Adjacent Instability after Instrumented Lumbar Fusion

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The invention of pedicle screw instrumentation has greatly improved outcomes of spinal fusion, which has become the treatment of choice for lumbar spondylolisthesis. As researchers accumulate experience, both theoretical and clinical advances are continually being reported. A review of the literature and the experience of the authors show that the development of adjacent instability, as in the breakdown of a neighboring unfixed motion segment, is a common consequence of an instrumented lumbar spine. This article reviews the risk factors and surgical treatment of adjacent instability. The authors believe that proper preoperative planning and complete surgical procedures are imperative to prevent adjacent instability. For those who need revision surgery, meticulous surgical techniques can achieve satisfactory results. *(Chang Gung Med J 2003:26:792-8)*

During the past 2 decades, transpedicle spinal instrumentation has been broadly accepted for treatment of spinal instability. Chen[1] reported the clinical experience of back pain after thoracolumbar fracture treated by long instrumentation and short fusion. Some surgeons use pedicle screws for anterior or reconstructive spinal surgery for a metastatic malignancy, even though the screws are fixed to the vertebral body instead of through the pedicles.[2] The authors used pedicle instrumentation for combined anterior and posterior surgeries in the treatment of spinal tuberculous spondylitis.[3] In a study of 116 consecutive patients with symptomatic spondylolisthesis treated with decompressive laminectomy, segmental fusion, and pedicle instrumentation at Chang Gung Memorial Hospital, 88% of the patients achieved solid fusion.[4] Some clinicians advocate autogenous bone grafts to achieve spinal fusion, while others suggest other modalities, including allografts, ceramic bone grafts, or even hyperbaric oxygen therapy.[5]

Many patients with lumbar instability have been treated with decompression and fusion with or without instrumentation. Pedicle screw instrumentation guarantees rigid fixation and increases the union rate. High fusion rates and satisfactory clinical outcomes have been reported.[4,6] A retrospective study analyzed the survivorship of Dorsale Kompressions Spondylodes (DKS) instrumentation and the clinical outcomes in 185 patients with spondylolisthesis.[6] Among those patients treated with Zielke DKS instrumentation for a mean follow-up period of 3.5 years, 14% experienced rod breakage, and 1.7% screw breakage, respectively. Adjacent instability developed in 9.7% of patients.

However, an increasing number of patients who have undergone lumbar fusion are now seeking further treatment. Instability of neighboring unfused segments is becoming common, because spinal surgeons are enthusiastic about instrumentation of the lumbar spine. Harris[7] reported that acquired spondylolysis is a sequel to spinal fusion. Patients with recurrent back pain and sciatica after lumbar spinal fusion present a complex problem. Several

studies have reported the accelerated degeneration of lumbar segments adjacent to a previous fusion.[4,6,8] Adjacent instability has been recognized as an important type of failed back surgery syndrome. Previous investigations have reported a 7% incidence of adjacent instability after 2.4 years and 45% after 33 years.[4,8]

Failed back surgery syndrome causes distress for both patients and spinal surgeons. Not only is the syndrome difficult to diagnose and treat appropriately, but the surgery also yields unpredictable results.[9-11] Factors related to successful results are inconsistent. Following surgical procedures to the lower lumbar spine, some patients continue to suffer back pain and sciatica. Favorable factors vary across patient populations, operation indications, follow-up procedures, and criteria for success. Conservative treatment, including orthosis and medication, can help patients accept their impairments, minimize aggravating factors, and improve their daily activity levels. Pain may be reduced with improved trunk strength and spinal mobility.[12] Surgery is the last method considered to resolve the problem. Success rates of revision lumbar spinal surgery in the relevant literature range from 60% to 80%.[10,13] The success rate of revision lumbar spinal surgery declines as the follow-up period and the number of spinal procedures increase. Finnegan analyzed 65 back patients who had multiple operations and concluded that the relief of mechanical compression, such as disc protrusions or bone impingement, yields satisfactory results.[14] Surgical treatment for adjacent instability after instrumented lumbar fusion has rarely been reported.

Diagnosis of adjacent instability

The period of the pain-free interval after the operation can assist in the differential diagnosis between disc herniation and fibrosis. A symptom-free period of 12 months or longer indicates a lesion type other than fibrosis.[10,13,14] The absence of any pain-free interval usually means that the previous operative procedure did not properly target the lesion.

A detailed history and physical evaluation must be conducted for a diagnosis of adjacent instability. Patients always address their symptoms when exposed to mechanical stimuli. Radiography can be used to clarify the status of the spinal fusion.

Although, pseudoarthrosis is usually correlated with poor results, solid fusion does not guarantee a satisfactory outcome. A dynamic lateral image of the lumbar spine is essential in diagnosing adjacent instability. Because of the distortion produced on MRI by metal artifacts, a myelogram is believed to be a better choice for evaluating stenosis due to adjacent instability after instrumentation.[15] A myelogram can clearly determine the status of the adjacent stenosis. The criteria for adjacent instability are well-defined spondylolisthesis or dynamic instability with slippage of more than 4 mm and/or an angle change of more than 10° on flexion and extension. Spondylolysis of the neighboring level occurring after spinal fusion is considered to result from operative damage or a stress fracture of the pars interarticularis on both sides and can be diagnosed by lateral film of the spine.[7,16] The motion segment just above the fused segment is the most common level of adjacent instability.[4,13,15,16]

Risk factors for adjacent instability

Risk factors for developing post-fusion adjacent instability have not been clearly defined. Fusion with instrumentation exhibits a higher rate of developing adjacent instability than does fusion without instrumentation.[4,17] Pedicle screw instrumentation has a supplementary effect on developing adjacent instability after lumbar fusion. In a study investigating the location of pedicle screws in relation to adjacent superior segment facet joints using computed tomography and plain radiographs, facet joint violation occurred in 30% of patients.[18]

Age has been considered a predisposing factor.[19] Older patients have higher baseline degeneration in their adjacent segments, which are possibly more susceptible to increased mechanical stress.[17,19] Patients who have degeneration in their adjacent segments are possibly more susceptible to developing adjacent instability. Young patients may have better supporting structures in their nucleus pulposus, annulus fibrosus, and facet joints than do older patients. However, older patients are less active in their daily life and have less exposure to high mechanical stresses.

Levels decompressed but not included in fusion are theoretically more susceptible to stress and more likely to undergo degeneration.[17] If the decompression level extends beyond the fusion level, adjacent

instability is more likely to develop. For a fused L4-L5 spine, if the decompression is localized to the lower L4 and upper L5, the chance of developing adjacent segment instability is less than with decompression which includes the entire L4 and upper L5. Removal of laminae and spinous processes of the entire L4 means sacrificing the anchoring point for the L3-L4 supraspinous ligament, which jeopardizes the stability of the spinous process-supraspinous ligament-spinous process posterior complex. This bone-tendon-bone model increases dynamic stability for adjacent unfused segments. We believe that the bone-tendon-bone complex between the fused segments and motion segment plays an important role in postoperative spine stability. Sacrificing either the supraspinous ligament or the anchoring points on the spinous processes will cause increased stress at the corresponding disc level.

Gender is not a significant contributing factor.[19,20] Even though the structure of the spine of a male is more rigid than that of a female, males are generally more active and their spines theoretically undergo more stress than do those of females.

The rigidity of an implant might affect adjacent instability. An implant is more likely to develop adjacent instability following more-rigid instrumentation.[4] However, other surgeons have challenged this idea.[17,19,21] Some claim that the choice of bone grafting technique is more important than the selection of implants.[22] Instrumented lumbar fusion usually achieves a high union rate. The relation of pseudoarthrosis and adjacent instability is difficult to analyze because of very small case numbers. To our authors' knowledge, there is no relevant report on this issue. Nagata et al. reported that immobilization of long segments caused increased facet force and adjacent segmental motion.[23] Clinically, it is not clear whether long instrumentation might accelerate adjacent instability more than short instrumentation. Shlegel et al. found no significant difference among patients classified as having short lumbar floating fusion, lumbosacral fusion, and long thoracolumbar fusion.[24]

The authors retrospectively reviewed 270 patients with spondylolisthesis who underwent a laminectomy, posterolateral fusion, and pedicle screw instrumentation between 1987 and 1991.[25] Thirty-two (11.9%) patients developed adjacent instability after a mean follow-up period of 4.7 (range, 3~8) years. Most of these (30/32) occurred proximal to the fusion. Neither the type of implant, the fusion level, nor the laminectomy level had a statistically significant relation to adjacent instability. However, the occurrence of adjacent instability in degenerative spondylolisthesis was more common than in the spondylolytic type. This may be explained by accelerated degeneration of preexistent degeneration of adjacent segments in degenerative spondylolisthesis.

Adjacent instability may be a time-related process. The interval of the follow-up period is an important factor. The longer the follow-up period is, the greater amount of adjacent instability which develops.[4,6,11]

Biomechanics of adjacent motion segments after spinal fusion

Degenerative changes follow alterations in biomechanics caused by the fused rigid segment, which puts additional stress on normal segments above and below the spinal fusion. Quinnell et al. suggested that floating fusion of a single disc generated additional localized loading on the disc immediately above and below the fusion.[21] Lee and Langrana studied three types of lumbosacral fusion using a mathematical model to analyze the stress distribution. In their study, posterior fusion caused the greatest amount of stress on the facet joints of the adjacent segment.[22] Since the advent of spinal instrumentation, some surgeons have reported that adjacent instability occurs within a shorter time. Increased angulatory and translational motions have also been identified at the motion segments adjacent to a spinal fusion.

The effects of spinal alignment on load transmission at the levels adjacent to the fusion have seldom been reported. Hypolordosis in fused lumbar segments causes increased loading on the posterior column of the adjacent segments. Oda et al. reported that a kyphotic deformity may have led to facet joint contracture and facet arthritis and may have served as the origin of low back pain at the cranially adjacent level in a sheep model.[26] Ha et al. demonstrated that after immobilization, the facet patterns of the adjacent segment changed, and segmental motion increased.[27] A study, funded by the National Science Council of Taiwan, used a porcine spine model to study the effect of sagittal alignment on the

instability of adjacent segments after lumbar fusion.[28] Twenty-four fresh porcine lumbar spines were instrumented using posterior pedicle screw implants between L2 and L4. Group I had kyphosis of 20˚, Group II was neutral, and Group III had lordosis of 20˚. The preliminary data revealed that the stress on the adjacent segment increased in the kyphotic group. However, no clinical study has shown that the configuration of a short fused segment is correlated with the development of adjacent instability.

Pathologic changes in adjacent motion segments

Segments proximal to the instrumentation might be required to compensate for changes in alignment to maintain a normal posture.[23] Lumbar malalignment might accelerate adjacent deterioration.[24] Possible pathologic changes at the adjacent unstable segment include instability of the motion segment, disc space narrowing, and stenosis caused by facet degeneration and ligament flavum hypertrophy. Spinal canal stenosis at the adjacent level can be easily demonstrated by myelography. Lee indicated that the most common pathologic condition at the adjacent segment is hypertrophic degenerative arthritis of the facet joints.[22,29] Damage to the posterior ligament complex may also contribute to the development of lesions by reducing the resistance to shearing forces at the intervertebral level next to the fusion. Chow et al. reported that neighboring unfused segments must work more frequently toward the extremes of their functional ranges of motion after fusion, and that such an effect becomes more marked after a 2-level fusion.[30] Under such circumstances, a patient may experience back pain, sciatica, and intermittent claudication.

Pitfalls of revision surgery

The major difficulty in revision surgery is adequate decompression of spinal stenosis when scar adhesion is present. Dural tears are a potential problem during revision surgery. Fritsch et al. and Kim and Michelsen reported dural tear rates of 5.1% and 8%, respectively in revision spinal surgery.[10,13] Two of 39 patients had dural tear in another study.[15] It was observed that scar tissue was less adherent in the lateral recess than in the midline area. The laminectomy was begun from the nonstenotic area, where the scar was less developed. Next, decompression was performed through the bilateral lateral recess by an extensive medial facetectomy. Notably, a medial facetectomy can prevent vigorous manipulation of the nerve root and decrease the rate of dural tearing.

Although successful arthrodesis does not always decrease symptoms, pseudoarthrosis usually leads to clinical failure. When a fusion is attempted between a previous fusion and the adjacent motion segment, the resulting increase in stress on this area makes pseudoarthrosis likely without instrumentation. Whitecloud et al. demonstrated that in a fusion to a degenerated segment adjacent to a lumbar fusion, the pseudoarthrosis rate of 80% fell to 17% with the use of supplemental instrumentation.[31] The author reported a nonfusion rate of 5.1% in the surgical treatment of adjacent segment instability.[15]

Surgical techniques

During the operation, patients are positioned prone on a 4-poster spinal frame. The hips are extended to maintain lumbar lordosis. A laminectomy is initially performed through an adjacent virgin site and then it is performed in the stenotic area, which is always the motion segment of adjacent instability. The main pathologic change of stenosis is at the cranial margin of the epidural fibrosis. A risk of dural tear or nerve injury during nerve decompression is present. A laminectomy is performed by extensive removal of the medial facet to prevent dural tearing. The inferior facet is carefully divided from the pars interarticularis using an osteotome and is completely removed. Then the lateral recess is unroofed using small, sharp Kerrison rongeurs and osteotomes. This procedure always includes removal of at least the medial 1/3 of the superior facet. After a medial facetectomy and foraminotomy, the nerve roots of the stenotic segment become decompressed. If bone chips or scar tissue adhere to the dura in the midline, they are carefully removed with a scalpel. All patients must undergo extension of the posterolateral fusion mass with a bone graft. Next, the old pedicle screws are removed and replaced with new pedicle screws of a larger diameter. A pair of pedicle screws is then inserted through the virgin pedicles of the adjacent segment (Fig. 1). After the screws are tightened, the bone graft is placed between the decorticated virgin transverse process and the decorticated old fusion mass.[15,19,31]
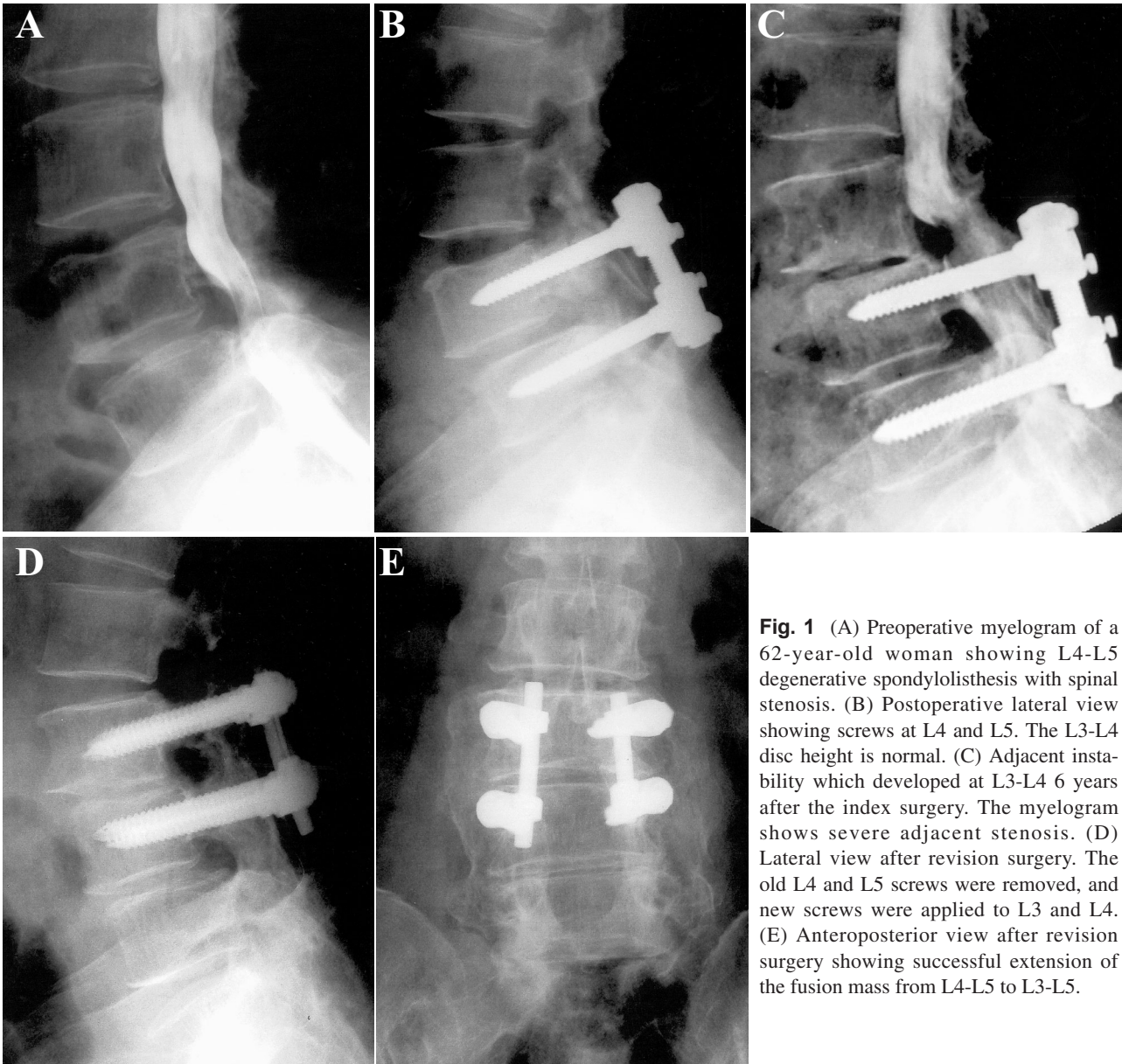
Fig. 1 (A) Preoperative myelogram of a 62-year-old woman showing L4-L5 degenerative spondylolisthesis with spinal stenosis. (B) Postoperative lateral view showing screws at L4 and L5. The L3-L4 disc height is normal. (C) Adjacent instability which developed at L3-L4 6 years after the index surgery. The myelogram shows severe adjacent stenosis. (D) Lateral view after revision surgery. The old L4 and L5 screws were removed, and new screws were applied to L3 and L4. (E) Anteroposterior view after revision surgery showing successful extension of the fusion mass from L4-L5 to L3-L5.

Conclusions

Failed back surgery syndrome is a troublesome problem. With the extensive use of instrumented lumbar fusion, increasing instances of adjacent instability cases occur. A thorough evaluation, including a detailed history and physical examination, is essential for making a correct diagnosis. Signs and symptoms of neurological claudication and mechanical pain should be noted. Revision is difficult in those patients and is fraught with complications. The major difficulty in surgical treatment is adequate decompression when scar adhesion is present. The authors follow the principles of (1) performing a wide decompression by a medial facetectomy to reduce nerve root injury and (2) extending the fusion with an autogenous bone graft and pedicle screw instrumentation. When meticulous procedures are followed, satisfactory outcomes of revision surgery for adjacent instability can be achieved.

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腰椎融合術後的鄰近節不穩定

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　　脊椎融合加上椎弓根螺釘內固定手術 (pedicle screw instrumentation) 是目前手術治療腰椎滑脫最好的方式。雖然其臨床結果相當好，但是脊椎融合術後鄰近節發生不穩定(adjacent instability) 也經常可見。本篇文章從臨床及生物力學的研究，綜合探討造成鄰近節不穩定的因素，同時提出手術治療的方法。了解造成鄰近節不穩定的相關因素，作妥善的術前規劃及正確適當的手術技術，可以減少其發生的機會。一旦腰椎融合術後發生鄰近節 不穩定必須開刀治療，作者提出的手術方式可以得到令人滿意的結果。(長庚醫誌 2003;26:792-8)

關鍵字：鄰近節不穩定，脊椎手術失敗症候群，腰椎融合，椎弓根螺釘。