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Clinical Article

The Change of Adjacent Segment and Sagittal Balance after Thoracolumbar Spine Surgery

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Objective : To characterize perioperative biomechanical changes after thoracic spine surgery.
Methods : Fifty-eight patients underwent spinal instrumented fusions and simple laminectomies on the thoracolumbar spine from April 2003 to October 2008. Patients were allocated to three groups; namely, the laminectomy without fusion group (group I, n = 17), the thoracolumbar fusion group (group II, n = 27), and the thoracic spine fusion group (group III, n = 14). Sagittal (ADS) and coronal (ADC) angles for adjacent segments were measured from two disc spaces above lesions at the upper margins, to two disc spaces below lesions at the lower margins. Sagittal (TLS) and coronal (TLC) angles of the thoracolumbar junction were measured from the lower margin of the 11th thoracic vertebra body to the upper margin of the 2nd lumbar vertebra body on plane radiographs. Adjacent segment disc heights and disc signal changes were determined using simple spinal examinations and by magnetic resonance imaging. Clinical outcome indices were determined using a visual analog scale.
Results : The three groups demonstrated statistically significant differences in terms of angle changes by ANOVA ($p < 0.05$). All angles in group I showed significantly smaller angles changes than in groups II and III by Turkey's multiple comparison analysis. Coronal Cobb's angles of the thoracolumbar spine (TLC) were not significantly different in the three groups.
Conclusion: Postoperative sagittal balance is expected to change in the adjacent and thoracolumbar areas after thoracic spine fusion. However, its prevalence seems to be higher when the thoracolumbar spine is included in instrumented fusion.

KEY WORDS : Adjacent Segment Degeneration (ASD) · Cobb's angle · Laminectomy · Pedicular Screw Fixation.

INTRODUCTION

The thoracic spine has structural characteristics that make it quite distinct from the cervical and lumbar spines. Furthermore, because it is a highly specialized region, it is uniquely adapted to serve the load-bearing demands imposed by an upright posture. The thoracic spine consists of three regions; the cervicothoracic transition zone, the thoracolumbar transition zone, and the midthoracic region[1,35]. Furthermore, the thoracolumbar spine contains a zone of transition between the relatively immobile kyphosis of the thorax and the flexible lordosis of the lumbar region[13], which can be presumed constitutes a gradual transition that protects the spine from fracture at the thoraco-lumbar zone after a sudden vertebral impact. This gradual change allows impact forces to be gradually transmitted between the anterior and posterior components of vertebrae, at junctions between the two spinal curves. Furthermore, the thoracic spine contains structures not present in the cervical and lumbar spines, namely, the rib cage and sternum[35]. During normal sagittal balance, the thoracic spine has a natural moment arm that may cause an increase in the kyphotic curve when the dorsal tension band is disrupted and/or ventral weight-bearing capacity is lost. However, where change is sudden, and single transitional vertebra must bear impact forces, they are more prone to pathologic fracture and adjacent degeneration. Oda et al.[27,33] suggested that increased stiffness due to the presence of instrumentation might accelerate degenerative changes in adjacent motion segments.

Various approaches have been used to manage thoracolumbar spine surgery cases, such as, fractures, ossification of the ligamentun flavum (OLF), or tumors. Fusion of the tho-

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racolumbar spine converts gradual change to sudden change. However, only few studies have addressed sagittal angular change after thoracolumbar spine surgery. In the present study, we compared postoperative changes in Cobb's angles (coronal and sagittal) and adjacent segment degeneration in cases that achieved fusion, or not, of the thoracic spine.

MATERIALS AND METHODS

Of the 1,245 patients who underwent spinal operations, the details of 64 cases of thoracic and thoracolumbar spine surgery were collected retrospectively by the first author who was not involved in surgical treatments. All patients were operated upon by two authors from April 2003 to October 2008. Six patients were excluded because of incomplete radiographic data or follow up for less than 1 year. Accordingly, the details of 58 patients were subjected to analysis.

Patient data

We allocated the 58 patients to three groups, as follows; 17 who underwent thoracic laminectomy without fusion or fixation were allocated to group I, 27 who underwent thoracolumbar fusion or fixation to group II, and 14 patients who underwent thoracic laminectomy with fusion or fixation to group III. We investigated adjacent segment sagittal and coronal Cobb's angles and thoracolumbar junction sagittal and coronal angles. In addition, the cohort was also dichotomized for the analysis into a traumatic group (n = 32) and a non-traumatic group (n = 26).

Radiographic measurements

We measured sagittal and coronal angles at adjacent segments from two disc spaces above lesions at the lower margin to two disc spaces below lesions at the upper margin. The sagittal and coronal angles of thoracolumbar junctions were measured from the lower margins of the 11th thoracic vertebral body to the upper margin of the 2nd lumbar vertebral body on a plane radiographs (Fig. 1). Adjacent segment disc heights were determined using by simple spinal examinations and adjacent disc signal changes were detected by magnetic resonance imaging (MRI). Clinical outcome indices were determined using a visual analog scale. SAS software was used for the statistical analysis.

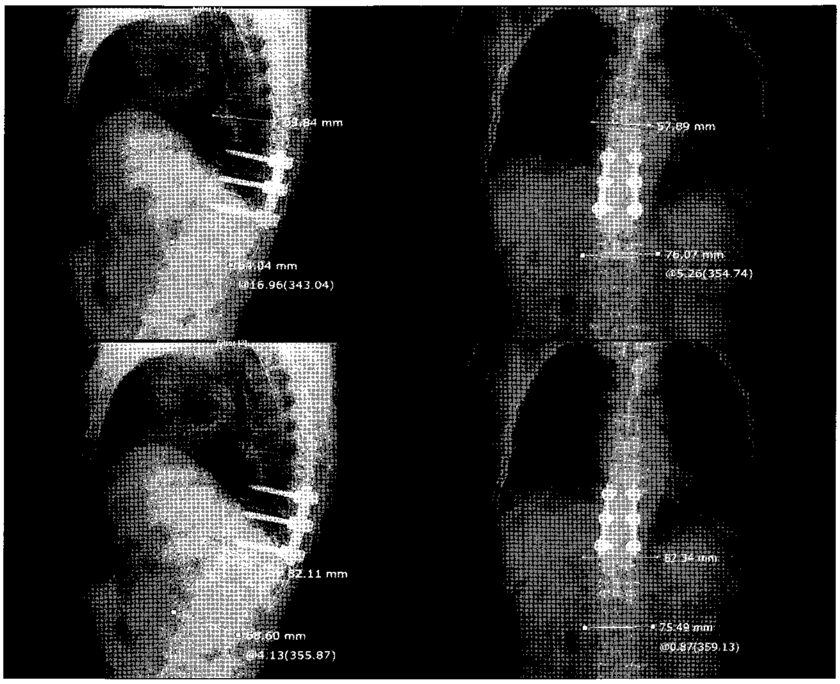

Fig. 1. A : Sagittal & Coronal Cobb's angle of Adjacent segment : from lower margine of above two disc space of lesion to upper margine of below two disc space of lesion. B : Sagittal & Coronal Cobb's angle of T-L junction : from margine of 11th thoracic spine to upper margine of 2th lumbar spine.

RESULTS

Demographic comparisons

Fifty-eight patients (37 males and 21 females) of mean age 50.1 years were enrolled in this study. Group I (the thoracic laminectomy group) included 17 cases (10 male, 7 female) with 12 spine tumors, 2 ossified ligamentum flavums, 2 infections, and 1 herniated nucleus pulposus. Group

Table 1. Demographic data (n = 58)

	Age	Sex	DM	HTN	PreV	PostV	M	T	NT					FL
							f/u		TU	O	I	H	CMS	
Group I	49.2	7 : 8	4	5	5.7	3	1,424	0	12	2	2	1	0	2.26
Group II	50.1	12 : 05	3	2	8.2	4.1	886	22	2	0	0	0	1	2.96
Group III	51.2	17 : 9	2	2	6.8	3.3	1,248	10	1	2	3	0	0	2.96
Total	50.1	36 : 22	9	9	6.9	3.4	1,186	32	15	4	5	1	1	2.72

CMS : cornus medullaris syndrome, DM : diabetes mellitus, FL : fused level, F/U : follow up, I : infection, H : HNP, M : mean, M/F : male/female, NT : non-trauma, OLF : ossified ligamentum flavum, PostV : postoperative visual analog scale, PreV : preoperative visual analog scale, T : trauma, TU : tumor

Table 2. Turkey's multiple comparison system between each groups

	Group I-II	Group II-III	Group I-III
T-L sagittal	N	N	S
T-L coronal	N	N	N
AS sagittal	N	N	N
AS coronal	S	N	N

AS : adjacent segment, N : non-significant, S : significant, T-L: thoracolumbar

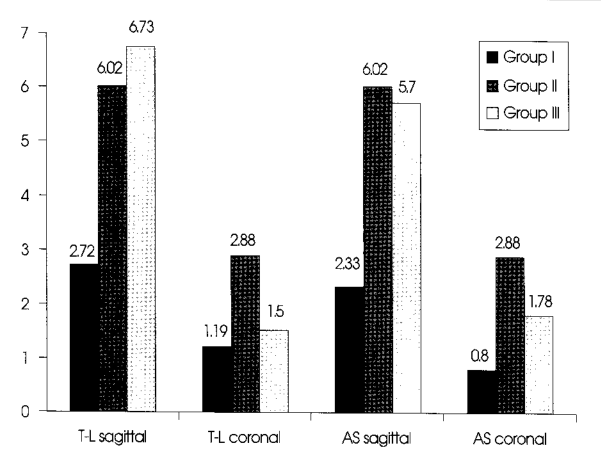

Fig. 2. Comparison of change in angles among the three groups using ANOVA testing (p < 0.05).

II (18 male, 9 female) included 27 cases with 24 traumas, 2 spine tumors, and 1 conus medullaris syndrome due to arachnoiditis ossificans. Group III (9 male, 5 female) included 14 cases with 8 traumas, 1 tumor, 2 ossified ligamentum flavums, and 3 infections. The 26 patients without trauma had 15 tumors, 4 ossified ligamentum flavums, 5 infections, 1 herniated nucleus pulposus, and 1 conus medullaris syndrome due to arachnoiditis ossificans. Of the 32 patients with traumatic fractures, 22 were in group II, and 10 were in group III. Average surgical extent was 2.26 laminectomies in group I and 2.96 level fusion in groups II plus III. Nine of the 58 patients had diabetes mellitus, and 9 had hypertension. Mean follow-up was 1,186 days. Mean visual analogue scale (VAS) score decreased from 6.9 preoperatively to 3.4 postoperatively (Table 1).

Radiographic comparisons

In group I, angular changes were; thoracolumbar junction sagittal angle 2.72 degrees, thoracolumbar junction coronal angle 1.19 degrees, sagittal angle of adjacent segments 2.33 degrees, and coronal angle of adjacent segments 0.80 degrees. Angular changes in group II were; thoracolumbar junction sagittal angle 6.02 degrees, thoracolumbar junction coronal angle 2.88 degrees, adjacent segment sagittal angle 6.02 degrees, and adjacent segment coronal angle 2.88 degrees. In group III, angular changes were; thoracolumbar junction sagittal angle 6.73 degrees, thoracolumbar junction coronal angle 1.50 degrees, adjacent segment sagittal angle 5.70 degrees, and adjacent segment coronal angle 1.78 degrees. The three groups were significantly different in terms of angle changes by ANOVA (p < 0.05) (Fig. 2). Turkey's multiple comparison was used to analyze differences between groups I and II, groups II and III, and groups I and III (p < 0.05) (Table 2). Significant differences were found between changes in adjacent segment coronal angles in groups I and II and between thoracolumbar junction sagittal angle in groups I and III. Of the 12 cases with perioperative MR images, 4 infectious cases were excluded because we wanted to investigate the effects of biomechanics. Of the remaining 8 cases, changes in disc height and signal in groups I (3 cases) and III (2 cases) were infrequent, but these were more common in group II (3 cases), which included 1 postoperative compressed fracture (Table 3). No change in adjacent segment disc height was found by simple radiography or MRI in group I. However, group II showed a 2.6 mm change in adjacent disc height by MRI and a 2 mm change in by radiography (Fig. 3). No significant change in adjacent disc height was observed in group III. However, numbers were too small to conduct meaningful statistical analysis.

Table 3. Radiologic changes of adjacent disc space on MRI

	N	Disc height change	MRI signal change
Group I	2	0.01	No change
Group II	3	2.51	Low
Group III	1	0.62	Low

MRI : magnetic resonance imaging, N : number of cases

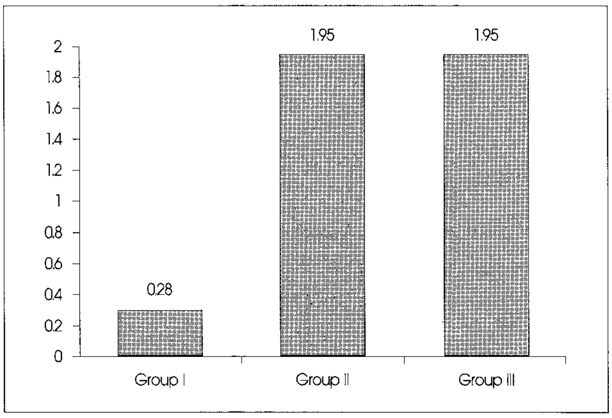

Fig. 3. Disc height change of each groups on simple X-ray : Group I - 0.28, Group II and III were 1.95.

DISCUSSION

Over the centuries, many methods have been developed to treat spinal column injuries. In fact, the first record of such treatment is described in the Edwin Smith papyrus, which dates back to 1550 BC[17]. Dr. Paul Harrington from

Houston, Texas, first described a treatment procedure for patients with progressive neuromuscular scoliosis, and in 1953, developed what is now referred to as the Harrington rod system. The initial procedure involved the placement of facet screws to correct the positions of facet joints. However, although initial postoperative results were favorable, long term follow-up results were poor[8,31)], and therefore, surgical intervention was subsequently developed. Various types of instruments have been used for anterior and posterior fixation of the spine, including laminar hooks, sublaminar wires, and interspinous wires, as well as screw-rods, screw-plate combinations, transpedicular screw fixation, and translaminar screw fixation[2,3,5,9,10,18,21,32,34)].

The recent interest in adjacent segment disease after lumbar or cervical arthrodesis has been driven by the development of disc arthroplasty. One of the most widely referenced studies on adjacent segment disease was conducted by Hilibrand and associates[11)]. After retrospectively reviewing the charts of 374 patients who had undergone anterior cervical decompression and fusion, and by using Kaplan-Meier survivorship analysis, the investigators determined that the annual rate of symptomatic adjacent segment disease was 2.9%. Furthermore, they found that the probability of developing adjacent segment disease during the 10 years following the procedure was greater than 25%. These findings have been cited by numerous publications as evidence of the direct effect of fusion on the degeneration of adjacent segments[7,22,29,30,36)]. Nagata[24)] investigated the biomechanical effects of long-segment thoracolumbar instrumentation on the remaining motion of adjacent segments, and found that lumbosacral motion and facet joint loading are significantly increased after surgical immobilization and that the extent of these increases depends on the number of segments immobilized.

The mechanical properties of the thoracic spine have been investigated in several experimental studies[25,26,28,37)]. But, only few studies have reported the incidence of adjacent segment disease (ASD) around the thoracic spine, although the anatomical and biomechanical characteristics of the thoracic and thoracolumbar spine have been well studied in relation to differences between the cervical and lumbar spine over the past two decades.

Different procedures have been examined for the treatment of OLF, tumors, infections, and fractures, such as, disc herniation of the thoracic spine. These procedures include simple laminectomies and extensive fusion techniques combined with costotransversectomy and transthoracic approaches[14,15,18,20,23,26)] In 2006, Li et al.[19)] concluded that the treatment of choice for thoracic OLF is laminectomy combined with lateral fusion. In contrast, Inamasu et al.[12)] used simple laminectomy or fenestration to treat thoracic myelopathy of OLF in Japanese patients. Both of these studies achieved good clinical outcomes. Kim et al.[16)] analyzed the advantage of stopping fusion in the upper lumbar spine rather than in the lower thoracic spine for long adult lumbar deformity instrumented fusions from the distal thoracic/upper lumbar spine (T9-L2) to L5 or S1. They determined that this would entail surgery at a lower scale, and that theoretically, the fusion of fewer segments would reduce the likelihood of pseudoarthrosis and operative morbidity. We investigated adjacent segment degeneration (ASD) and postoperative biomechanical changes after thoracic fusion, thoracolumbar fusion, and simple laminectomies. Although clinical outcomes were similar for all three modalities, we observed some differences between them in terms of adjacent segmental disc degeneration and postoperative biomechanical changes.

The anatomy and biomechanics of the spine lead us to speculate that gradual transition may help protect the spine from fracture following sudden vertebral impact. This would cause forces to be transmitted gradually between the anterior and posterior components of vertebrae at the junction between the two spinal curves. Despite the limitations imposed

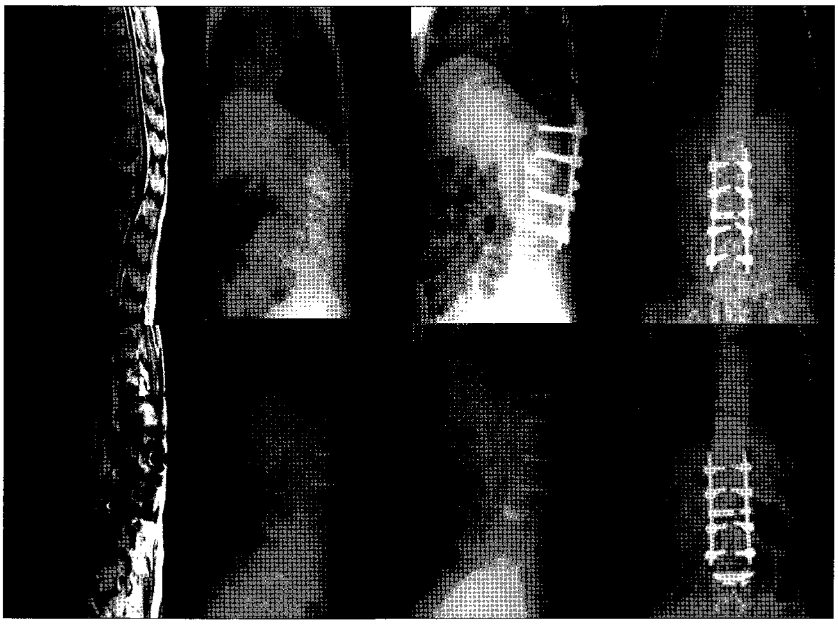

Fig. 4. Preoperative magnetic resonance image T2WI shows burst fracture with dural sac compression on T12 and L1. One year later, simple X-ray and magnetic resonance imaging reveals L4 compression fracture below the preciously fused level. Vertebroplasty on L4 was done.

by different etiologies in our series, we focused on sudden changes in anatomy and biomechanics, adjacent segment degeneration (ASD), and back pain, as we believed that sagittal-coronal angle and adjacent disc what would change. We found that ASD tended to increase in cases treated by multilevel fusion of the thoracolumbar spine, such as, the lumbosacral spine. According to Chou et al.[4], after lumbosacral spine fusion, ASD was more frequently observed in adjacent segments above a fusion than below with respective rates of 25.5% and 2.6%. To explain the possible causes of this phenomenon, Etebar and Cahill[6] hypothesized that the thoracic spine acts as a lever across remaining mobile segments, which act as a fulcrum. In our case series of thoracic and thoracolumbar spinal fusions, one patient with a compressed fracture developed ASD below fusion, which concurs with the notion that the thoracic spine acts as a fulcrum.

In an overview of the complications of thoracic disc surgery, McCromick et al.[23] summarized complications as; postoperative instability, pulmonary embolism, cerebrospinal fluid leakage, infection, pleural effusion, and intercostal neuralgia. They also noted higher rates of complications following lengthy and complex procedures, and concluded that these different approaches have their own sets of advantages and disadvantages. In the present study, there were two cases of cerebrospinal fluid leakage, one wound infection, and one adjacent segment compressed fracture (Fig. 4). Lumbar drainage with antibiotics was conducted over 6 weeks and vertebroplasty was performed on the fourth lumbar vertebrae body. Optimal approaches should be determined after considering : patient's general health, surgeon's skill level and experience of the approach in question, specific aspects of the disease, and finally, the biomechanical condition of the spine. The procedure described in our study raises the possibility that a simpler, less costly, procedures provide outcomes that are comparable to those of other procedures, including relief of back pain. The results of our study are difficult to interpret because of inherent limitations, such as, differences between patient populations and surgeons. Accordingly, a further, randomized, prospective study is required to determine the actual rate of adjacent segment disease associated with thoracic spine instrumentation.

CONCLUSION

Some postoperative biomechanical changes occur in adjacent and thoracolumbar areas after thoracic spine fusion, and the prevalence of these changes appear to be greater if the thoracolumbar spine has been fixed.

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