

Comparison of Clinical Outcomes and Natural Morphologic Changes between Sequestered and Large Central Extruded Disc Herniations

Sang-Ho Ahn¹, Hea-Woon Park¹, Woo-Mok Byun², Myun-Whan Ahn³, Jang-Ho Bae⁴, Sung-Ho Jang¹, and Yeung-Ki Kim¹

Departments of ¹Rehabilitation Medicine, ²Diagnostic Radiology, ³Orthopedic Surgery, and ⁴Neurological Surgery, College of Medicine, Yeungnam University, Daegu, Korea.

A prospective and longitudinal investigation concerning clinical outcomes and morphologic changes of large lumbar disc herniations by MR imaging.

To compare the clinical outcomes and the natural morphologic changes of between sequestered and large central extruded disc herniations.

The spontaneous disappearance or diminution of large herniated lumbar discs in the spinal canal is known. Poor clinical outcome and small changes of herniated discs have been shown for large central extruded disc herniations with conservative treatment.

The study population consisted of 22 patients with sequestration and a large central as extrusion established by an MR imaging study. Seventeen (11 patients with sequestration, and 6 patients with a large central extrusion) patients underwent a follow-up MR imaging study. The size of the herniated disc was measured on serial MR imaging studies, and the changes in size were classified into four categories.

Clinical evaluations were also performed using a visual analogue scale (VAS), the Oswestry lowback pain disability questionnaire, the straight leg raising test (SLRT) and so forth.

Both the sequestered and large central extruded disc herniations showed a successful clinical outcome after conservative treatment in 17 of 22 patients (77%) in total: 11 of 13 patients (85%) with sequestered disc herniations, and 6 of 9 patients (67%) with large central extruded disc herniations. VAS and Oswestry disability scoring showed a greater change in the group with sequestration than in the group with large central extrusions. In the group with sequestration, seven patients reported the disappearance of herniated disc materials, and four

patients showed a marked decrease in the size of their herniated discs in follow-up MR images. However, in the group with large central extrusions, only two patients showed a decrease in the size of their herniated discs.

Large central extruded disc herniations can be treated successfully by conservative treatment. Outcomes seemed to be as good as or slightly inferior to those of sequestered disc herniations. However, a greater morphologic decrease in the herniated discs occurred more frequently for sequestered disc herniations than for large central extruded disc herniations.

Key Words: Sequestered disc, large central extruded disc, conservative treatment, magnetic resonance imaging

INTRODUCTION

Ever since Mixter and Barr drew attention to the rupture of the intervertebral disc as a causal factor in sciatica, the presence of disc extrusion has been considered by many to be an indication for prompt surgical treatment. However, satisfactory clinical results have recently been documented in patients who avoided surgical decompression.¹⁻⁵ Moreover, recent advances in imaging methods, such as computed tomography (CT) and magnetic resonance imaging (MRI) have made it possible to determine the natural course of lumbar herniated discs in the spinal canal.^{4,5,6-9} After the first CT demonstration of the regression of herniated lumbar discs upon conservative treatment by Guinto et al.,¹⁰ many authors have reported the spontaneous disappearance or diminution of lumbar herniated discs.^{7-9,11-13}

It has also been reported that a greater regres-

Received June 16, 2001

Accepted January 3, 2002

Reprint address: requests to Dr. Sang-Ho Ahn, Department of Rehabilitation Medicine, College of Medicine, Yeungnam University, Daegu 705-717, Korea. Tel: 82-53-620-3268, Fax: 82-53-625-3508, E-mail: shahn@med.yu.ac.kr

sion of the herniated fragment took place in larger initial disc herniations.^{1-8,11-13} Large central extruded disc herniations have been reported to change less than sequestered disc herniations.¹⁴ However, few studies have been undertaken to compare the morphologic changes of sequestered and large central extruded disc herniations.

Recently, successful outcome was reported in eighty-three to ninety percent of patients with disc extrusions and radiculopathy that were treated non-operatively.^{7,11,12,15} However, there have been few investigations upon the clinical outcome of large central extruded disc herniations treated conservatively.

Therefore, we postulated that there are some differences in the clinical outcomes and natural morphologic courses of sequestered disc herniations and large central extruded disc herniations. This study was aimed at comparing the clinical outcomes and morphologic changes of sequestered disc herniations and large central extruded disc herniations.

MATERIALS AND METHODS

We investigated 22 patients (15 men, 7 women; mean age, 42.7 years; range, 19-73 years) who complained primarily of low back pain, buttock pain or leg radicular pain. Many patients complained of leg radicular pain bilaterally, especially in the case of large central extruded disc herniations. However, they complained that one leg was significantly more painful. Using MR images, we divided the patients into a large central extruded disc group (9 patients) and a sequestered disc group (13 patients). Large central extruded disc herniations were defined as those greater than one half of the anteroposterior diameter of the lumbar spinal canal, according to the axial images. Sequestered disc herniations were established as soft tissue masses with ring-enhancements, which were distinctly separated from the parent disc on Gadolinium-DTPA enhancement MR imaging.

Patients who had far lateral disc herniations, multiple disc herniations, spinal stenosis, spondylolysis, spondylolisthesis, or some other concurrent spinal disorders were excluded from this study.

MR imaging was performed with a 1.5-T (Vision; Siemens, Erlangen, Germany) imager at the initial visits. Axial and sagittal T1-weighted images (583/12 [repetition time msec/echo time msec]) were obtained before and after the administration of gadopentetate dimeglumine (Magnevist; Schering, Berlin, Germany; 0.1 mmol per kilogram of body weight). Axial and sagittal turbo T2-weighted images (3800/128) were also obtained before the administration of gadopentetate dimeglumine. All patients described, the duration of their symptoms, the intensity of the pain using a visual analogue scale (VAS), and their level of pain disability, as scored by the Oswestry low back pain disability questionnaire.¹⁶ Physical examinations included motor, sensation, reflexes, the degree of pain-onset by the straight leg raising test (SLRT), and the development of radicular pain by back extension in three prone positions i.e., full extension, elbow support, and lying prone. Strength of motor was determined using a manual muscle test and results were classified as, normal(N), good(G), fair(F), poor(P), trace(T) and zero(Z). Sensation was judged according to whether or not there were some hypesthetic or hypalgesic changes. Radiculopathy was confirmed according to the results obtained by electromyographic studies.

During the acute stage, all patients received conservative treatment, i.e., bed rest for 2-3 days, oral steroids and non-steroidal anti-inflammatory drugs (NSAIDs), massage, and physical therapy. A rehabilitation program used during the subacute and chronic phases, consisted of, NSAIDs and antidepressants, pelvic stabilization exercises, back school program, and pelvic traction over a period of 3 months. Subsequently, patients continued home exercise themselves without medication. The same rehabilitation program was used for both groups. Translumbal or transforaminal epidural steroid injection was prescribed to those that complained of intractable radicular pain.

Follow-up MR imaging and clinical evaluation were performed when the radicular pain had improved to the extent that the patients could resume their normal daily activities. If obvious changes were found on follow-up MR imaging, additional MR images were not taken. If morphologic changes could not be discretely recognized

on second MR imaging, despite an improvement in symptoms, follow-up MR imaging was done 2 months after the second round of MR imaging. Follow-up studies were compared with the results of the initial MR studies. All MR images were evaluated in a blinded manner by three physicians: one neuroradiologist, one physiatrist and one orthopedic surgeon. Morphologic changes in herniated lumbar discs that were determined by follow-up MR imaging were divided into four categories: disappearance, marked decrease (more than 75%), moderate decrease (25-75%), slight decrease or no change (less than 25%). In addition, the correlation between the morphologic changes and the clinical outcomes was also analyzed for various clinical parameters including VAS, Oswestry disability scoring, SLRT and so on.

The clinical outcomes were classified as successful or unsuccessful. Successful outcomes were defined as good or excellent results, and unsuccessful outcomes corresponded to fair or poor results.

Successful

Excellent: no pain, no limitation of physical activity, no analgesic medication

Good: relief from most of the pain, slight or no limitation of physical activity, infrequent or no use of analgesics

Unsuccessful

Fair: partial relief from pain, definite limitation of physical activity, frequent use of analgesics

Poor: no relief from pain, great limitation of physical activity, regular use of analgesics

If patients were referred for surgical decompression, they were regarded as having unsuccessful outcomes. The Statistical Package for the Social Sciences (SPSS) was used in the study. Statistical significance was evaluated by nonparametric testing.

RESULTS

Seventeen patients (11 patients with a sequestered disc herniation, 6 patients with a large central extruded disc herniation) of 22 patients (13 patients with a sequestered disc herniation, 9

patients with a large central extruded disc herniation) were monitored by MR imaging and clinical evaluation. Because of a poor response to conservative treatment, one patient with a sequestered disc herniation and one patient with a large central extruded disc herniation were referred for surgical decompression. These patients were regarded as having unsuccessful outcomes. The other three patients (1 patient with a sequestered disc herniation, and 2 patients with a large central extruded disc herniation) did not want a follow-up examination because they considered themselves cured, and were excluded from the final analyses. The symptomatic disc levels were L4/5 in 12 patients, and L5/S1 in 5 patients. Symptom duration had a median of 4.5 weeks with a range of 1 to 10 weeks. The interval between initial presentation and follow-up had a mean of 6.9 months and a range of 3 to 11 months. There was no statistical difference between the follow-up intervals of sequestered disc herniations and large central extruded disc herniations (Table 1).

The interval between the initial presentation and the first follow-up MR had a mean of 4.3 months and a range of 1.5 to 8 months. Transforaminal epidural steroid injection was administered once in seven patients; 4 with a sequestered disc herniation, and 3 with a large central extruded disc herniation. Only one patient with a large central extruded disc herniation received two epidural injections.

A successful clinical outcome, after conservative treatment, was obtained in 17 of 22 patients (77%), i.e., 11 of 13 patients (85%) with sequestered disc herniations, and 6 of 9 patients (67%) with large central extruded disc herniations.

The changes in various clinical parameters, namely, VAS, Oswestry disability scoring, motor, sensation, SLRT, and the development of radicular pain by back extension in three prone positions, were compared at the initial presentation and at the follow-up. At initial presentation, no statistical difference was found between the values of VAS, SLRT and the Oswestry disability scores of the sequestered disc herniations and the large central extruded disc herniations. During follow-up examinations, clinical improvements were observed in many patients (Table 1).

The association between VAS, the Oswestry

Table 1. Clinical Data on the Patients at Initial Presentation and Follow-up

| Case | HT | Age (yr) | SD (wk) | Sex | Follow-up interval(Mo) | SLRT (°) | VAS | Osw (%) | Motor | Sensory change | Pain induced by back extension |
|---------------------|-----|----------|---------|-----|------------------------|----------|-------|---------|-------|----------------|--------------------------------|
| Initial → follow-up | | | | | | | | | | | |
| 1 | SQ | 56 | 6 | M | 7 | 90→90 | 10→2 | 68→20 | G→G+ | - → - | None*→None |
| 2 | SQ | 29 | 3 | F | 5 | 90→90 | 10→3 | 87→22 | N→N | + → + | PL→None |
| 3 | SQ | 63 | 3 | M | 10 | 70→90 | 10→2 | 90→9 | G→N | + → - | FE→None |
| 4 | SQ | 45 | 1 | M | 8 | 70→90 | 9→2 | 44→4 | G→N | - → - | FE→None |
| 5 | SQ | 73 | 10 | F | 10 | 90→90 | 10→3 | 91→2 | F+→N | + → - | None→None |
| 6 | SQ | 47 | 2 | M | 9 | 40→70 | 9→2 | 60→12 | P→G+ | + → + | None→None |
| 7 | SQ | 32 | 2 | M | 3 | 90→90 | 10→1 | 70→8 | F+→N | + → - | FE→None |
| 8 | SQ | 25 | 1 | M | 6 | 30→90 | 7.5→1 | 27→0 | F+→N | + → - | None→None |
| 9 | SQ | 41 | 5 | M | 5.5 | 80→80 | 9→4 | 86→54 | G→G | + → + | PL→None |
| 10 | SQ | 48 | 3 | F | 3 | 40→90 | 10→1 | 76→16 | G→N | + → - | FE→None |
| 11 | SQ | 51 | 8 | M | 4 | 80→90 | 6→0 | 30→12 | G+→N | - → - | FE→None |
| 12 | LCE | 26 | 3 | F | 8 | 70→90 | 8→2 | 57→17 | G→G+ | + → - | ES→None |
| 13 | LCE | 19 | 8 | M | 9 | 20→30 | 10→5 | 53→29 | G→G | + → + | ES→None |
| 14 | LCE | 27 | 6 | M | 4 | 90→90 | 7→3 | 53→29 | N→N | - → - | None→None |
| 15 | LCE | 20 | 4 | M | 11 | 60→80 | 4→0 | 18→7 | N→N | - → - | FE→None |
| 16 | LCE | 40 | 8 | F | 7 | 60→90 | 9→1 | 70→30 | G→G | + → + | ES→None |
| 17 | LCE | 46 | 4 | F | 8 | 90→90 | 9→3 | 46→18 | G→G+ | - → - | None→None |

*No pain induced by full extension on prone.

+Hypalgesic or hypesthetic change. -: No sensory change.

HT, herniation type; SD, symptom duration; SLRT, straight leg raising test; VAS, visual analogue scale; Osw, The Oswestry low back pain disability questionnaire scoring; SQ, sequestration; LCE, large central extrusion; FE, pain induced by full extension on prone; ES, pain induced by elbow support on prone; PL, pain induced by lying prone.

disability score, and SLRT and herniation type were investigated (Table 2). In sequestered disc herniations and large central extruded disc herniations, the VAS score decreased significantly from 9.1 to 1.9 ($p < 0.01$) and from 7.8 to 2.3, respectively ($p < 0.05$); by Oswestry disability score, from 66.3% to 14.5% ($p < 0.01$) and from 49.5% to 21.7% ($p < 0.05$); and SLRT, increased from 70.0° to 87.2° ($p < 0.05$) and from 65.0° to 78.3°. Changes in the VAS and Oswestry disability scores were greater for sequestered disc herniations than for large central extruded disc herniations ($p < 0.05$).

Greater decreases in the sizes of herniated discs, were found for sequestered disc herniations than

for large central extruded disc herniations ($p < 0.01$; Table 3). In the sequestered disc herniation group, the disappearance of the herniated disc was observed in 7 of 11 patients (63%) and a decrease in size of more than 75%, in 4 of 11 patients (37%; Fig. 1). Follow-up MR imaging in three of the four patients showing a decrease in size of more than 75%, showed that the enhanced area had gradually thickened and had intruded into the disc materials as the herniated nucleus pulposus (HNP) reduced in size (Fig. 2). However, in the large central extruded disc herniation group, four of six patients (66%) showed a slight decrease or no change in the size of their disc herniations, and two of the six patients (34%)

Table 2. Correlation between Clinical Outcomes and Herniation Type

| Parameters | Herniation type | | | |
|---------------------|-----------------|-----------------------|-------------------------|-----------------------|
| | Sequestration | | Large central extrusion | |
| | Initial | Follow-up | Initial | Follow-up |
| VAS [†] | 9.1±1.3 | 1.9±1.1* | 7.8±2.1 | 2.3±1.7 [†] |
| Osw(%) [†] | 66.3±23.4 | 14.5±14.9* | 49.5±17.3 | 21.7±9.2 [†] |
| SLRT(°) | 70.0±22.8 | 87.2±6.4 [†] | 65.0±25.8 | 78.3±24.0 |

Values are given mean ± standard deviation.

p values from a Mann-Whitney test. **p*<0.01. [†]*p*<0.05.

p values from a Wilcoxon signed ranks test. [†]*p*<0.05, difference between sequestered disc and large central extruded disc.

Osw, The Oswestry low back pain disability questionnaire scoring; SLRT, straight leg raising test; VAS, visual analogue scale.

Table 3. Correlation between Herniation Type and Morphologic Changes on Follow-up MR Imaging

| Decrease in size | No. of cases (%) | |
|------------------|------------------|-------------------------|
| | Sequestration* | Large central extrusion |
| Disappearance | 7 (64%) | 0 (0%) |
| ≥ 75% | 4 (36%) | 0 (0%) |
| 25% - 75% | 0 (0%) | 2 (33%) |
| < 25% | 0 (0%) | 4 (67%) |
| Total | 11 (100%) | 6 (100%) |

p values from a Mann-Whitney test. **p*<0.01.

presented 25-75% decreases in size (Fig. 3).

DISCUSSION

The results of this study demonstrated that, a successful clinical outcome was achieved, by conservative treatment. In addition, the change in the VAS and the Oswestry disability scores was larger for sequestered disc herniations than for the large central extruded disc herniations. In the sequestered disc herniation group, sixty-four percent of patients exhibited disappearance, and 36% of patients showed a marked decrease in the sizes of their herniated discs, according to follow-up MR images. In the large central extruded disc herniation group, 33% of patients showed moderate decreases in the sizes of their herniated discs.

The sequestered disc herniation group showed a greater herniated discs size decrease than the

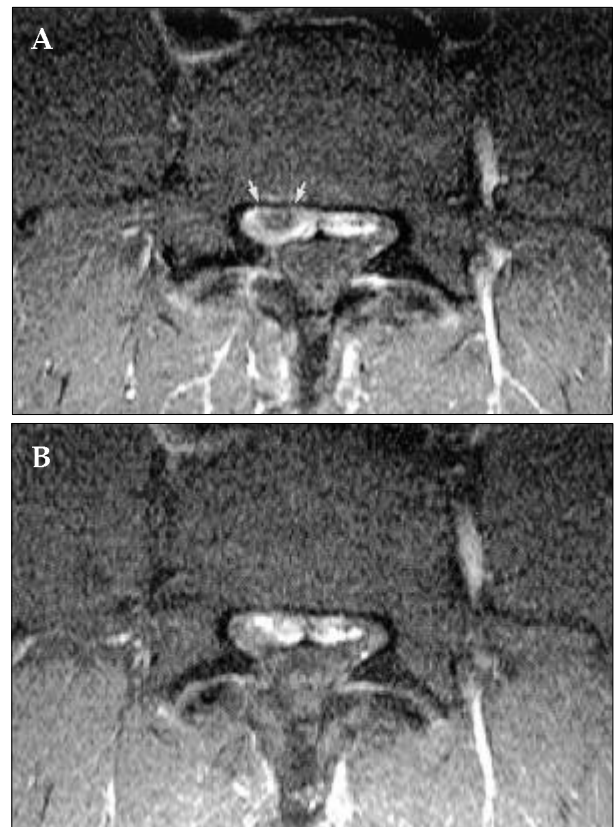


Fig. 1. Morphologic changes in a sequestered disc. Postcontrast fat suppressed axial T1-weighted images (583/12) in a 25-year-old man with right-side sciatica. A, Sequestered disc with ring-enhancement was observed in the initial study (arrows). B, Follow-up study showed nearly complete disappearance of the sequestered disc herniation 6 months later. The patient showed no pain or activity limitation.

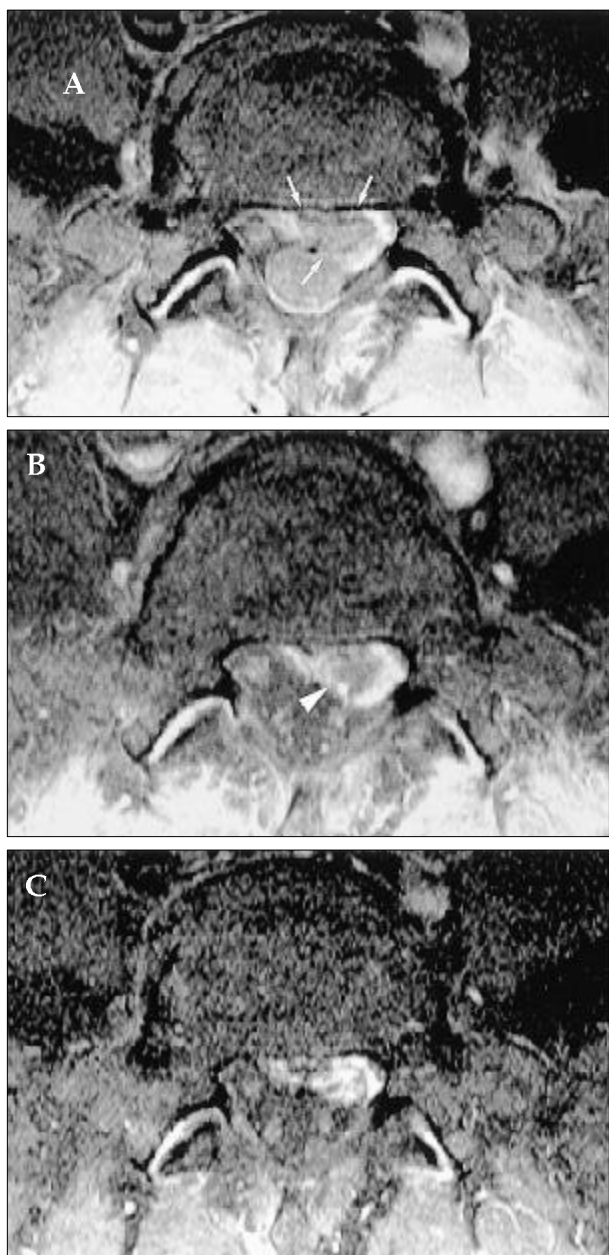


Fig. 2. Morphologic change in a sequestered disc. Post-contrast fat suppressed axial T1-weighted images (583/12) in a 41-year-old man with left-side sciatica. A, Sequestered disc with ring-enhancement was observed in the initial study (arrows). B, A second MR imaging was performed 1.5 months later. The enhanced area had thickened and intruded into the sequestered disc materials as the size of the HNP decreased (arrow head). C, A follow-up study showed nearly complete disappearance of the sequestered disc herniation 5.5 months later. The patient showed no pain and daily activities were unaffected.

large central extruded disc herniation group.

In this study, successful clinical outcomes were

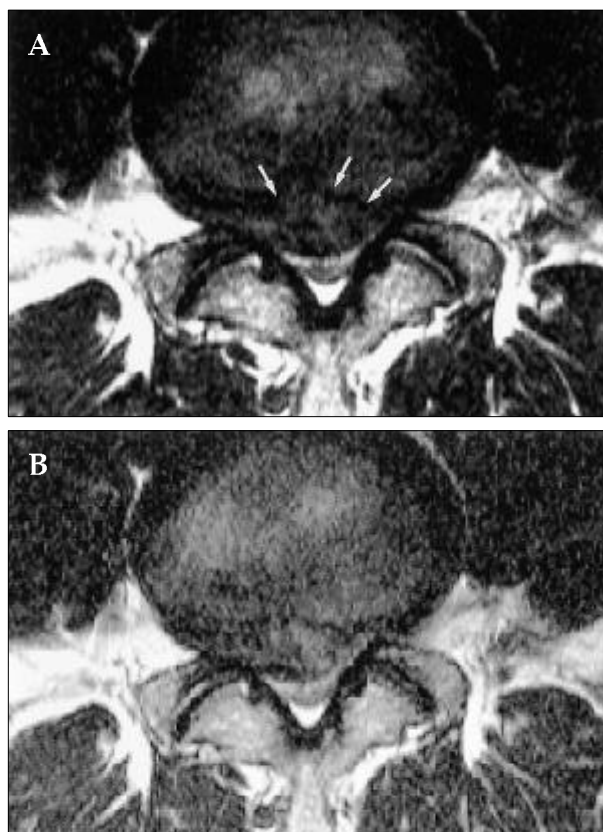


Fig. 3. Morphologic changes in a large central extruded disc. Axial turbo T2-weighted images (3800/128) in a 27-year-old man with right-side sciatica. A, Large central extruded disc was observed in the initial study (arrows). B, A follow-up study showed no change of size in the herniated disc 4 months later. However, the patient showed no pain or limitation, except for a mild low back pain during work.

achieved in 77% of the patients by conservative treatment. Other reports have documented similar results, without categorizing the types of lumbar disc herniations.^{3,7,11,12,15,17} In addition, the clinical outcomes of this study are compatible with published studies regarding clinical outcomes assessed by up to 2-years follow-up after the surgical treatment of lumbar disc herniations.¹⁸⁻²⁰

Recently, Nakamura et al.¹⁷ reported that a lot of patients with sequestered disc herniations showed rapid improvement and all regained their prior activity level within three months. However, in the case of patients with large central extruded disc herniations, little improvement was observed, and conservative treatment was abandoned in all who then received operations. However, in the

present study, successful clinical outcomes were achieved by conservative treatment in 67% of patients with a large central extruded disc herniation. The authors believe that the discrepancy might be the result of the application of an aggressive rehabilitative treatment. All of the patients in the present study received aggressive rehabilitative treatment including, pelvic stabilization exercises and back school program, and some patients who complained of intractable radicular pain, received epidural steroid injections.

A greater improvement in the VAS and Oswestry disability scores was achieved in the sequestered disc herniation group than in the large central extruded disc herniation group. A greater decrease in the size of herniated discs, was found in the sequestered disc herniations than in the large central extruded disc herniations. It has previously been reported that successful clinical outcomes are obtained more frequently in patients with major changes of the herniated lumbar disc than in those with minor changes.^{1,2,8} Our results tend to support the belief that successful clinical outcomes tend to be obtained more frequently in patients with marked herniated lumbar disc changes than in those with small changes, although regression of HNP is not absolutely essential for clinical improvement.

By using CT and MR imaging, it is possible to recognize the natural morphologic course of lumbar herniated discs in the spinal canal. Recently, it has been widely acknowledged that HNP resolves itself with conservative management,^{1,2,6-9,11} and greater regression of the herniated fragment has been observed in larger initial disc herniations. Komori et al.⁸ reported that the natural course of HNP varies with the HNP type, and that the disappearance of HNP is significantly more frequent in migrating HNP.

We believed that there might be some difference in the natural morphologic course of sequestered disc herniations and large central extruded disc herniations. In this study, a greater decrease in the size of herniated discs was found in sequestered disc herniations than in large central extruded disc herniations. This difference in the size reduction of sequestered disc herniations and large central extruded disc herniations

has been attributed to the a greater exposure of sequestered discs to the epidural vascular supply.²¹⁻²⁴ Exposure to the epidural vascular supply might induce neovascularization at the periphery of the sequestered discs. Moreover, neovascularization might be associated with the resorption process, which occurs during the healing process of the lumbar disc herniations.^{23,24} It has been reported that this resorption phenomenon is more predominant in transligamentous extensions than in subligamentous extensions.^{21,25} In this study, two patients having large central extruded disc herniations, which showed moderate decreases in size, had transligamentous extensions rather than subligamentous herniations, by MR imaging.^{21,26,27}

In conclusion, large central extruded disc herniations can be treated successfully with conservative treatment. Their outcome seemed to be as good as or slightly inferior to that of sequestered disc herniations. However, a greater morphologic decrease in the herniated discs occurred more frequently in the case of sequestered disc herniations than in large central extruded disc herniations.

REFERENCES

1. Delauche-Cavallier MC, Budet C, Laredo JD, Debie B, Wybier M, Dorfmann H, et al. Lumbar disc herniation. Computed tomography scan changes after conservative treatment of nerve root compression. *Spine* 1992;17:927-33.
2. Dullerud R, Nakstad PH. CT changes after conservative treatment for lumbar disk herniation. *Acta Radiologica* 1994;35:415-9.
3. Fraser RD, Sandhu A, Gogan WJ. Magnetic resonance imaging findings 10 years after treatment for lumbar disc herniation. *Spine* 1995;20:710-4.
4. Maigne JY, Rime B, Delinnet B. Computed tomographic follow-up study of forty-eight cases of nonoperatively treated lumbar intervertebral disc herniation. *Spine* 1992;17:1071-4.
5. Matsubara Y, Kato R, Mimatsu K, Kajino G, Nakamura S, Nitta H. Serial changes on MRI in lumbar disc herniation treated conservatively: *Neuroradiology* 1995; 37:378-83.
6. Bozzao A, Gallucci M, Masciocchi C, Aprile I, Barile A, Passariello R. Lumbar disk herniation: MR imaging assessment of natural history in patients treated without surgery. *Radiology* 1992;185:135-41.
7. Bush K, Cowan N, Kats DE, Gishen P. The natural history of sciatica associated with disc pathology. *Spine*

- 1992;17:1205-12.
8. Komori H, Shinomiya K, Nakai O, Yamaura I, Takeda S, Furuya K. The natural history of herniated nucleus pulposus with radiculopathy. *Spine* 1996;21:225-9.
9. Kwon DY, Nam YH, Seong IY. Follow-up of herniated nucleus pulposus by MRI. Report of three cases with lumbar radiculopathy. *J Korean Acad Rehabil Med* 1993;17:274-9.
10. Guinto FC, Hashim H, Stumer M. CT demonstration of disk regression after conservative therapy. *Am J Neuro-radiol* 1984; 5:632-3.
11. Ellenberg MR, Ross MR, Honet JC, Schwartz M, Chodoroff G, Enochs S. Prospective evaluation of the course of disc herniations in patients with proven radiculopathy. *Arch Phys Med Rehabil* 1993;74:3-8.
12. Saal JA, Saal JS, Herzog RJ. The natural history of lumbar intervertebral disc extrusions treated nonoperatively. *Spine* 1990;15:683-6.
13. Tepleck JG, Haskin ME. Spontaneous regression of herniated nucleus pulposus. *Am J Roentgenol* 1985;145: 371-5.
14. Nakamura T, Kikuchi T. Natural course of lumbar disc herniation-prospective study. NASS 13th annual meeting proceedings. San Francisco: 1998. p.116-7.
15. Saal JA, Saal JS. Nonoperative treatment of herniated lumbar intervertebral disc with radiculopathy. An outcome study. *Spine* 1989;14:431-7.
16. Fairbank JCT, Mbaot JC, Davies JB, O'Brien JP. The Oswestry low back pain disability questionnaire. *Physiotherapy* 1980;66:271-3.
17. Saal JA. Natural history and nonoperative treatment of lumbar disc herniation. *Spine* 1996;21:2S-9S.
18. Hanley EN, Shapiro DE. The development of low-back pain after excision of a lumbar disc. *J Bone Joint Surg Am* 1989;75:719-21.
19. Herron LD, Turner JA, Novell LA, Kreif SL. Patient selection for lumbar discectomy with a revised objective rating system. *Clin Orthop* 1996;325:148-55.
20. Spengler DM. Lumbar discectomy. Results with limited disc excision and selective foraminotomy. *Spine* 1982; 7:604-7.
21. Ahn SH, Ahn MW, Byun WM. Effect of the transligamentous extension of lumbar disc herniations on their regression and the clinical outcome of sciatica. *Spine* 2000;25:475-80.
22. Hirabayashi S, Kumano K, Tsuiki T, Eguchi M, Ikeda S. A dorsally displaced free fragment of lumbar disc herniation and its interesting histologic findings. A case report. *Spine* 1990;15:1231-3.
23. Ikeda T, Nakamura T, Kikuchi T, Umeda S, Senda H, Takagi K. Pathomechanism of spontaneous regression of the herniated lumbar disc: histologic and immunohistochemical study. *J Spinal Disord* 1996;9:136-40.
24. Ito T, Yamada M, Ikuta F, Fukuda T, Hoshi SI, Kawaje Y, et al. Histologic evidence of absorption of sequestration-type herniated disc. *Spine* 1996;21:230-4.
25. Haro H, Shinomiya K, Komori H, Okawa A, Saito I, Miyasaka N, et al. Upregulated expression of chemokines in herniated nucleus pulposus resorption. *Spine* 1996;21:1647-52.
26. Grenier N, Greselle JF, Vital JM, Kien P, Baulny D, Broussin J, et al. Normal and disrupted lumbar longitudinal ligaments: correlative MR and anatomic study. *Radiology* 1988;171:197-205.
27. Masaryk TH, Ross JS, Modic MT, Boumphrey F, Bohlman H, Wilber G. High-resolution MR imaging of sequestered lumbar intervertebral disks. *AJNR* 1988;9: 351-8.