THE JOURNAL OF BONE & JOINT SURGERY (BRITISH)

MRI of cervical intervertebral discs in asymptomatic subjects

Morio Matsumoto, Yoshikazu Fujimura, Nobumasa Suzuki, Yukimi Nishi, Masaya Nakamura, Yutaka Yabe, Hayao Shiga

From Keio University School of Medicine, Tokyo, Japan

We studied degenerative changes in the cervical intervertebral discs of 497 asymptomatic subjects by MRI and evaluated disc degeneration by loss of signal intensity, posterior and anterior disc protrusion, narrowing of the disc space and foraminal stenosis. In each subject, five disc levels from C2-C3 to C6-C7 were evaluated.

The frequency of all degenerative findings increased linearly with age. Disc degeneration was the most common observation, being present in 17% of discs of men and 12% of those of women in their twenties, and 86% and 89% of discs of both men and women over 60 years of age. We found significant differences in frequency between genders for posterior disc protrusion and foraminal stenosis. The former, with demonstrable compression of the spinal cord, was observed in 7.6% of subjects, mostly over 50 years of age.

Our results should be taken into account when interpreting the MRI findings in patients with symptomatic disorders of the cervical spine.

J Bone Joint Surg [Br] 1998;80-B:19-24.
Received 2 May 1997; Accepted after revision 18 July 1997

MRI is often used for patients with cervical spine disorders. Its high sensitivity for detecting disc disease[1-4] allows it to show degeneration in both symptomatic and asymptomatic patients. Boden et al[5] consider that abnormal MRI findings in asymptomatic subjects are false-positive results, since it is difficult to distinguish between ageing discs and pathologically degenerate discs which cause symptoms. It is therefore important to know the frequency of degenerative changes on MRI in an asymptomatic population. Such abnormalities have been reported in several studies,[5-7] but the age and gender distribution of these findings have not been given in detail.

We have therefore prospectively investigated degenerative changes on MRI in the cervical discs of a sample of an asymptomatic Japanese population.

Patients and Methods

We recruited a total of 497 volunteers (262 male and 235 female; Tables I and II). Most of them were known to the investigators, and were chosen to provide a range of age groups in both genders. No subject had any current symptoms related to the cervical spine, such as neck pain or brachialgia, and had no previous history of disease or trauma to the cervical spine or brain which had needed medical care. These criteria were confirmed by a questionnaire before MRI, but no detailed neurological examination was performed. It was difficult to exclude possible minor symptoms in the past, since episodes of mild neck pain, brachialgia or shoulder girdle pain could be forgotten;

Table I. Age and gender of 497 asymptomatic subjects

Age (yr)	Male	Female
10 to 19	39	37
20 to 29	40	44
30 to 39	49	37
40 to 49	49	35
50 to 59	46	39
Over 60	39	43
Total	262	235

Table II. Occupation of 497 asymptomatic subjects

Occupation	Number
Office workers	214
Doctors, nurses and medical coworkers	138
Manual workers (construction, farming etc)	12
Students (junior, high school and college)	75
Others (housewives, retired, etc)	58

M. Matsumoto, MD, Instructor in Orthopaedic Surgery and Spine Surgery
Y. Fujimura, MD, Associate Professor of Orthopaedic Surgery
N. Suzuki, MD, Assistant Professor of Orthopaedic Surgery
Y. Nishi, MD, Instructor in Orthopaedic Surgery and Spine Surgery
M. Nakamura, MD, Instructor in Orthopaedic Surgery and Spine Surgery
Y. Yabe, MD, Professor and Chairman of Orthopaedic Surgery
H. Shiga, MD, Associate Professor of Radiology
School of Medicine, Keio University, Shinanomachi 35, Shinjyuku-ku, Tokyo 160, Japan.

Correspondence should be sent to Dr M. Matsumoto.

0301-620X/98/17929 $2.00

Table III. Grading system used to record the results

	Grade*		Binary notation
Disc degeneration	0	Bright as or slightly less bright than CSF	Negative
	1	Dark and/or speckled	Positive
	2	Almost black	
Posterior disc protrusion	0	Disc material confined within the posterior margin of the VB	Negative
	1	Disc material protruding beyond the posterior margin of the VB without cord compression	Positive
	2	Beyond VB with cord compression	
Anterior disc protrusion	0	Disc material confined within the anterior margin of the VB	Negative
	1	Disc material protruding beyond the anterior margin of the VB	Positive
Narrowing of the disc space	0	No narrowing or less than 25% loss in height compared with the most adjacent normal disc space	Negative
	1	25% to 50% loss of height	Positive
	2	More than 50% loss of height	
Foraminal stenosis	0	No obliteration of intraforaminal fat	Negative
	1	Disc material or bony spurs obliterating intraforaminal fat unilaterally or bilaterally	Positive

* CSF, cerebrospinal fluid; VB, vertebral body

for this reason we used the criterion of medical care for a cervical disorder.

Imaging. We performed MRI using a 1.5 T MRI scanner (Signa: GE Medical Systems, Milwaukee, Wisconsin) with a phased array coil or a 0.5 T MRI scanner (Resona; Yokogawa Medical Systems, Tokyo, Japan) with a surface neck coil. With the 1.5 T scanner we obtained T1-weighted sagittal images (T1WSI), T2-weighted sagittal images (T2WSI), and T1-weighted axial images (T1WAI) using fast spin-echo sequences (T1WI: TR/TE 520/12 ms, echo train length 4; T2WI: 5000/102 ms, echo train length 16; slice thickness 5 mm, no slice gap, field of view (FOV) 24 cm for sagittal images and 16 cm for axial images, matrix 256 $\times$ 192, 4 excitations). With the 0.5 T scanner, we obtained conventional spin-echo images (T1WI: TR/TE 450 to 500/20 ms; T2WI: 2000/100 ms; slice thickness 7 mm, no slice gap, FOV 25 cm for sagittal images and 20 cm for axial images, matrix 256 $\times$ 256 or 256 $\times$ 192, 2 excitations for T2WSI and 4 excitations for T1WSI and T1WAI).

We examined 134 subjects using the 1.5 T and 363 with the 0.5 T scanner. The age distribution of the subjects in these two groups was matched approximately, although most of the teenagers and men in their fifties were studied using the 0.5 T scanner.

Interpretation. Before any of the MRI images were studied, a grading system was developed by spine surgeons and a neuroradiologist (Table III) to evaluate disc degeneration, posterior disc protrusion, anterior disc protrusion, narrowing of the disc space and foraminal stenosis. We defined disc degeneration as a decrease in signal intensity on T2WSI, graded from 0 to 2. Anterior or posterior protrusion was recorded if disc material extended beyond the confines of the vertebral bodies on T1WSI.[5] Disc protrusion with bony spurs was recorded only when the disc material protruded beyond the tips of the spurs.

The three grades of posterior disc protrusion on T1WSI were normal (0), intermediate (1) and compression or impingement on the spinal cord (2) (Fig. 1). A bulge was

Fig. 1

T1-weighted sagittal image at 1.5 T of a 45-year-old man with no symptoms. There are grade-1 posterior disc protrusions at C5-C6 and C6-C7 (small arrows) and a grade-2 protrusion at C4-C5 (large arrow). There is an anterior disc protrusion with small spurs at C5-C6 (arrowhead).

defined as a small, diffuse, non-focal protrusion of non-osseous disc material[5,7] and prolapse as a focal extrusion. Posterior disc protrusion on T1WAI images was diagnosed when non-osseous material with an intermediate signal level protruded into the spinal canal or a neural foramen or both. These protrusions were classified as median, paramedian, or lateral according to the location of their apex on axial images in relation to the spinal cord. Median protrusions were opposite the middle third of the cord, paramedian opposite the lateral third and lateral protrusions lateral to the cord.

Foraminal stenosis was evaluated on T1WAI and diagnosed when epidural fat was obliterated by disc material of intermediate signal intensity or by osseous material of low signal intensity. We recorded all sagittal MRI findings from C2-C3 to C6-C7 except for narrowing at the C2-C3 level.

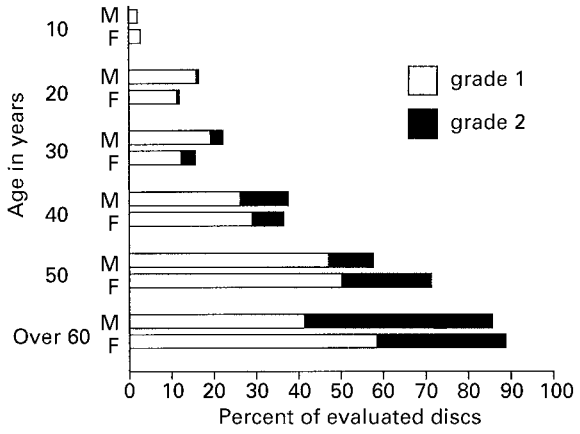

Fig. 2a

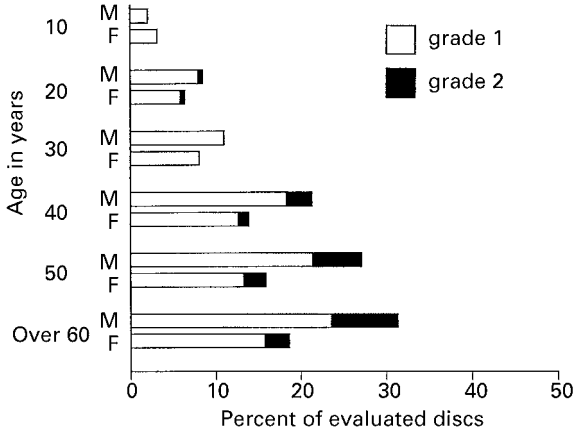

Fig. 2b

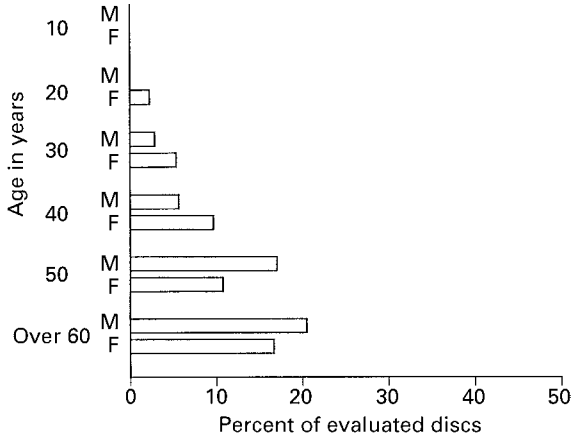

Fig. 2c

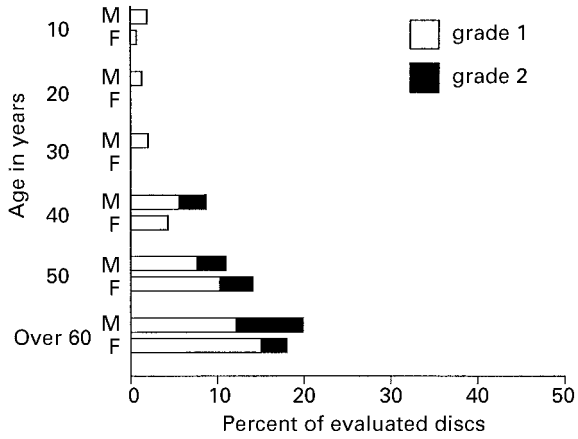

Fig. 2d

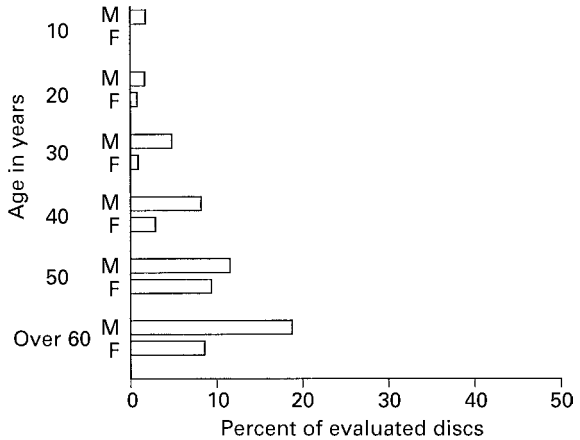

Fig. 2e

Percentages of discs with positive MRI findings by age and gender:
a) disc degeneration
b) posterior disc protrusion
c) anterior disc protrusion
d) disc space narrowing
e) foraminal stenosis.

Table IV. Incidence of posterior disc protrusions in 497 asymptomatic subjects

Morphological* classification	Grade 1	Grade 2	Total (%)
Bulge	253	31	284 (*80*)
Prolapse	51	19	70 (*20*)

*see text

This level was excluded because narrowing was diagnosed by comparison with the next disc space above. Axial images were obtained at C3-C4, C4-C5, and C5-C6 only; C2-C3 and C6-C7 were excluded to save scanning time and the cost of hard copies.

The assessments were made blind by one spine surgeon (MM). Two other spine surgeons (YN, MN) also evaluated 103 MRI studies (20% with a similar age, gender and MRI distribution) blindly and separately to allow evaluation of the reliability of the results. Each of the three surgeons had over ten years' clinical experience and were familiar with the interpretation of MRI of the cervical spine.

Analysis. We recorded the frequency of positive findings for each age group and at each intervertebral level and also assessed the coexistence of different MRI appearances. For statistical evaluation, the grading scores were converted into a binary notation, as positive or negative as shown in Table III. Chi-squared tests were used to study the relationship between the frequency of MRI findings and subject age and gender on the statistical package, SPSS 6.1J (SPSS Inc, Chicago, Illinois), taking a p value of less than 0.05 as significant. Kappa statistics were used to assess interobserver agreement with correction for chance between the readers, using the method of Fleiss[8] for more than two observers.

Results

The Kappa scores for the three observers were 0.59 for posterior disc protrusion, 0.51 for anterior disc protrusion, 0.54 for disc degeneration, and 0.60 for foraminal stenosis. These show fair to good agreement.

A total of 2480 discs was evaluated and the frequencies of single positive findings are shown in Figure 2 as percentages of discs in every age and gender group. Positive MRI findings increased significantly with age (chi-squared test, $p < 0.0001$), disc degeneration being the most frequent. Grade-1 or grade-2 disc degeneration was seen in 17% of discs of men and 12% of those of women in their twenties, rising to 86% and 89%, respectively, in subjects over 60 years of age. Posterior disc protrusions were more common in men than in women, especially those over 40 years of age ($p < 0.001$). Grade-2 posterior disc protrusion, with spinal cord compression, was seen in 50 discs of 38 subjects (7.6%), most of them over 40 years of age. Of the posterior disc protrusions 80% were classified as bulges, and the remainder as prolapsed (Table IV). Nineteen of the prolapsed discs (27%) and 31 of the bulging discs (11%) were of grade 2 in severity. On the axial images, median protrusions were the most common (67%), with fewer paramedian (26%) and lateral protrusions (7%). Anterior disc protrusions and narrowing of the disc space were less frequent than disc degeneration and posterior disc protrusion.

On T1WAI, we frequently found foraminal stenosis in subjects over 50 years of age, and more often in men ($p < 0.01$), but only 5.9% of all disc levels showed this finding.

The frequency of each MRI finding at various levels is

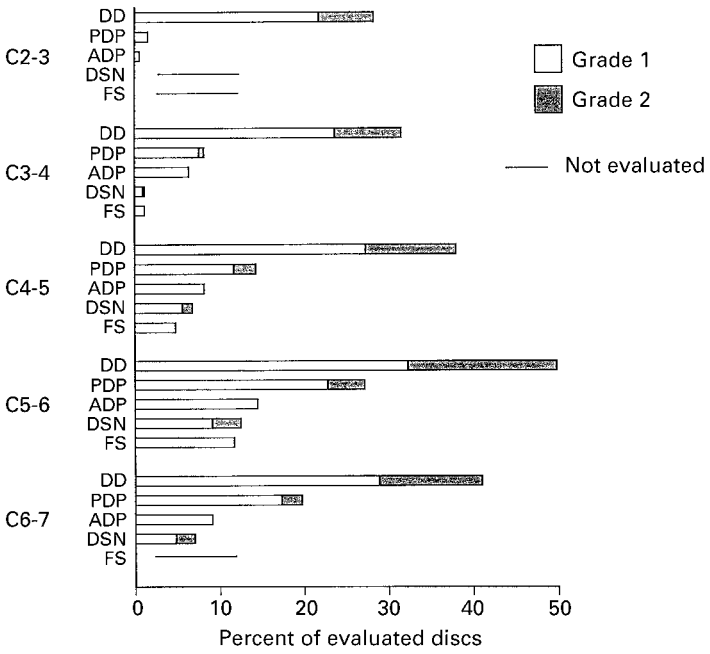

Fig. 3

Frequency of positive MRI findings for each disc level (DD, disc degeneration; PDP, posterior disc protrusion; ADP, anterior disc protrusion; DSN, narrowing of the disc space; FS, foraminal stenosis).

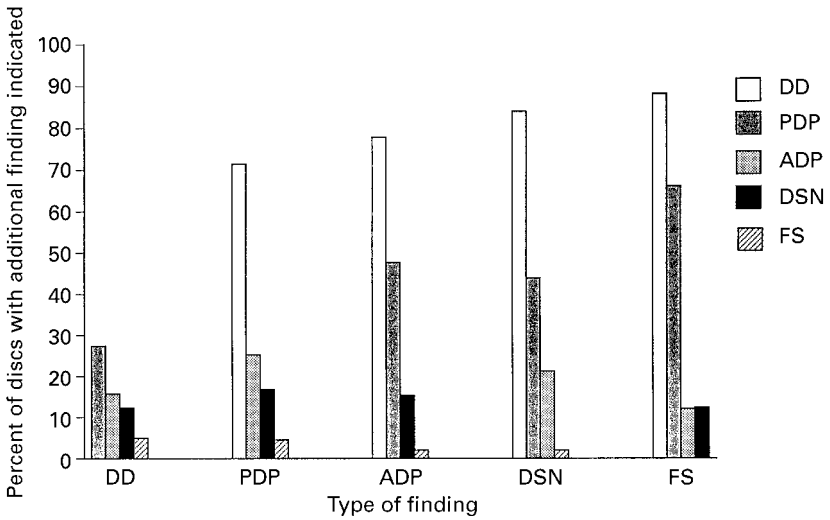

Fig. 4

The coexistence of MRI findings (DD, disc degeneration; PDP, posterior disc protrusion; ADP, anterior disc protrusion; DSN, narrowing of the disc space; FS, foraminal stenosis).

shown in Figure 3. The highest was at C5-C6, followed by C6-C7 and C4-C5. MRI signs of degeneration were rare at C2-C3 and C3-C4. Posterior disc protrusion with compression of the spinal cord was most common at C5-C6, followed by C4-C5 and C6-C7.

The correlations between different MRI findings are shown in Figure 4. Disc degeneration was often accompanied by other MRI findings, being present in 71% of discs with posterior protrusions and 78% of those with anterior protrusions. Of discs showing degeneration, 27% had posterior protrusion and 16% had anterior protrusion.

Discussion

The asymptomatic degenerative findings shown by MRI of the cervical spine are probably normal age-related changes. Boden et al[5] reported major abnormalities on MRI in 19% of 63 asymptomatic subjects, with degeneration increasing with age, except for herniation of the nucleus pulposus and disc bulging. Lehto et al[7] also demonstrated a strong correlation between abnormalities and age, and showed that the signal intensity of discs, measured as regions of interest, differed between age groups. These studies used gradient-echo sequences to evaluate disc degeneration. Our more detailed analysis, stratified by age and gender, used spin-echo and fast spin-echo sequences which are more sensitive to disc desiccation.

We found that the frequency of each degenerative MRI finding increased linearly with age, disc degeneration on T2WSI being the most prevalent finding in every age group. There is no generally accepted definition of disc degeneration morphologically, biochemically, or radiologically,[9] but a decrease in signal intensity on MRI is considered to be a very sensitive radiological sign, and the two descriptions are often used without distinction.[2] We found that the MRI indication of disc degeneration was significantly associated with disc protrusion and narrowing of the disc space, both of which suggest advanced structural deterioration. Of all discs with signal loss on MRI, however, only 16% showed anterior and 27% posterior protrusion. This suggests that signal loss on MRI depends more on age-related biochemical change than on structural deterioration; such changes may not have pathological consequences particularly in elderly people.

Posterior disc protrusion is clinically important since it may cause radiculopathy and myelopathy. We found that posterior protrusion and even compression of the spinal cord were not rare in symptomless subjects over 40 years of age. This has been previously reported by Teresi et al,[6] who studied MR images of the laryngeal region in 100 asymptomatic patients over 45 years of age. They found that 23% of patients over 64 years showed involvement of the spinal cord, but noted that reduction of the cross-sectional area of the spinal cord never exceeded 16%. Mild cord compression does not necessarily cause myelopathy,[10] but long-term follow-up of these asymptomatic subjects may provide information about the natural course of cervical myelopathy.

We used two different MRI scanners which may have had an adverse effect on our interpretation. In particular, the signal intensity of discs on T2WSI may differ on fast spin-echo and conventional spin-echo sequences. A preliminary study on four volunteers (20 discs) using the two scanners within one month allowed us to compare the frequency of disc degeneration by mixing these studies with others and interpreting blindly. We found that the frequency of disc degeneration was essentially the same with either scanner. Ross et al[11] have also compared these two sequences, for the lumbar spine, and found no significant differences in ranking normal and degenerative disc signals on the two sequences. The use of two MRI scanners probably did not cause a significant bias in our study.

Conclusions. The frequency of degenerative findings on MRI of cervical intervertebral discs of asymptomatic sub-

jects increased with age. These findings should be taken into consideration when reading MR images of patients with various cervical disorders.

This study was supported and collaborated by The Marine and Fire Insurance Association of Japan. We wish to thank Dr T. Sato, Assistant Professor, Department of Public Health Medicine, Tokyo Womens' Medical College, for his kind advice.

Although none of the authors have received or will receive benefits for personal or professional use from a commercial party related directly or indirectly to the subject of this article, benefits have been or will be received but are directed solely to a research fund, educational institution, or other non-profit institution with which one or more of the authors is associated.

References

1. **Modic MT, Masaryk TJ, Mulopulos GP, et al.** Cervical radiculopathy: prospective evaluation with surface coil MR imaging, CT with metrizamide, and metrizamide myelography. *Radiology* 1986;161: 753-9.
2. **Tertti M, Paajanen H, Laato M, et al.** Disc degeneration in magnetic resonance imaging: a comparative biochemical, histologic, and radiologic study in cadaver spines. *Spine* 1991;16:629-34.
3. **Brown BM, Schwartz RH, Frank E,Blank NK.** Preoperative evaluation of cervical radiculopathy and myelopathy by surface-coil MR imaging. *Am J Roentgenol* 1988;151:1205-12.
4. **Larsson EM, Holtas S, Cronqvist S, Brandt L.** Comparison of myelography, CT myelography and magnetic resonance imaging in cervical spondylosis and disc herniation: pre- and postoperative findings. *Acta Radiol* 1989;30:233-9.
5. **Boden SD, McCowin PR, Davis DO, et al.** Abnormal magnetic-resonance scans of the cervical spine in asymptomatic subjects. *J Bone Joint Surg [Am]* 1990;72-A:1178-84.
6. **Teresi LM, Lufkin RB, Reicher MA, et al.** Asymptomatic degenerative disk disease and spondylosis of the cervical spine: MR imaging. *Radiology* 1987;164:83-8.
7. **Lehto IJ, Tertti MO, Komu ME, et al.** Age-related MRI changes at 0.1 T in cervical discs in asymptomatic subjects. *Neuroradiology* 1994;36:49-53.
8. **Fleiss JL.** *Statistical methods for rates and proportions.* 2nd ed. New York, etc: John Wiley & Sons, 1981.
9. **Yu S, Haughton VM, Sether LA, Ho KC, Wagner M.** Criteria for classifying normal and degenerated lumbar intervertebral disks. *Radiology* 1989;170:523-6.
10. **Penning L, Wilmink JT, van Woerden HH, Knol E.** CT myelographic findings in degenerative disorders of the cervical spine: clinical significance. *Am J Roentgenol* 1986;146:793-801.
11. **Ross JS, Ruggieri P, Tkach J, et al.** Lumbar degenerative disk disease: prospective comparison of conventional T2-weighted spin-echo imaging and T2-weighted rapid acquisition relaxation-enhanced imaging. *Am J Neuroradiol* 1993;14:1215-23.