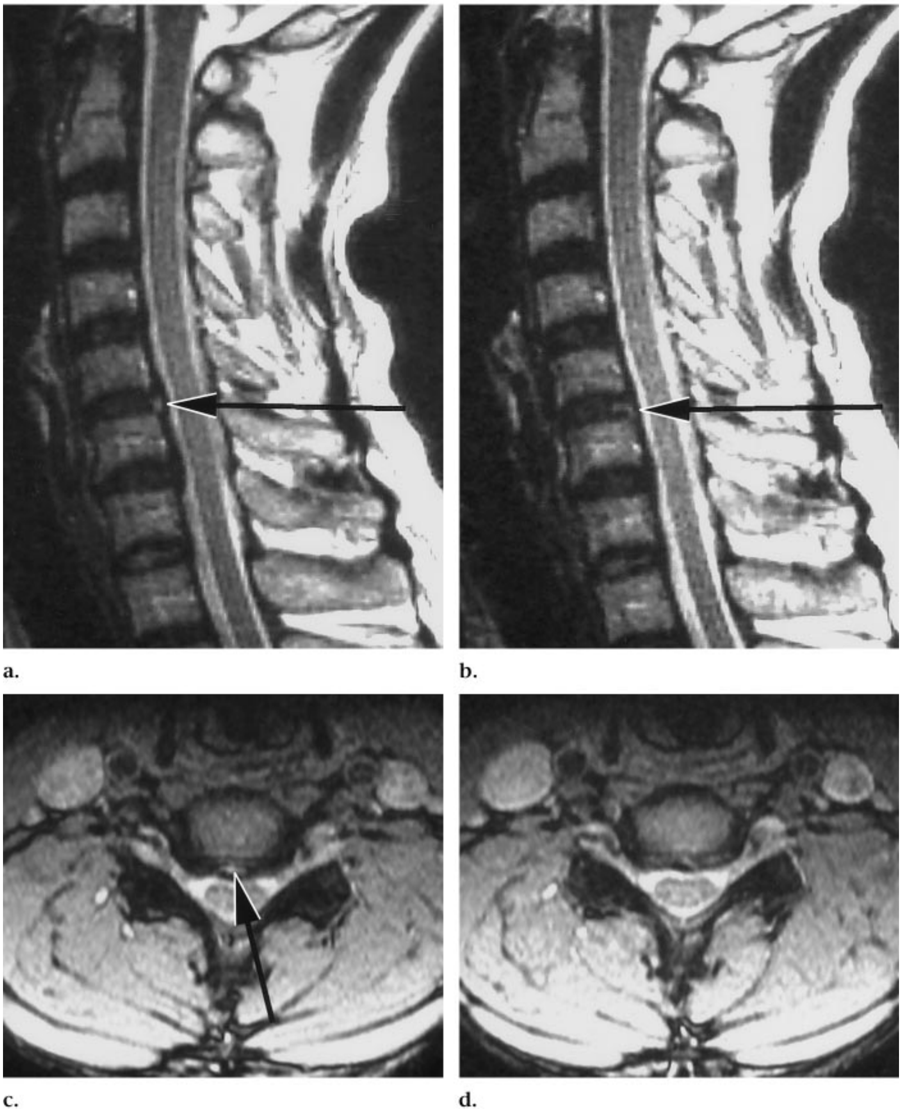


Figure 4. **(a, b)** Sagittal (4,000/128) and **(c, d)** transverse (two-dimensional fast low-angle shot sequence, 550/12, 30° flip angle) MR images of a partially reduced cervical disk herniation after traction. **(a, c)** Neutral-state MR images show a small area of high signal intensity (arrow) that corresponds to a herniated disk fragment in the posterior central direction at the C5-6 cervical disk level. **(b, d)** Traction-state MR images show a reduction of the fragment (arrow in **b**) through a torn tract of the annulus fibrosus at the C5-6 cervical disk level.

TABLE 2
Dimpling of Annulus Capsules and Changes in Facet Joints and Intervertebral Foramina during Traction

Spinal Column Change	No. of Volunteers ($n = 7$)	No. of Patients ($n = 29$)
Annulus capsule dimpling	3 (43)	12 (41)
Facet joint space widening	2 (29)	5 (17)
Intervertebral foraminal widening	1 (14)	5 (17)

Note.—Numbers in parentheses are percentages.

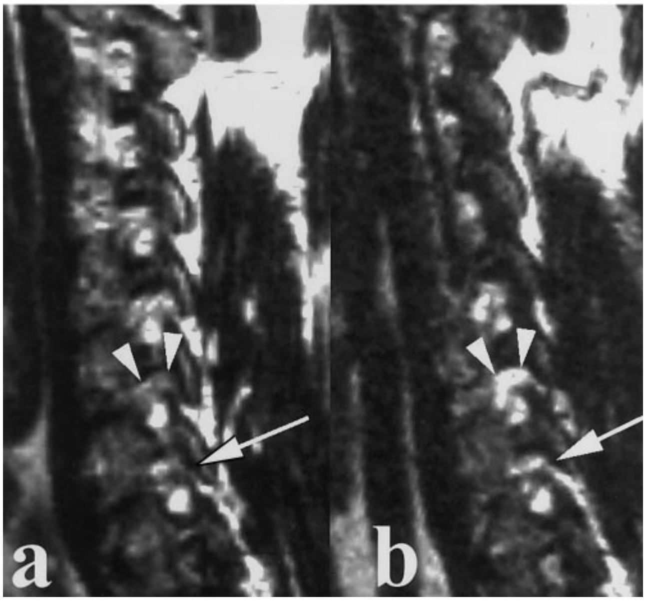
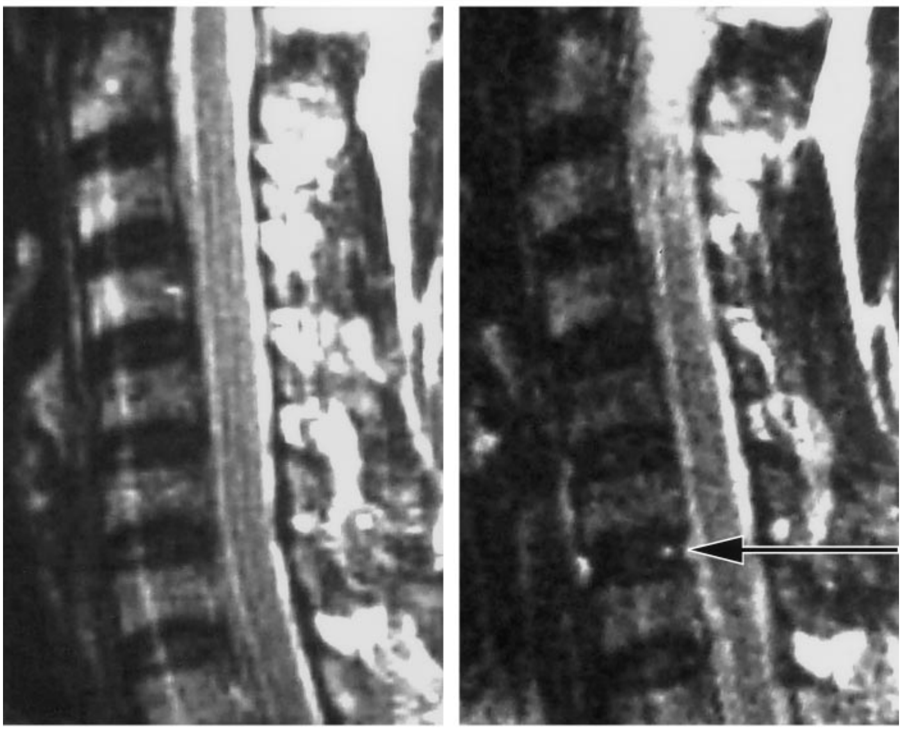


Figure 5. Sagittal T2-weighted MR images (4,000/128) of the foramen at the C6-7 cervical disk level and the facet joint at the C7-T1 cervical disk level in a patient with HCD in *(a)* neutral and *(b)* traction states. The facet joint (arrow) is widened at traction *(b)* compared with in the neutral state *(a)*. The width of the foramen (arrowheads) also increased with traction.



a. b.

Figure 6. Sagittal T2-weighted MR images (4,000/128) of the cervical spine of a healthy volunteer in **(a)** neutral and **(b)** traction states. Dimpling of the annulus capsule (arrow in **b**) is seen at traction.

than that in the healthy volunteers (*P* = .02). There was a significant difference in elongation of the vertebral column between the patients who did and those who did not have some herniation reduction (*P* = .01).

Widening of the facet joint space was observed at MR imaging during traction in two (29%) of the seven healthy volunteers and in five (17%) of the 29 patients (Fig 5). In addition, foraminal widening was observed in one (14%) of the seven volunteers and in five (17%) of the 29 patients. Dimpling of the annulus capsule due to the secondary retraction effect of the increased disk length was observed on the sagittal MR images obtained in three (43%) of the seven healthy volunteers and in 12 (41%) of the 29 patients (Fig 6) (Table 2).

Discussion

Although regression of a herniated intervertebral disk at follow-up has been reported in up to 3% of cases of herniated cervical or lumbar disks (6,7), the exact mechanism of the regression of a herniated intervertebral disk is still not understood. The disk may be subject to desiccation and shrinkage from loss of hydrophilic proteoglycans, which leads to a loss of water content and, consequently, a decrease in disk size (7). Reports (8,9) have suggested that traction therapy can induce HCD regression. However, the mechanism of the disappearance of the HCD at follow-up MR imaging after traction—that is, whether it is a reduction or a spontaneous resorption—is still unclear.

In a report (1), it is stated that the length of a cervical disk increases during traction. The report only describes those changes in disk length that were identified by measuring the distance between the bone margins of adjacent vertebral bodies on radiographs, however. Therefore, the reduction of a herniated disk particle during traction could not be precisely evaluated in that study.

If cervical spinal MR imaging could be performed simultaneously with traction, the changes in intervertebral disks could be directly evaluated. A cervical traction device for MR imaging should be made of nonmagnetic materials. In addition, the volume of the device should be small enough to fit easily on the limited space of an MR gantry and coil while inducing an adequate traction force. Therefore, we designed a device that can be expanded by means of air inflation. With expansion of the device, elongation of the neck between the shoulder and the occiput can be achieved. The device has a traction effect on the cervical vertebral column that is similar to that of conventional traction methods that are applied at bedside. We used 30 pounds of traction force (ie, pressure to the internal space of 0.4 kgf/cm^2) because early separation of the posterior vertebral segment is induced by applying a minimum pressure of 25 pounds (10).

In our evaluation of the changes in HCDs during traction at MR imaging, we observed a reduced herniated nucleus pulposus particle through the tract of a torn annulus (Fig 4). This suggests that direct reduction effects on HCDs can be verified at MR imaging performed during traction. Although long-term follow-up was not performed in this study, we believe that reduction of the herniated nucleus pulposus might lead to healing of the torn annulus and resolution of the disk herniation. Complete resolution or partial reduction of a disk herniation was seen in 21 patients; these results suggest that traction has an effect on HCDs.

All seven healthy volunteers and 21 (72%) of the 29 patients with HCD showed substantial elongation of the cervical vertebral column after the traction device was applied and inflated.

In a cadaveric study (11), there were significant increases in the intervertebral foraminal volume and the size of the area at the foraminal isthmus. We also induced a flexion posture of the cervical spine during traction. However, neither widening of the facet joint space (in two [29%] volunteers and five [17%] patients) nor widening of the intervertebral foramen (in one [14%] volunteer and five [17%] patients) was frequent. These results might have been due to the thickness of sections on sagittal images, which may have been such that very rapid changes in the facet joint and intervertebral foramen could not be sufficiently evaluated.

Dimpling of the annulus capsule of the cervical disk was seen in three (43%) of the seven volunteers and in 12 (57%) of the 21 patients who had elongation of the cervical vertebral column during traction. This dimpling might have been a secondary effect of cervical vertebral column traction and may represent a response to the traction. Responding to the traction, intervertebral disks can show dimpling of the annulus capsule by increasing the length of disk space, which instantly results in negative pressure on the disk. Owing to its flexibility, the disk decreases in width to resolve this phenomenon. However, a disk that does not respond to the traction might not show dimpling of the annulus capsule.

In conclusion, cervical spinal MR imaging performed during cervical traction with a portable intermittent traction device can be used to evaluate the reducibility of cervical disk herniation with traction.

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