Fukushima J. Med. Sci.,
Vol. 50, No. 1, 2004

[Original Article]

# ANATOMIC AND CLINICAL INVESTIGATION OF A LOW SIGNAL PERIPHERAL LINE (BLACK LINE) AROUND THE LUMBAR HERNIATED NUCLEUS PULPOSUS ON MAGNETIC RESONANCE IMAGING

MASUMI IWABUCHI, SHINICHI KIKUCHI and KATSUHIKO SATO

*Department of Orthopaedic Surgery,*
*Fukushima Medical University School of Medicine, Fukushima*

(Received December 27, 1999, accepted May 31, 2004)

**Abstract**: It has been reported that a low signal peripheral line (black line) around the lumbar herniated nucleus pulposus (HNP) on magnetic resonance imaging (MRI) can be used for the evaluation of the interruption of the posterior longitudinal ligament (PLL). However, the previous reports have showed that different rates of agreement between MRI and surgical findings. In order to clarify this matter, the black line on MRI was assessed by a combined anatomic and clinical investigation. Three cadavers were used for the anatomic part of the study. For the clinical study, 11 patients with the diagnosis as HNP and 5 healthy volunteers were subjected to MRI to compare with the results from the anatomic study. The lumbo-sacral spine was dissected en bloc from the cadavers. The first imaging on MRI of the specimens was performed with the dural sac; the second imaging was performed after the dural sac and the nerve roots have been removed but with the PLL left; the third imaging was performed after the PLL was completely removed. After completion of imaging, the specimens were cut in sagittal and horizontal planes for histological evaluation. In the cadavers after removing the PLL histologically, the black lines were still shown on MRI. Finally, after changing encoding, the black lines were interrupted at some disc levels in the cadaver specimen, the patients with HNP, and healthy volunteers. Therefore the black lines could be interpreted as a chemical shift artifact. These results indicate that the continuity or the discontinuity of the black line is not appropriate sign to diagnose whether disruption of the PLL has occurred or not.

**Key words**: magnetic resonance imaging, lumbar spine, herniated nucleus pulposus

岩渕真澄，菊地臣一，佐藤勝彦
Correspondence to: Masumi Iwabuchi MD, Department of Orthopaedic Surgery, Fukushima Medical University School of Medicine, Fukushima City 960-1295, Japan.
e-mail: miwabu@fmu.ac.jp

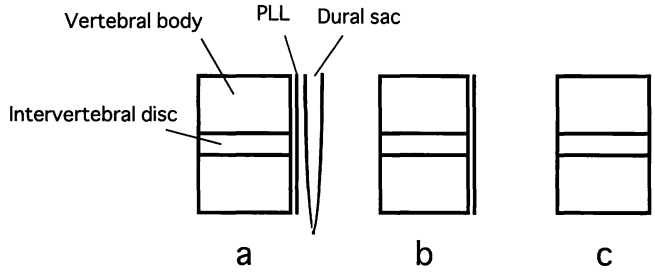
## INTRODUCTION

It is important to assess that the posterior longitudinal ligament (PLL) is ruptured or not for treatment of the patients with lumbar herniated nucleus pulposus because of the different prognosis lying between the 2 types of herniations. It has been reported that a low signal peripheral line (black line) around the lumbar herniated nucleus pulposus on magnetic resonance imaging (MRI) is available to evaluate interruption of the PLL. Grenier[1] performed an anatomic and clinical study of the low signal peripheral line and reported that absence of depiction of the peripheral line appears to be the most reliable sign of ligament disruption. However, the previous reports concerning the black line on MRI have reported different rates of agreement between MRI and surgical findings[1-3]. In order to clarify this matter, we assessed the black line by an anatomic investigation by using of cadavers and a clinical investigation by using of the patients with lumbar herniated nucleus pulposus and healthy volunteers.

## MATERIALS AND METHODS

The lumbo-sacral specimens were removed from 3 cadavers: a 50 years old man, an 84 years old man and a 75 years old woman. The cadavers were detected no disc herniation on MRI. The lamina was removed and the dural sac as well as the lumbar nerve roots was exposed. A 1.5-T magnet MRI system (Gyroscan ACS-NT, Philips, Netherlands) was employed for all MRI procedures. When MRI was applied, the specimens were put in a casket made from styrol foam, which was filled with physiological saline. The MRI sequence that we used was TR 550 ms/TE 15 ms for T1-weighted sagittal images and TR 4,100 ms/TE 120 ms for T2-weighted sagittal images. A $230 \times 512$ matrix size was used for reconstruction, with a 340 mm field of view. Section thickness was 5 mm for all images. Vertical phase-encoding and horizontal frequency-encoding were set. The first imaging with MRI was applied on the specimens with the dural sac and the nerve roots left as it is. The second imaging was performed after the dural sac and the nerve roots were removed from the specimens but with the PLL left in place. The third imaging was performed after the PLL had been removed from the specimens (Figure 1). After imaging, the specimens were cut in sagittal and horizontal planes at the intervertebral disc levels for the histological certification of the absence of the PLL. The sections were stained with Hematoxylin-Eosin.

In 11 patients (7 men and 4 women; mean age, 41 years; range, 21-70 years) who had been diagnosed as herniated nucleus pulposus (HNP) and 5 healthy volunteers (4 men and 1 woman; mean age 26 years; range, 25-27), MRI was also applied in the clinical part of the study. The first MRI sequence in the clinical study was the same way in the anatomic part of the study.




First imaging : with the dural sac and the PLL (a)
Second imaging : with only the PLL (b)
Third imaging : removal of the PLL (c)

Fig. 1. Conditions of the specimens for MRI

Table 1. The black line in the anatomic study

| No. | 1 | | | 2 | | | 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| Imaging | a | b | c | a | b | c | a | b | c |
| L1/2 | − | − | − | − | − | − | − | − | − |
| L2/3 | + | + | + | − | − | − | + | + | + |
| L3/4 | + | + | + | + | + | + | − | − | − |
| L4/5 | + | + | + | + | + | + | − | − | − |
| L5/S | + | + | + | + | + | + | + | + | + |

a : with the Dural sac and the PLL + : black line is observed
b : with only the PLL − : black line is not observed
c : removal of the PLL

The final MRI was performed with another sequence at vertical frequency-encoding and horizontal phase-encoding for one of the anatomic specimens removed the PLL and all of the clinical subjects in order to investigate the changes of the black line.

## RESULTS

### *Anatomic study*

In the all cadaver specimens, it was possible to see the black lines on MRI at L5/S intervertebral disc levels. However, the black line at L1/2 intervertebral disc levels was not observed (Table 1). In spite of removing the PLL from the specimens, it was still possible to see the black lines on MRI at the intervertebral disc levels at which the black lines had been observed in the first imaging. We confirmed that the PLL was completely removed histologically in all subjects. (Figure 2, a-c). In the final imaging after changing encoding for one specimen removed the PLL, the black lines were interrupted at some intervertebral disc levels (Figure 3).

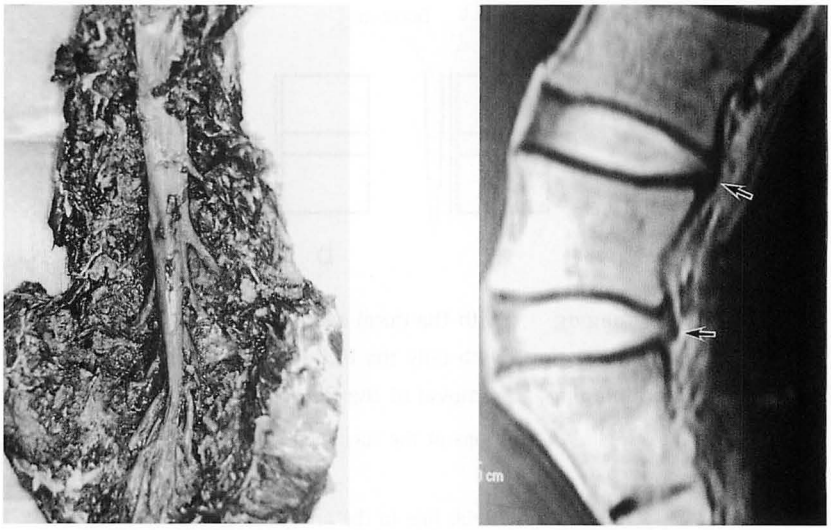


Fig. 2-A. First imaging (Specimen with the dural sac and the PLL)
The black line is observed at posterior surface of the L4/5 and L5/S intervertebral disc (arrows).

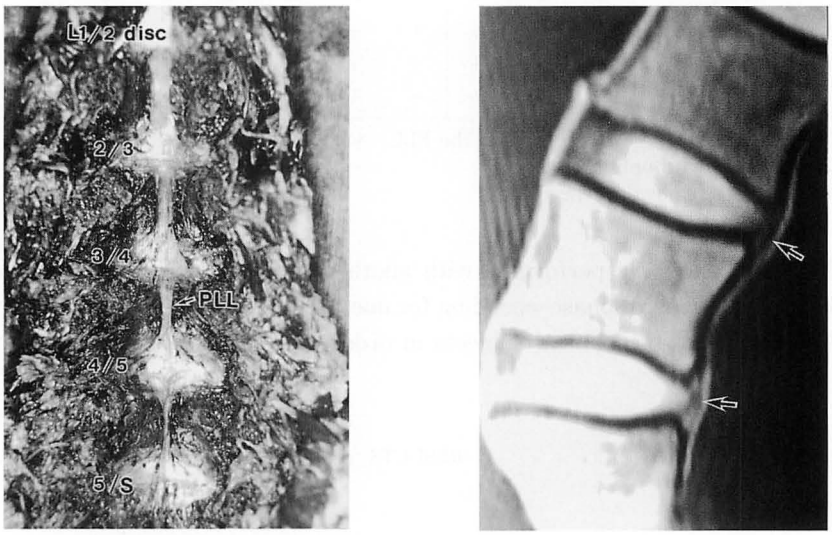



Fig. 2-B. Second imaging (Specimen with only the PLL)
The black line is observed like on the first imaging at posterior surface of the L4/5 and the L5/S intervertebral disc (arrows).

*Clinical study*

In the all patients diagnosed as HNP, the black lines on MRI were observed at the herniated nucleus pulposus levels (Table 2). Continuous black lines at the

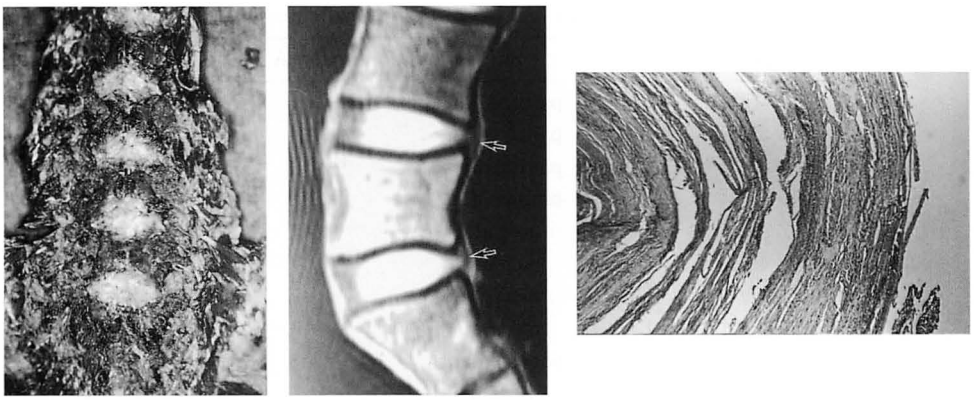
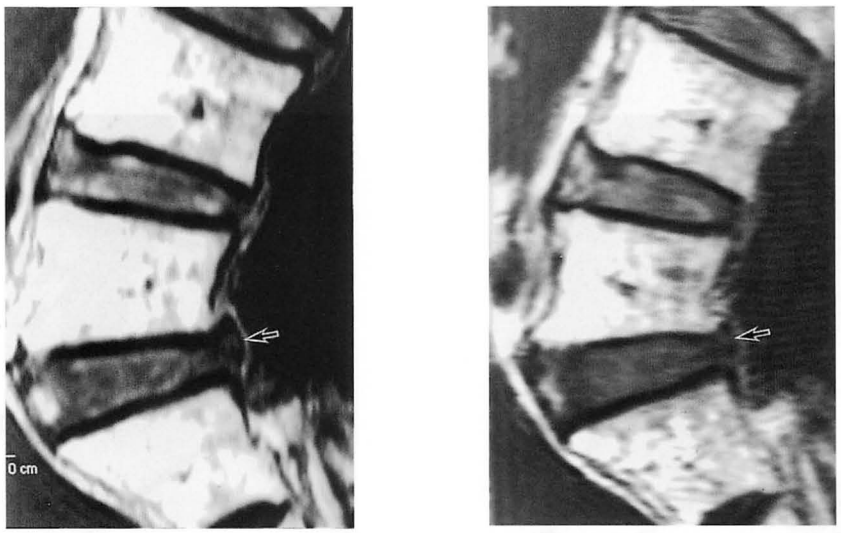


Fig. 2-C. Third imaging (Specimen after removal of the PLL)
The black line is still observed at the posterior surface of the L4/5 and L5/S intervertebral disc while the PLL has been removed (arrows).




A B

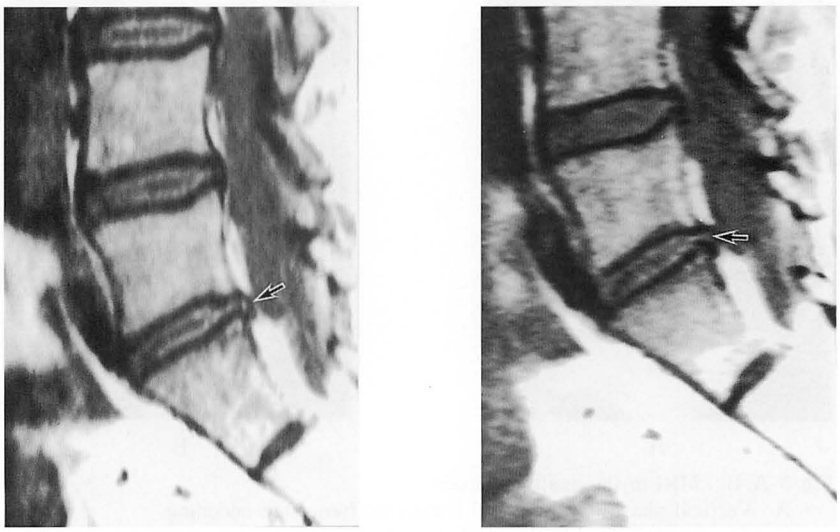
Fig. 3-A, B. MRI in the anatomic study
A : Vertical phase-encoding and horizontal frequency-encoding.
Continuous black line is observed at posterior surface of the L5/S intervertebral disc (arrow).
B : Vertical frequency-encoding and horizontal phase-encoding.
The black line is interrupted (arrow).

herniated nucleus pulpous levels were observed in 6 out of 11 patients in the first imaging. The black lines were interrupted in the second imaging after changing encoding in all 6 patients (Figure 4). Furthermore, in 3 out of 5 healthy volunteers, continuous black lines, which were observed in the first imaging, were interrupted at some intervertebral disc levels in the second imaging after changing encoding (Table

Table 2. MRI findigns of the clinical cases

| Case | Age/Sex | Level | Site | Continuity/A | Continuity/B |
|---|---|---|---|---|---|
| 1 | 41/M | L5/S | paramedian | + | − |
| 2 | 39/F | L5/S | paramedian | + | − |
| 3 | 21/M | L5/S | paramedian | + | − |
| 4 | 48/M | L5/S | paramedian | − | − |
| 5 | 70/M | L4/5 | median | + | − |
| 6 | 42/F | L4/5 | median | − | − |
| 7 | 37/F | L4/5 | median | − | − |
| 8 | 26/M | L4/5 | median | + | + |
| 9 | 45/M | L4/5 | paramedian | + | − |
| 10 | 47/F | L4/5 | median | + | − |
| 11 | 38/M | L4/5 | paramedian | − | − |

Continuity = Continuity of the black line
A = vertical phase-encoding, horizontal frequency-encoding
B = vertical frequency-encoding, horizontal phase-encoding



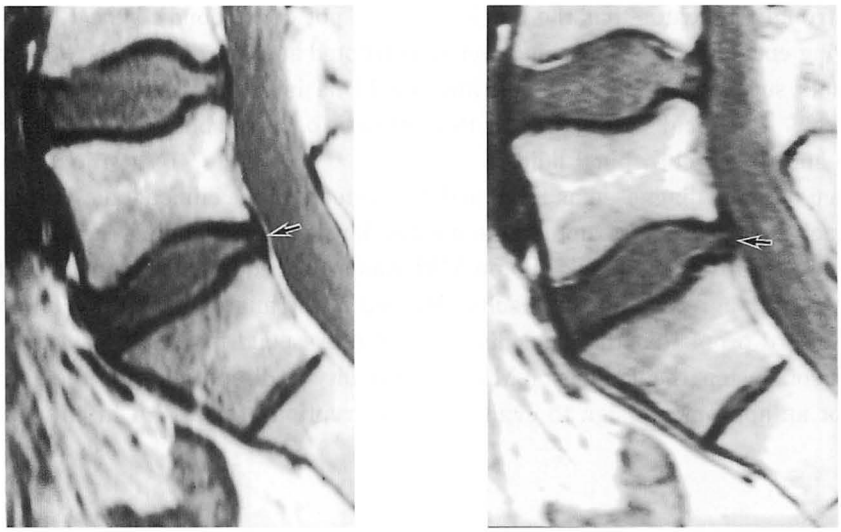
A B

Fig. 4-A, B. MRI of a patient diagnosed as HNP (39 years old woman)
A : Vertical phase-encoding and horizontal frequency-encoding.
Continuous black line is observed at posterior surface of the L5/S intervertebral disc (arrow).
B : Vertical frequency-encoding and horizontal phase-encoding.
The black line is interrupted (arrow) similar to the anatomic study.

Table 3. The black line in the healthy volunteers

| No. | 1 | | 2 | | 3 | | 4 | | 5 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Imaging | a | b | a | b | a | b | a | b | a | b |
| L1/2 | + | − | + | + | + | + | + | + | + | + |
| L2/3 | + | + | + | + | + | + | + | + | + | + |
| L3/4 | + | + | + | + | + | + | + | + | + | + |
| L4/5 | + | + | + | + | + | + | + | + | + | − |
| L5/S | + | − | + | − | + | + | + | + | + | − |

a : vertical phase-encoding and horizontal frequency-encoding
b : vertical frequency-encoding and horizontal phase-encoding
+ : continuous black line
− : discontinuous black line



A B

Fig. 5-A, B. MRI of a healthy volunteer (25 years old man)
A : Vertical phase-encoding and horizontal frequency-encoding.
Continuous black line is observed at posterior surface of the L5/S intervertebral disc (arrow).
B : Vertical frequency-encoding and horizontal phase-encoding.
The black line is interrupted (arrow) similar to the anatomic specimens and the patients.

3, Figure 5).

## DISCUSSION

Macnab[4] classified HNP into 4 types, disc protrusion, subligamentous extrusion, transligamentous extrusion and sequestrated intervertebral disc. According to this

classification, it has been reported that a peripheral black line seen on MRI was regarded as the PLL and that the black line was an available sign to evaluate disruption of the PLL[1-3,5-7]. However, in the previous literature different degrees of agreement have reported between the MRI findings and the surgical findings[1,2,6]. Thus, our hypothesis was that the black line on MRI might not correspond to the PLL.

In the lumbar spine, the PLL does not cover the whole posterior surface of the intervertebral disc[8]. This is most typical in the lower lumbar spine. However, in the present study, inconsistent results regarding the black lines on MRI were obtained. The black lines were seen at L5/S intervertebral discs in all specimens, but not observed at L1/2 intervertebral discs in any of the specimens. The black lines that had been observed at the first imaging were still observed at the imaging for all 3 specimens after removing the dural sac, the nerve roots and the PLL. This fact strongly indicates that the black line does not correspond to the PLL. After changing encoding, the black lines were interrupted at some disc levels. Therefore, the facts suggested that the black lines could be interpreted as a chemical shift artifact[9]. Chemical shift artifact is thought to be occurred between the epidural fat tissue and the cerebrospinal fluid.

In 6 patients diagnosed as HNP and 3 volunteers in the clinical part of the study, the black lines were interrupted at some disc levels after changing encoding. This fact suggested that the black line on MRI was produced by chemical shift artifact. These results agreed with the results obtained in the anatomic study. The results could afford proof that the black line did not correspond to the PLL in vivo.

In conclusion, the findings on MRI of continuity or discontinuity of the black line are not an appropriate sign to evaluate the disruption of the PLL in patients with HNP.

## REFERENCES

1. Grenier N, Greselle JF, Vital JM, Kien P, Baulny D, Broussin J, Senega Caille JM. Normal and disrupted lumbar longitudinal ligaments: Correlative MR and anatomic study. Radiology, **171**: 197-205, 1989.
2. Kim KY, Kim YT, Lee CS, Kang JS, KIm YJ. Magnetic resonance imaging in the evaluation of the lumbar herniated intervertebral disc. Int Orthop, **17**: 241-244, 1993.
3. Maruo S. The conservative treatment for lumbar disc herniation. J Jpn Orthop Assoc, **70**: 673-684, 1996.
4. Macnab I, McCulloch J. Backache. 2nd ed. Williams and Wilkins, Baltimore, 132, 1990.
5. Komori H, Shinomiya K, Nakai O, Yamaura I, Takeda S, Furuya K. The natural history of herniated nucleus pulposus with radiculopathy. Spine, **21**: 225-229, 1996.
6. Enzmann DR. Degenerative disc disease. *In*: Magnetic resonance imaging of the spine. Mosby, St. Louis, 473-509, 1990.
7. Mink JH. Imaging evaluation of the candidate for percutaneus lumbar discectomy. Clin Orthp & Related Res, **238**: 83-91, 1989.
8. Ohshima H, Hirano N, Osada R, Matsui H, Tsuji H. Morphologic variation of lumbar posterior longitudinal ligament and the modality of disc herniation. Spine, **18**: 2408-

2411, 1993.
9. Babcock EE, Brateman L, Weinreb JC, Honer SD, Nunnally RL. Edge artifacts in MR images: chemical shift artifact. J Comput Assist Tomogr, **9**: 252-257, 1985.