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## **Lumbosacral nerve root enhancement with disk herniation on contrast-enhanced MR.**

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*AJNR Am J Neuroradiol* 1996, 17 (9) 1619-1625

<http://www.ajnr.org/content/17/9/1619>

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# Lumbosacral Nerve Root Enhancement with Disk Herniation on Contrast-Enhanced MR

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**PURPOSE:** To evaluate the clinical importance of nerve root enhancement associated with lumbar disk herniation. **METHODS:** Thirty-two patients with lumbar disk herniation were examined with unenhanced and contrast-enhanced MR imaging. We investigated the relationship between nerve root enhancement and location of herniated disk in the epidural space, onset pattern of symptoms, subsequent treatment, and surgical findings. **RESULTS:** Ten of the 32 patients had nerve root enhancement, and all belonged to the group with abrupt and severe nerve root compression with no residual space for the root between the herniated disk and the pedicle in the lateral recess. Tight compression of the root without mobility was seen in the four patients with nerve root enhancement who were treated surgically. **CONCLUSION:** Nerve root enhancement may indicate the existence of abrupt and severe compression of the nerve root as well as the presence of severe adhesion of the herniated disk and the nerve root. This finding does not necessarily determine the type of subsequent treatment.

**Index terms:** Nerves, lumbar; Spine, intervertebral disks, herniation; Spine, magnetic resonance

*AJNR Am J Neuroradiol* 17:1619–1625, October 1996

Nerve root enhancement on contrast-enhanced magnetic resonance (MR) images has been observed in patients after lumbosacral surgery (1, 2), in healthy subjects (3–6), and in patients with disk herniation (3–5). In some patients with lumbar disk herniation, contrast-enhanced MR images show nerve roots with enhancement from the site of compression to the conus medullaris. This type of root enhancement has been described as multisegmental or multilevel enhancement (3), selective enhancement (4), or continuous intradural enhancement (5), and it is distinguished from the minimal enhancement seen in normal intrathecal roots. Various causes of this phenomenon have been proposed (3–5), including breakdown of the blood-nerve barrier by compression of the

root. However, the clinical importance of this MR finding is controversial. Our study was undertaken to evaluate the relationship between nerve root compression and nerve root enhancement associated with disk herniation, and to discuss the usefulness of contrast-enhanced MR imaging for the evaluation of lumbosacral disk herniation that is not operated on.

## Materials and Methods

From October 1992 to February 1994, MR imaging was performed in 32 patients with unoperated lumbar disk herniation. Contrast-enhanced MR images were obtained to differentiate herniated disks from neoplastic lesions in the epidural space. The patients included 18 women and 14 men, ranging in age from 18 to 77 years (mean, 44 years). The parent interspaces of the herniated disks were as follows: two at L3–4, 13 at L4–5, and 17 at L5–S1. The period between the abrupt onset of symptoms in 25 patients and the MR examination ranged from 5 to 157 days (mean, 38 days). Seven of the patients had insidious onset of herniation. One patient was examined twice, on the 27th and 55th day after onset, to reevaluate an intradural extramedullary tumor located at a different level from the herniated disk.

MR imaging was performed with a 1.5-T magnet and a surface coil. T1-weighted (600/15/2 [repetition time/echo time/excitations]) sagittal spin-echo images with a 5-mm

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Received July 31, 1995; accepted after revision April 1, 1996.

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*AJNR* 17:1619–1625, Oct 1996 0195-6108/96/1709–1619

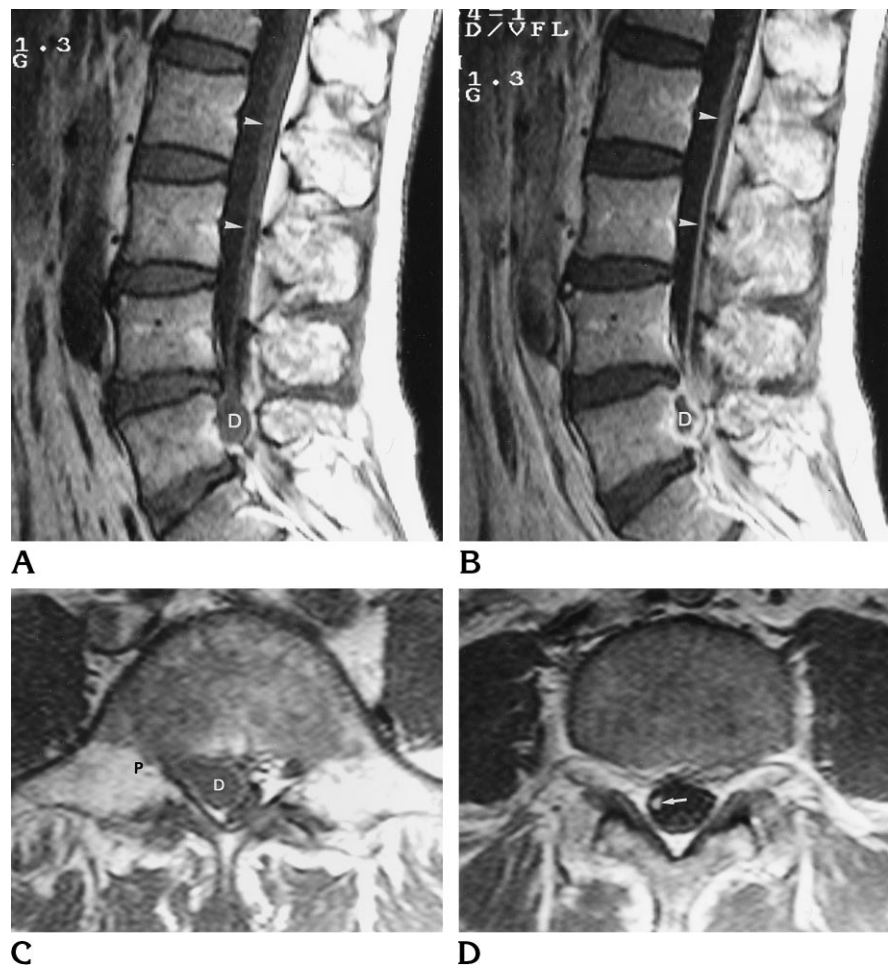
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Fig 1. Fifty-year-old man with L4–5 disk herniation.

Sagittal T1-weighted MR images before (A) and after (B) contrast administration show root enhancement (arrowheads) of the fifth lumbar nerve root from the site compressed by a herniated disk (D) to the first lumbar level.

C, Axial unenhanced T1-weighted MR image shows the herniated disk (D) at the pedicle (P) level in the right lateral recess.

D, Axial contrast-enhanced T1-weighted MR image above the herniated disk shows ipsilateral nerve root enhancement (arrow).



section thickness, a 1-mm intersection gap, and a  $256 \times 160$  matrix, were obtained both before and after intravenous injection of 0.1 mmol/kg of gadopentetate dimeglumine. T2-weighted (600/15/2) sagittal gradient-echo images with a  $15^\circ$  flip angle were obtained using the same section thickness, intersection gap, and matrix as for the T1-weighted images. Five-millimeter-thick T1-weighted (600/15/2) axial spin-echo images were obtained parallel to the disks at the affected levels before (in 18 of 33 examinations) and after intravenous administration of gadopentetate dimeglumine. Contrast-enhanced MR imaging was initiated a few minutes after administration of contrast material and completed within 30 minutes.

All MR images were reviewed retrospectively by two radiologists. The presence of nerve root enhancement was judged by making a comparison between the unenhanced and contrast-enhanced T1-weighted sagittal images (Figs 1 and 2). In cases with nerve root enhancement, the root enhancement was also confirmed on contrast-enhanced T1-weighted axial images (Figs 1 and 2).

For this study, we analyzed the relationship between nerve root enhancement and such factors as the location of the herniated disk relative to the nerve root in the epidural space, the onset pattern of symptoms, the subse-

quent treatment (surgery or not), and the surgical findings.

Patients were divided into four categories depending on the degree of extension of the herniated disk and on whether there was room for the root in the epidural space as judged by findings on the contrast-enhanced axial T1-weighted images. Patients with herniated disk extending within the level of the neural foramen (NF) but not obliterating the neural foraminal space were classified as having type NF(+) herniation; those in whom the neural foraminal space was obliterated were classified as having type NF(-) herniation. Patients who had herniated disk extending to the level of the pedicle (P) with room for the root in the epidural space at the lateral recess were classified as having type P(+) herniation; those without residual epidural space between the pedicle and herniated disk were regarded as having type P(-) herniation. We evaluated the relationship between nerve root enhancement and these types. The  $\chi^2$  test was used to analyze the difference in the frequency of nerve root enhancement among types.

The clinical course was observed in 28 patients. We compared frequency of surgical treatment between patients with and without nerve root enhancement. The surgical findings of the eight patients treated surgically were noted relative to the presence of nerve root enhancement.

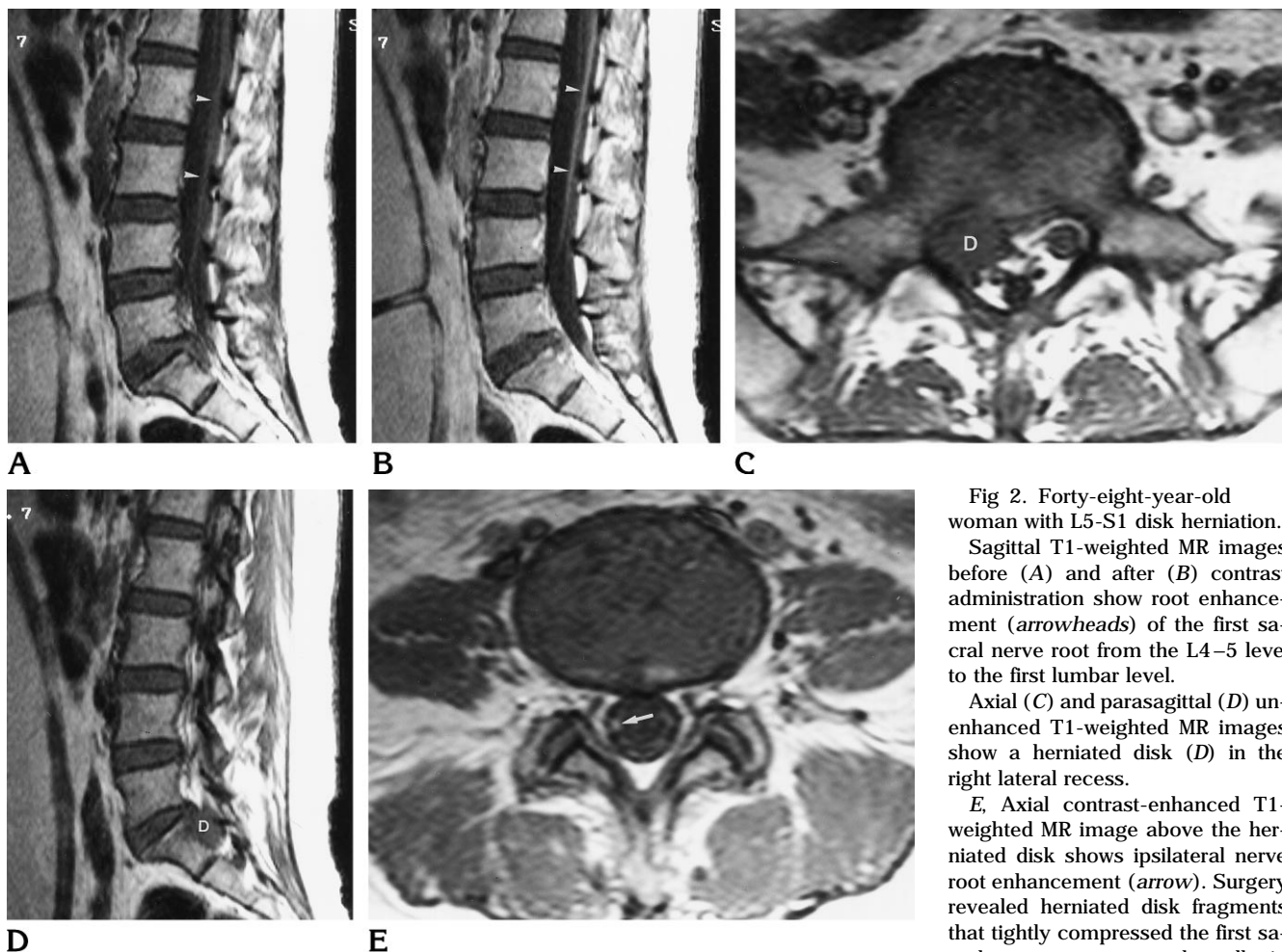


Fig 2. Forty-eight-year-old woman with L5-S1 disk herniation.

Sagittal T1-weighted MR images before (A) and after (B) contrast administration show root enhancement (arrowheads) of the first sacral nerve root from the L4-5 level to the first lumbar level.

Axial (C) and parasagittal (D) unenhanced T1-weighted MR images show a herniated disk (D) in the right lateral recess.

E, Axial contrast-enhanced T1-weighted MR image above the herniated disk shows ipsilateral nerve root enhancement (arrow). Surgery revealed herniated disk fragments that tightly compressed the first sacral nerve root posterolaterally in the right lateral recess.

## Results

Classification of the location of herniated disk relative to the nerve root in the epidural space produced nine patients with type NF(+) herniation (Fig 3), 10 patients with type P(+) herniation (Fig 4), 13 patients with type P(-) herniation (Fig 5 and Table 1), and no patient with type NF(-) herniation. Although 10 patients with type P(-) herniation showed nerve root enhancement, all other patients with type NF(+) or type P(+) herniation did not. The frequency of nerve root enhancement among types was significantly different ( $P < .001$ ).

Abrupt onset of symptoms occurred in 25 patients, and onset was insidious in seven patients. Ten of the 25 with abrupt onset showed nerve root enhancement whereas none of the patients with insidious onset had nerve root enhancement. An evaluation of the relationship

between the frequency of nerve root enhancement and the onset pattern of symptoms by type (Table 2) showed that among the patients with type P(-) herniation and abrupt onset of symptoms ( $n = 11$ ), only one patient did not have nerve root enhancement.

Of the 28 patients in whom the clinical course could be observed, eight had nerve root enhancement. Four, all type P(-), of the eight patients with nerve root enhancement and four, two type NF(+) and two type P(+), of the 20 patients without nerve root enhancement underwent surgery. Although patients with nerve root enhancement required surgery more frequently than those without nerve root enhancement (50% versus 20%), this difference was not statistically significant.

Among the four patients with nerve root enhancement, surgery revealed tight compression

**A**

Fig 3. Thirty-eight-year-old woman with L5-S1 disk herniation.

A, Parasagittal unenhanced T1-weighted MR image shows a herniated disk (*D*) at foraminal level of the parent interspace.

Axial T1-weighted MR images before (*B*) and after (*C*) contrast administration show the herniated disk (*D*) without compression of the nerve root (*arrow*) in the neural foramen.

*D*, Axial T1-weighted MR image shows the herniated disk does not extend to the pedicle level. This is a type NF(+) herniation.

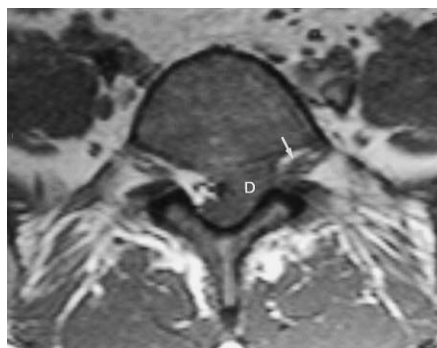
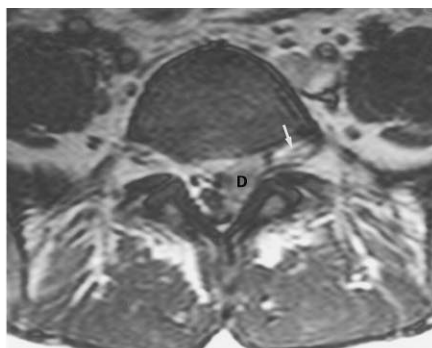
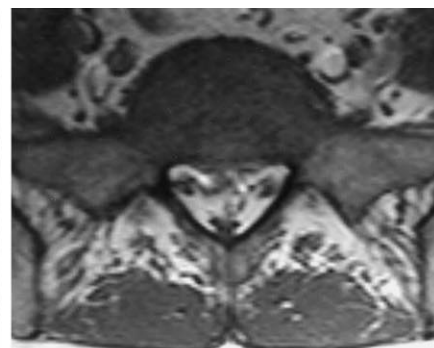
**B****C****D**

Fig 4. Twenty-two-year-old man with L4-5 disk herniation.

A, Sagittal unenhanced T1-weighted MR image shows a herniated disk (*D*) extending inferiorly.

B, Axial unenhanced T1-weighted MR image shows the spared epidural space between the pedicle (*P*) and the herniated disk (*D*) at the pedicle level. This is a type P(+) herniation.

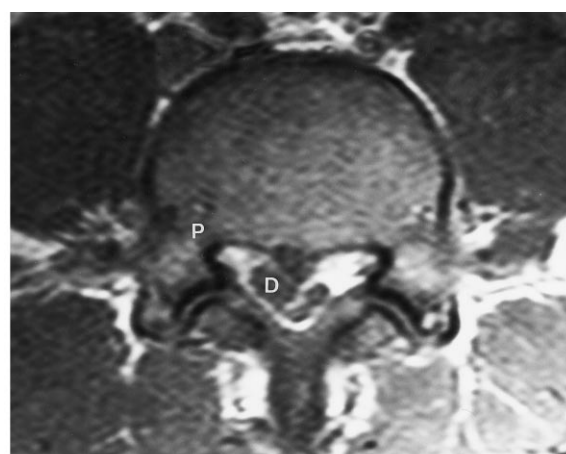
**A****B**



Fig 5. Thirty-six-year-old woman with L4-5 disk herniation and radicular symptoms and paresthesias of the right foot, which began about 5 years earlier.

A, Parasagittal unenhanced T1-weighted MR image shows a herniated disk (D) extending inferiorly.

B, Axial contrast-enhanced T1-weighted MR image shows the herniated disk (D) extending to the pedicle level, with no space for the nerve root in the right lateral recess. This is a type P(-) herniation.

Sagittal T1-weighted MR images before (C) and after (D) contrast administration do not show root enhancement.

of the nerve root without mobility and adhesion between the nerve root and herniated disk. In comparison, the four patients without nerve root enhancement had mild compression with mobility of the nerve root.

### Discussion

Nerve root enhancement has been observed on contrast-enhanced MR images after successful lumbar disk surgery (1) and at nerve root levels both with and without disk disease (3-6). In nerve root enhancement related to disk herniation, it has been suggested that the enhancement may be associated with the breakdown of the blood-nerve barrier and the change in capillary permeability of nerve roots at the level of nerve root compression (2-4).

To evaluate the degree of nerve root compression with nerve root enhancement, we directed our attention to the relationship among herniated disks, nerve root, and nearby bony structures. We hypothesized that the location of herniated disk relative to the root and bony structures would reflect the degree of nerve root compression. On the basis of this hypothesis, we thought there might be severe nerve root compression in patients in whom there is no room for the root between the herniated disk and the bony structure, types NF(-) and P(-), and that there might be mild compression of the root in patients in whom there is room for the root in the epidural space, types NF(+) and P(+). Surgery confirmed our hypothesis in all types except NF(-), as there were no such pa-

TABLE 1: MR and clinical findings of patients with type P(-) disk herniation

Patient	Age, y	Level of Disk Herniation	Direction of Disk Herniation	Level of Nerve Root Enhancement	Pattern of Onset	Interval from Onset of Herniation to Imaging, d	Treatment
1	45	L4-5	R downward	R L-5	Abrupt	14	Surgery
2	18	L5-S1	L downward	L S-1	Abrupt	15	Conservative
3	43	L5-S1	R upward	R L-5	Abrupt	16	Surgery
4	56	L4-5	L upward	L L-4	Abrupt	17	Conservative
5	49	L3-4	L downward	None	Abrupt	25	Conservative
6*	39	L5-S1	R downward	R S-1	Abrupt	27	Conservative
		L5-S1	R downward	R S-1	Abrupt	55	Conservative
7	60	S5-S1	L upward	L L-5	Abrupt	32	Conservative
8	50	L4-5	R downward	R L -5	Abrupt	33	Conservative
9	48	L5-S1	L downward	L S-1	Abrupt	39	Conservative
10	59	L4-5	L downward	L L-5	Abrupt	48	Surgery
11	48	L5-S1	R downward	R S-1	Abrupt	97	Surgery
12	36	L4-5	R downward	None	Insidious	Unknown	Conservative
13	36	L4-5	R downward	None	Insidious	Unknown	Conservative

\* Patient 6 was examined twice.

TABLE 2: Relationship between the onset pattern of symptoms and nerve root enhancement in each type of herniation

Onset pattern	NF(+)		P(+)		P(-)	
	Abrupt	Insidious	Abrupt	Insidious	Abrupt	Insidious
No. of patients	7	2	7	3	11	2
No. of nerve root enhancements	0	0	0	0	10	0
Frequency (%) of nerve root enhancement	0	0	0	0	91	0

tients in our study group. In the four patients with type P(-) herniation, surgery revealed tight compression of the nerve root without mobility and adhesion between the nerve root and herniated disk. In contrast, the four patients who had type NF(+) and type P(+) herniation had mild compression with mobility of the nerve root.

The relationship between large disk herniation and nerve root enhancement and the relationship between the thickness of peridiskal enhancement and root enhancement has been studied previously (4); however, in that study, the authors could not show any statistically significant relationships. If we hypothesize that a herniated disk causes nerve root enhancement, it is reasonable to direct our attention to the relationship between the herniated disk and the nerve root. It was thought inappropriate to address only factors related to the disk, such as peridiskal enhancement or the size of herniation. We believe our method reflects the degree of nerve root compression more accurately than methods based on the size of the disk herniation, because the relationship between herniated disk and nerve root may vary according to

the degree and location of the herniated disk extension. Furthermore, it is difficult to grade objectively the degree of peridiskal enhancement or the size of disk herniation.

There were not enough patients in each group to analyze the differences among the groups statistically; however, a factor strongly associated with nerve root enhancement was the abruptness with which symptoms appeared. Nerve root enhancement was observed only in patients of type P(-) herniation with abrupt onset. Therefore, a rapid, severe compression of a nerve root may be a significant factor in nerve root enhancement.

Experimental studies have shown that mechanical injuries to nerves cause an increase in microvascular permeability of the endoneurial capillaries within the nerves (7, 8). Fluid and macromolecules then leak from the vessels into the endoneurial space, resulting in intraneural edema (7-9). The edema was found to be more pronounced after rapid onset of compression (9). These experimental studies may explain the results of our clinical study, which showed that mechanical factors, such as rapid and strong compression of nerve roots, may play an

important role in causing nerve root enhancement in patients with disk herniation.

To assess the clinical usefulness of nerve root enhancement, we investigated whether there was a difference in the frequency of surgical treatment required between the patients with nerve root enhancement and those without it. Although patients with nerve root enhancement required surgery more often than those without nerve root enhancement, this difference was not statistically significant. The poor relationship between the degree of root compression and the necessity of surgery may be partly explained by the spontaneous regression of herniated disks (10, 11). Severe compression of the nerve root at the onset of disk herniation, which would cause nerve root enhancement, may not influence the clinical course, since spontaneous regression of herniated disks may result in decompression of the nerve roots. In fact, some cases of spontaneous disappearance of both disk herniation and nerve root enhancement have been reported (4, 5). However, if compression is prolonged, intraneural edema might impair nerve root function. With long-standing edema, fibroblast invasion may occur, resulting in formation of intraneural fibrotic scar tissue (8). In addition, compression of nerve roots by disk herniation may also cause local demyelination and wallerian degeneration (8). Therefore, we propose that prolonged nerve root enhancement associated with abrupt onset of disk herniation indicates continued severe nerve compression and should be considered an important indication for surgical treatment.

In our study, the interval between the onset of symptoms and MR studies showing nerve root enhancement was within 1 month in five patients, within 2 months in five patients, and over 3 months in one patient. One patient who had both nerve root enhancement and symptoms for more than 3 months' duration did undergo surgery. Nine patients with nerve root enhancement were examined within 2 months of their abrupt onset and were thought to be in an early phase. Further study is needed to evaluate the clinical significance of prolonged nerve root enhancement.

In conclusion, intradural nerve root enhancement in lumbar disk herniation may indicate the existence of abrupt and severe compression of nerve roots and severe adhesions between a herniated disk and the nerve root. Our results show that this finding may not necessarily contribute to the selection of the subsequent treatment despite the probable existence of acute pathologic changes in the nerve root.

### Acknowledgment

This work was performed in Toyooka Public Hospital.

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