Anterior Interbody Fusion in the Treatment of the Lumbar Herniated Nucleus Pulposus

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--- Abstract ---

One hundred and fourteen cases of lumbar herniated nucleus pulposus were studied retrospectively. I reviewed the clinical records and radiographs of patients treated with discectomy and anterior interbody fusion. I followed the patients from 2 years up to 15 years, for an average of 2.9 years. The results were calculated statistically by Fisher exact test and Chi-square test. Among 114 patients, 69 patients (60.5%) were male and 45 patients (39.5%) were female. The most common age group was in its twenties (28.1%), while the whole study group ranged from 19 to 65 years. The most commonly involved level was L4-S1 (73 cases, 60.4%). In clinical results, 83.5% of cases were excellent or good. The rate of solid fusion was 87.8%. The most common type of fusing pattern was type I. The satisfying clinical result had statistical correlation with the solid union of grafted bone and the fusion state of maintained intervertebral disk height, respectively, by Fisher exact test (p<0.001). The affecting factors in clinical results were the solid fusion and fusion with the state of maintenance of intervertebral disk height (fusing pattern type I and II). I concluded that anterior discectomy and interbody fusion is a recommendable method of treatment for lumbar herniated nucleus pulposus.

Key Words: Lumbar herniated nucleus pulposus, surgical treatment, anterior interbody fusion

INTRODUCTION

There have been various surgical methods for the treatment of lumbar herniated nucleus pulposus since 1934 when Mixter and Barr performed the first laminectomy. There are several modalities of surgical treatment in lumbar herniated nucleus pulposus (HNP), such as laminectomy, laminectomy and discectomy, laminectomy and posterior lateral fusion (PLF), laminectomy and anterior lumbar interbody fusion (ALIF), anterior discectomy and interbody fusion (AIF), and modification with cage instrumentation.

Low back pain due to instability resulting from removal of the nucleus pulposus was not infrequent in clinical practice.

Low back pain and referred pain was mainly from the facet capsule caused by irritation of the sinuvertebral nerve and sensory branch of the primary ramus, which was distributed to the facet joint and surrounding soft tissues. Whenever back pain was undiminished and restricted daily activity, operative treatment such as laminectomy for decompression and spinal fusion was recommended to maintain stability of the spine. For this purpose, Watkins performed posterolateral fusion and Harmon reported the results of anterior interbody fusion. Of all the techniques that have been introduced, I have adopted anterior interbody fusion, which seems to be the most suitable treatment for lumbar HNP, considering the vertebral anatomy and biomechanics over a long period.

This technique used in intervertebral disk herniation has several advantages, including: prevention of damage to neural tissues and microcirculation of the roots; leaving the spinal canal free of adhesion or callus; restoration of normal disk height and open intervertebral foramen; good alignment of posterior facet joints; preservation of segmental stability that have become jeopardized by weakened bony and soft tissues; prevention of a recurrence or secondary disk protrusions posteriorly at the same level; and spontaneous absorption of osteophyte in the posterior aspect of vertebral body and facet joint.
The purpose of this study was to evaluate the number of involved disks, to evaluate the fusion rate, to evaluate the fusing pattern, to evaluate the clinical results, and to calculate the relationship between them.

Finally, I attempted to find out the factors affecting the clinical results.

MATERIALS AND METHODS

From November 1975 until April 1994, the author performed anterior interbody fusion in 167 cases of intervertebral disk herniation. Among them, 114 cases included those whose radiographs and clinical records were available and who could be monitored for more than 2 years. Sixty-nine patients were men and 45 were women. Patients age ranged from 19 to 65 years (average 28.1 years). The average follow-up period was 2.9 years (2–15 years). Medical records and radiological studies of 114 patients were retrospectively reviewed. In radiological study, preoperative evaluation was performed by x-ray and myelography before 1984, and CT, CT metrozamide myelography (CTMM) or MRI after 1984. In the case of multilevel disk derangement, it was confirmed dynamogram and MRI.

Postoperative radiographical study was done every 3 months up to one year and dynamogram in 32 selected cases showing obscure fusion state in plain film during the follow-up period.

Tomogram was done at 6 months, 9 months or one year after surgery in selected cases that showed obscure fusion state in plain film, and dynamogram to confirm the fusion status. The criteria of solid fusion was decided as 1) no tenderness over the operation site, 2) no motion in dynamogram at the fused segments, 3) crossing of trabeculae between mother bone and grafted bones, 4) and no sclerotic changes between host and grafted bones in plain films. I statistically analyzed the results by Fisher exact test and Chi-square test.

The levels of the disk herniation were L3-4 in one patient, L4-5 in 73 patients, L5-S1 in 7 patients, L3-4,5 in 13 patients, L4-5-S1 in 19 patients and L5-4,5-S1 in one patient.

Regarding the duration of symptoms, 18 cases (15.8%) had symptoms for less than one month, 52 patients (45.6%) had symptoms from 1 to 6 months, 14 cases (12.3%) from 6 to 12 months, while 30 cases (26.3%) had symptoms for more than one year.

Before the operation, 100 patients (87.7%) had low back pain and radiating pain, 11 patients (9.6%) had low back pain only and 2 cases (1.7%) had radiating pain only. In physical signs, 43 cases (37.7%) had weakness of motor power in the ankle and toes, 40 cases (35.1%) had sensory changes in lower extremities and 82 cases (71.9%) had positive results in a straight-leg-raising test. The deep tendon reflex was reduced in 24 cases (21.0%) and disappeared in 3 cases (2.6%). Before admission, 84 patients (73.7%) had medication and physiotherapy, 53 patients (46.5%) had acupuncture or herb medicine, 13 patients (11.4%) had no other treatment, 8 patients (7.0%) had laminectomy and diskectomy and 2 patients (1.8%) had chemonucleolysis.

The indications that an operation was necessary were in the cases of failure of conservative treatment with persistent pain and sciatica for more than 8 weeks (44 cases), progressive neurologic deficit (40 cases), recurrence (17 cases) and instability with severe discomfort (13 cases). The instability measured in this study was abnormal range of motion in the spinal segment.16

All operations were performed with the standard technique of retroperitoneal approach. After removal of the disk material, a gutter was made by an osteotome with removal of the cartilage end plate of the adjacent vertebrae. The disk space was expanded to normal height with a spreader and 2 or 3 blocks of tricortical graft were inserted into the gutter at the disk space.

In postoperative treatment, the patient was encouraged to sit up within 3 days after the operation.
Ten to 14 days after the operation, the Knight type back brace for L3-4 and L4-5 lesions, Knight-Kim type (Yonsei rehabilitation center, Seoul, Korea) for L5-S1 lesions were fitted and walking exercises were started. The back-brace fitting was continued for 6 to 8 months postoperatively.

After that, a tomogram was performed to evaluate the fusion state. When the fusion was complete, the brace was removed. When the fusion was incomplete, the back brace was maintained for 3 or more additional months.

The fate of grafted bone was evaluated by the
fusing pattern in 5 types (Fig. 1). The disk space of the operated sites is measured and compared with the value of average of adjacent upper and lower disk space.

Type I is a status of solid fusion in the normal intervertebral joint space (Fig. 2-a, b and c).

Type II is a pattern of fusion with maintained intervertebral disk space and with anterior bridging.

Type III is a status of fusion with disk space narrowing which was thought to be partially absorbed grafted bone (Fig. 3). In this type, the disk space narrowing is less than three-quarters of the adjacent disk space.

Type IV is a fusion state with anterior bridging, but the grafted bone is partially absorbed or of uncertain viability (Fig. 4).

Type V is a fusion failure with an aseptic state of grafted bones.

The author's standard used in the assessment of clinical results was Kim and Kim's criteria (Table 1).\textsuperscript{11}

### RESULTS

The fusion rate was evaluated every 3 months during the follow-up period. The criteria of fusion was clinically based on no tenderness at the operated area, and radiologically no motion on the dynamogram and crossing of bony trabeculae at the grafted sites. Fusion was complete at 6 months postoperatively in 47 patients (41.2%). At 9 months, the fusion rate was 73 patients (64.0%) and the fusion rate at 1 year after the operation was solid fusion in 100 patients (87.7%), incomplete fusion in 9 patients (7.9%) and absorption of the grafted bone or nonunion in 5 cases (4.4%). The 9 cases of incomplete fusion had been fused at 15 months after the operation. Of those, 6 cases had fused in the state of disk space narrowing (Type III) and 3 cases fused with anterior bridging and partial absorption of the grafted bones (Type IV). Two cases with failed anterior fusion at 1 year had decompressive laminectomy and posterolateral fusion, while the remaining 3 cases had no specific clinical problems during follow-up.

The fusing patterns at 1 year after operation were type I in 85 patients (74.6%), type II in 15 patients (13.2%), type III in 6 patients (5.3%), type IV in 3 patients (2.6%) and type V in 5 patients (4.4%).

The evaluation of clinical results was performed at the time of complete fusion, at 1 year and at 2 years postoperatively. The clinical results at 1 year after the

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### Table 1. Criteria for Clinical Results\textsuperscript{11}

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<th>Criteria</th>
<th>Description</th>
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<td>Excellent</td>
<td>Complete relief of pain in back and lower limb&lt;br&gt; No limitation of physical activity&lt;br&gt; Analgesics not used&lt;br&gt; Able to squat on the floor</td>
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<tr>
<td>Good</td>
<td>Relief of most pain in back and lower limb&lt;br&gt; Able to return to accustomed employment&lt;br&gt; Physical activities slightly limited&lt;br&gt; Analgesics used only infrequently&lt;br&gt; Able to squat on the floor</td>
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<tr>
<td>Fair</td>
<td>Partial relief of pain in back and lower limb&lt;br&gt; Able to return to accustomed employment with limitation, or return to lighter work&lt;br&gt; Physical activities definitely limited&lt;br&gt; Mild analgesic medication used frequently&lt;br&gt; Mild limitation to squatting on the floor</td>
</tr>
<tr>
<td>Poor</td>
<td>Little or no relief of pain in back and lower limb&lt;br&gt; Physical activities greatly limited&lt;br&gt; Unable to return to accustomed employment&lt;br&gt; Analgesic medication used regularly&lt;br&gt; Unable to squat on the floor without support</td>
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### Table 2. Correlation between Number of Involved Segments and Fusion Status at 1 Year after Operation

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<th>Involved segments</th>
<th>Fusion status</th>
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<td></td>
<td>Solid fusion cases (%)</td>
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<td>Single segment (n=81)</td>
<td>78 (96.3)</td>
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<tr>
<td>2 or 3 segments (n=33)</td>
<td>22 (66.7)</td>
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Chi-square test p<0.001.
operation were excellent in 30 patients (26.3%), good in 65 patients (50.7%), fair in 18 patients (15.8%) and poor in 1 patient (0.9%). At 2 years after the operation, the clinical results had improved in 5 patients from fair to good and 1 patient in poor condition remained in poor grade. The poor grade patient was evaluated by MRI at 2 years and we found stenotic changes at the level of the fusion site and a protruded disk on the adjacent level above. In this patient, decompressive laminectomy and diskec- tomy were performed at the lesion sites. The clinical results were improved to good. Two years after the second operation, the clinical results were unchanged during follow-up periods.

In the single level, solid fusion at 1 year after the operation was obtained in 78 cases (96.3%) and incomplete fusion was the result in 3 cases (3.7%). In 2 or 3 level fusion, solid fusion was obtained in 22 cases (66.7%), incomplete fusion in 6 cases (18.2%) and non union in 5 cases (15.2%) (Table 2).

The relationship between the number of involved segments and fusion state at 1 year had significance in statistical analysis by Chi-square test (p<0.001).

In the single level, the clinical result was excellent in 24 cases (30%), good in 47 cases (58%), and fair in 10 cases (12%). Where 2 or 3 segments were involved the clinical results were excellent in 6 cases (18%), good in 18 cases (55%), fair in 8 cases (24%) and poor in 1 case (3.0%) (Table 3). The satisfactory clinical result was 71 cases (87.7%) in single level and 24 cases (72.7%) in multiple levels. The statistical analysis showed insignificant correlation by Chi-square test (p=0.096).

As for postoperative complications, sympathetic chain injury was noted in 5 cases (4.4%), superficial infection in 5 cases (4.4%), transient paralytic ileus in 3 cases (2.6%), and urination difficulty in 6 cases (5.3%), but there were no cases of retrograde ejaculation in the current study. Sympathetic chain irritation symptoms such as flushing and mild skin discoloration of the lower-left extremity were pro- longed for a few months. All other complications were resolved within a few days. The displacement of grafted bone within the gutter was observed in 2 cases (1.8%), and in these cases, the grafted bone was partially resolved and belonged with fusion failure.
(Type V).

To determine the factors affecting clinical results, statistical analysis was done in the fusion rate and fusing pattern by Fisher exact test. The p value was \( p < 0.001 \) between clinical results and bony fusion rate (Table 4), and it was also \( p < 0.001 \) between clinical results and fusing pattern (maintenance of disk height) (Table 5). There was statistical significance in clinical results, fusion rate and fusing pattern.

DISCUSSION

Lumbar herniated nucleus pulposus is the most common cause of low back pain and radiating pain. The level of disk herniation reported by Hakelius was 47.4% at the L4-5 level and 50.5% at the lumbosacral level.\(^{17} \) In the report of Tsuchiya in Japan, it was 62.4% at the L4-5 level and 10.2% at the lumbosacral level, while the remainder were at other levels and involved multiple-level lesions.\(^{18} \) In this study, the level of disk herniation was 64% at the L4-5 level and only 6.1% in the lumbosacral region, similar to the report of Tsuchiya.

In occidental reports, there was no significant difference between the L4-5 level and lumbosacral level,\(^{17} \) but in oriental reports it was more frequent at the L4-5 level than lumbosacral level.\(^{18,19} \) This phenomenon is very interesting and the reason is unclear, but I suspect that it results from different lifestyles and habits. Oriental people (Korea, Japan and China) have different sitting and sleeping postures from occidental people. They sit on the floor in kneeling or squatting positions and sleep on the hard ondol (Korea) or tatami (Japan) instead of on a bed as in occidental countries.

Pathoanatomically in intervertebral disk herniation, the breakdown of the proteoglycan of the nucleus pulposus causes loosening and tearing of the annulus fibrosus and complete disorganization of disk material. Such pathological changes in disk protrusion, disk extrusion and disk degeneration causes disruption of the tripod joint complex, and apophyseal joint stenosis may develop. Therefore, the appropriate method of treatment should be planned on the basis of pathophysiology.

Regarding the biomechanics of vertebra, the intervertebral discal pressure is increased in the flexion state by body weight, gravity and muscular contractile force.\(^{20} \) The load acts as a positive force and is supported by the intervertebral disk, posterior articular process, articular capsule and surrounding muscles.

Both Kim et al. and Regan reported that if the ligaments were relaxed or the height of the intervertebral disk was decreased, the function of the posterior joints would be disturbed.\(^{9,21} \)

There are many operative methods, including laminectomy through posterior approach, posterior decompression and posterolateral fusion, posterior decompression and vertebral fusion with an instrument and anterior interbody fusion, which was performed in this study.

Operative reconstruction is required and this can be achieved by anterior interbody fusion. In intervertebral disk herniation, anterior interbody fusion relieves not only posterolateral nerve compression by the disk herniation ventral to the lateral recess, but also in restoring disk height and the correction of spinal alignment.

Kim et al. stated that the fusion sites of a vertebral segment can be found at 5 locations:\(^{13} \) 1) spinous process, 2) transverse process, 3) articular process, 4) lamina, and 5) the vertebral body.

In choosing the best point, one should consider the kinetic relationship between rotation and pressure. Therefore, the most ideal operating technique should acquire immediate stability during the postoperative period and maintain stability in the anatomical position by a balance between the force of ligaments and muscles. The operation should be able to release nerve tissue by a decompressive effect.

Anterior interbody fusion is thought to be the best technique for restoring and maintaining the height of the intervertebral disk space, preventing displacement of grafted bones and acquiring bony union.\(^{11} \)

Anterior interbody fusion has been widely applied to spinal disorders, such as infection, deformities, spinal tumors and traumatic lesions. The indications of the operation are acute low back pain with sciatica, failure of conservative treatment for more than 6 weeks, persistent chronic low back pain, progressive neurologic deficit, recurrence and salvage operation in failed posterior operation. However, there are contraindications, i.e., multiple level lesions, patients younger than 18 and older than 65, and sequestrated disk herniation.\(^{12,22} \)

The mechanism of pain relief has been studied in some aspects. Kim et al. showed that the factors affecting early clinical results are the changes in the spinal canal, such as an increase in AP diameter of the dural sac and a decrease in the amount of disk bulging after anterior interbody fusion. But the late clinical results were influenced by multiple factors including solid bony fusion. Inoue et al. reported normalization of the radicular sheath in 60% of cases, normalization of the large hourglass defect and total block of the dural sac in 82% in A-P view, and normalization of the dural sac indentation in lateral view in 70%. For postoperative immobilization, there are some different views. Goldner et al. applied a low-back corset for immobilization. As well, Turner and Bianco immobilized operated cases by cast for Gill's operation and posterolateral fusion in spondylolysis and spondylolisthesis in children and teenagers. Kim and Kim, and Kim and Seo recommended a back brace for 3-to-6 months of immobilization to get sound bony union.

I believe the tissues are made rigid by the spasms of the surrounding musculature in the early days after an operation. After subsidence of the muscle spasms, the operating site becomes unstable because the primary stabilizer, such as the anterior longitudinal ligament, annulus fibrosus and disk material, and the secondary stabilizer, such as the abdominal muscles, have been disrupted and in the healing state. It is necessary to reinforce and stabilize the operating sites to heal the soft tissue and solidify the grafted bone site in this period. I applied the Knight-Kim back brace because it is more adaptable, limiting a range of motion on the lumbosacral joint in the case of L-S lesion. The Knight-Kim type back brace has a function of marked limitation in flexion - extension and rotation motion.

As far as I know, there are no reports in the literature about the fusing pattern after anterior interbody fusion. This classification was based on radiological appearance during follow-up until solid fusion. The cases of type V had insufficient immobilization during the first 3 months after the operation. I thought it was caused by some violation of the grafted site to osteoinduction.

Lane and Moore reported anterior disectomy and interbody fusion through the transperitoneal approach in 36 patients in 1948. In 1963, Harmon reported the results of anterior interbody fusion through the retroperitoneal approach for 244 patients with intervertebral disk syndrome. In this study, we looked at the fusion rate and fusing patterns for the evaluation of the long-term result. In our 1993 report, the fusion rate was 96.7% after 2 years follow-up and in the current study it was 95.6%, even though the fusion types were different. The 5 cases which showed nonunion at 1 year belonged to type V. Of those, 2 cases had decompressive laminectomy and posterolateral fusion at 1 year and were classified as nonunion. The clinical result was 4 cases classified as fair and 1 case as poor. After the second operation, those patients were clinically classified as satisfactory. In bony fusion rate, the reports by the authors varied from 63% to 96%. It was 90% for Freebody et al., 96% for Fujimaki et al., 95% for Harmon, 94.3% for Inoue et al., 56% for Stauffer and Coventry, 63% for Chow et al., 96.7% for Kim and Seo and 80% for Kim et al.

In this study, the solid bony fusion rate was 87.7% at 1 year and 95.6% at 2 years (Table 3). Among the 114 patients, 81 had single segment involvement, and of those, 78 cases (96.3%) had solid bony fusion at 1 year after the operation. Otherwise, solid bony fusion was obtained in 22 (66.7%) of 33 patients with multiple level lesions. The correlation between the number of involved segments and fusion rate at 1 year after the operation was statistically significant (Table 2) (p < 0.001).

The cases of nonunion (absorption) had insufficient immobilization during first 3 months indicating the back brace was discarded early by the patient himself. Harmon, reported good clinical results in 90% and a 95% bony fusion rate. Thereafter, other good clinical results were reported by Sacks, Freebody et al., Flynn and Haque, Fujimaki et al., Inoue et al., Chow et al., Kim and Seo, and Kim et al.

The satisfactory results showed little difference between the authors, i.e. 52% of Flynn and Haque, 89% of Chow et al., 92% of Freebody et al., 75% of Kim and Seo and 86.9% of Kim et al. at 1 year follow-up. However, Batchelor reported that satisfactory results were obtained in only 26%.

In this study, satisfactory clinical results were obtained in 83.3% at 1 year and 87.7% at 2 years. Ninety-five cases (83.3%) were satisfactory in clinical results and in this group all cases had solid bony fusion (Table 4) and those cases were in the type I
or type II category of fusing pattern (Table 5).

The solid bony union with maintenance of the intervertebral disk space and clinical result had a significant statistical correlation (p<0.001).

As for the involved segment, the clinical results were satisfactory in 71 cases (88%) with a single segment and in 24 patients (72.7%) with 2 or 3 segments at 1 year. The correlation between the number of involved segments and clinical results at 1 year after operation was statistically insignificant (p=0.096).

The early clinical results were affected by normalization of the spinal canal, normalization of dural sac, reduction of protruded disk, expansion of A-P diameter of spinal canal and increased unit area of spinal canal. The late clinical results and fusion rate were closely correlated.

As a postoperative complication, Goldner et al. reported deep vein thrombosis and retrograde ejaculation, while Freebody et al. reported pulmonary embolism. Other complications reported in the literature include retrograde ejaculation, urinary retention, paralytic ileus, meralgia paresthetica, warm leg, donor site pain, infection, swelling of the legs and genitofemoral nerve damage.

Of those, urinary retention, paralytic ileus and swelling of the legs are usually transient. In this study, warm leg sensation from sympathetic chain damage was noted in 5 cases (4.4%) and it continued for over 1 year. Superficial infection was reported in 2 cases by Knutsson and Wiberg and in 3% by Freebody et al. In this study, superficial infection occurred in 5 cases (4.4%), but it healed within 10 days. I had no cases of meralgia paresthetica or ejaculation disorders.

I reconstructed the donor site of the ilium by the methylmethacrylate (Palacos) for the prevention of groove deformity of the iliac crest and donor site pain. Genitofemoral nerve damage was reported by Sacks, but in this study we had no nerve damage.

In conclusion, anterior discectomy and interbody fusion have shown to be a good method of treatment for lumbar herniated nucleus pulposus. The fusing patterns are closely correlated to the fusion rate and those are also very closely correlated to the clinical results. The factors affecting the late clinical results are solid bony union and restoration of disk height.

REFERENCES


