Radiological study on disc degeneration of thoracolumbar burst fractures treated by percutaneous pedicle screw fixation

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Abstract

Objective To examine disc degeneration at levels adjacent and next adjacent to the fractured vertebra and to analyses, if the disc degeneration is determined by the endplate fracture.

Summary of background data Thoracolumbar burst fracture is one of the most common spinal injuries. The diagnostic (clinical and imaging) approach and treatment of a fractured vertebra is well established; however, some controversy remains. The associated disc degeneration is less well known after 9–12 months of the short segment pedicle screw fixations. There is a major controversy whether spinal trauma with vertebral endplate fractures can result in posttraumatic disc degeneration. No study to date, however, has assessed disc degeneration of the AO type A3 thoracolumbar fractures without neurologic deficits after pedicle screw fixations.

Methods Twenty-six patients with single-level AO type A3 thoracolumbar fractures and no neurological deficit were treated by using postural reduction and short segment percutaneous pedicle screw fixation. No laminectomy and fusion were performed. Implants were removed 9–12 months after the first operation. The thoracolumbar magnetic resonance imaging (MRI) was used to assess disc degeneration at levels adjacent and next adjacent to the fractured vertebra before the first operation and after the second operation in a retrospective study.

Results After the instrumentation removal, new disc degeneration was usually found at level adjacent to the cranial endplate of fractured vertebra by MRI examination in 24 patients. The average Pfirrmann grade of degenerative discs adjacent to the cranial fractured endplates deteriorated from 2.1 pre-operatively to 3.4 after the second operation. No change of disc degeneration was seen at the caudal disc space adjacent to the fractured vertebra and the levels next adjacent to the fractured vertebra. The discs next adjacent to the fractured vertebra were showed to be relatively normal without changes of degeneration during the study period.

Conclusions Disc degeneration usually occurs at level adjacent to the fractured endplate of thoracolumbar burst fractures. Endplate fracture is strongly associated with disc degeneration. No correlation between fixation level and disc degeneration is seen in this study.

Keywords Disc degeneration · Thoracolumbar fracture · Endplate · Pedicle screw fixation · Minimally invasive surgery

Introduction

Approximately 90 % of all spinal fractures are found in the thoracolumbar junction, and burst fractures make up 10–20 % of such injuries [1, 2]. The treatment of stable thoracolumbar burst fractures without neurologic deficit remains controversial [3, 4]. The use of pedicle screws for posterior spinal stabilization has been established worldwide and multiple studies suggest that this procedure is a safe and effective method for thoracolumbar fractures [5]. Although improvements in surgical treatments are on track, clinical study on the intervertebral disc (IVD) degeneration relating to the fractured vertebra is nascent. Narrowing of

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the disc space has commonly been observed after fractures of the thoracolumbar spine and has been associated with progressive kyphosis and pain in patients treated conservatively or with recurrent kyphosis after posterior reduction and fixation [1, 6]. The patterns of degeneration and healing of discs adjacent to fractured vertebra are largely unknown. Kerttula [7] found that the young patients (mean 15.5 years) with wedge-shaped vertebral compression fracture had more disc degeneration than did the asymptomatic healthy subjects in the control group. The disc degeneration of thoracolumbar burst spine after surgery, however, is not well investigated. The aim of this study was to investigate retrospectively by magnetic resonance imaging (MRI) the occurrence of disc degeneration in the spines of patients with thoracolumbar burst fracture treated using short segment pedicle screw fixation.

Materials and methods

Clinical data

Between July 2007 and November 2009, a consecutive series of 26 patients (19 males and 7 females) with ages ranging between 21 and 54 years (mean 39.6 ± 10.3 years) were surgically treated and followed up at our department for thoracolumbar burst fractures; five patients were lost to follow-up during the study period. Inclusion criteria were traumatic fracture of T11–L2, single vertebral fracture, AO comprehensive classification type A3, neurologically intact, no or mild disc degeneration. Exclusion criteria were pathologic or osteoporotic fracture, patients with a history of operation on the upper back or accompanying injury which interferes with the clinical outcome. The retropulsed fragment was more than 50 % of spinal canal volume.

The injuries were caused by falling from height (15 cases), motor vehicle accidents (9 cases), and direct blows (2 cases). The fractures were distributed as follows: T11 (1), T12 (7), L1 (16), and L2 (2). Twenty-six patients underwent indirect reduction and short segment pedicle screw fixation within 10 days after injury. The time to operation after injury averaged 5.8 days. The range of days between injury and operation is from 3 to 10 days. All procedures were performed by two senior surgeons (Dr. Wang and Dr. Li) with more than 15 years of professional experience at the same hospital.

Surgical technique

Under general anesthesia, patients were laid in hyperextension prone position by adjusting radiolucent operating table to obtain postural reduction which was confirmed by a lateral view of the thoracolumbar spine under C-arm

fluoroscopic control. After 2 cm longitudinal incision was made, pedicle entry point of the vertebra below the fractured vertebra at the junction of the superior articular process and transverse process was directly touched through the surgeon's finger within the incision. Using the Sextant percutaneous pedicle screw system (Medtronic Sofamor Danek, USA), six appropriately sized cannulated pedicle screws was placed along the guidewire into the pedicles of the fractured vertebra and adjacent vertebra. After reduction screw holding sleeve was pushed down against the rod (during the procedure, partial reduction was achieved), the screw heads were tightened. No laminectomy and fusion were performed for 26 patients. Removal of implants was suggested 9–12 months after the operation in order to avoid implant failure.

Radiological evaluation

The vertebral fractures were classified according to the AO classification system by two experienced spinal surgeons using preoperatively obtained conventional radiographic film, computed tomography, and MRI. The MRI examinations of 26 patients were performed using a 1.5-T MR unit (Signa, Echo Speed, General Electric Medical Systems, Milwaukee, WI) with a phased-array surface coil. It was performed according to the standard discopathy protocol of our radiology department (T2: TR:2000 TE:101). MRI examination was used before the first operation and on the third day after the second operation, partly at latest follow-up, because of cost reduction and artifacts in the image due to metallic implants. Discs adjacent and next adjacent to the fracture vertebra were graded on pre and post operative MRI by two senior musculoskeletal radiologists with more than 20 years of professional experience using the grading system validated by Pfirrmann [8] on the T2-weighted sagittal images in Table 1. Endplate fracture was estimated based on either an irregularity in contour or possible signal intensity changes of the endplates on the CT and MRI.

The serial supine anteroposterior and lateral views were taken after the first surgery at 2 days, 1, 3, and 9 months. The bone healing of fractured vertebra was verified by radiography. We performed retrospective measurements of fracture kyphosis using the Cobb method. Cobb angles were measured from the inferior endplate of the vertebra above the fractured vertebra to the superior endplate of the vertebra below the fractured vertebra. When kyphotic deformity was reversed into lordosis after surgery, the value of the Cobb angle changed from plus to minus.

Statistical analysis

Statistical analyses were performed using SPSS 13.0 for windows. Mann–Whitney non-parametric tests were used

Table 1 Explanation of Pfirrmann grading system [8]

Grade	Nucleus pulposus signal on T2 MRI	Disc height	Other characteristics
I	Bright, hyperintense, homogenous	Normal	
II	Bright, hyperintense, inhomogeneous	Normal	May have gray bands with nucleus signal
III	Intermediate gray signal, inhomogeneous	Normal or slightly decreased	Unclear distinction between annulus and nucleus
IV	Dark grey signal, inhomogeneous	Normal to moderately decreased	
V	Black signal, inhomogeneous	Collapsed	Distinction between annulus and nucleus lost

Fig. 1 Male, 37 years old. Type A3 fracture. The time interval between the pre and postoperative imaging examination was 10 months. The Cobb-angles in the pre and postoperative conventional radiograph were, respectively, 19° and 11°. Preoperative lateral

radiograph (a) and MRI (b) showed T11 vertebral fracture and Pfirrmann grade 2 of disc degeneration. Postoperative radiograph (c) and MRI (d) showed short segment pedicle screw fixation and Pfirrmann grade 4 of T10–T11 disc

to evaluate the scores of the preoperative and postoperative MRI disc grading systems. Student *t* test was used for the comparison of continuous variables. *P* values below 0.05 were accepted for significance.

Results

Mean follow-up was 23.5 months (15–36 months). Preoperative MRIs demonstrated 80 discs with grade 2 and 24 discs with grade 3 changes in 26 patients. No normal discs (grade 1) were found at levels adjacent and next adjacent to the fractured vertebra. No discs had Pfirrmann grade 4

degenerative changes on preoperative imaging. Postoperative MRI studies showed that degenerative scores increased from 2 pre-operatively to 4 post-operatively in one case (Fig. 1), from 2 to 3 in 17 cases (Fig. 2), from 3 to 4 in 6 cases. New disc degeneration was only found at level adjacent to the cranial endplate of fractured vertebra by MRI examination in 24 patients. The increase in average Pfirrmann disc score was statistically significant between pre-operative (2.1) and post-operative (3.4) measurement ($P < 0.01$) using Mann–Whitney non-parametric tests in Table 2. No change of disc score occurred in all level next adjacent to the fractured vertebra ($P > 0.05$). Although caudal endplate fracture occurred in two vertebral

Fig. 2 Male, 46 years old. Type A3 fracture. The time interval between the first and second MRI was 11 months. The Cobb-angles in the pre and postoperative radiograph were, respectively, 15° and –8°. Preoperative CT (a) and MRI (b) showed L2 fracture and Pfirrmann

grade 2 disc degeneration. Postoperative radiograph (c) and MRI (d) revealed L2 fracture with reduction and instrumentation, as well as grade 3 of T12–L1 degenerative disc

fractures, there was no statistically significant increase of degenerative score at the caudal discs adjacent to the fracture vertebra ($P > 0.25$). The association between endplate fracture and adjacent IVD degeneration was statistically significant ($P < 0.01$). Of 26 patients in our study, cranial endplate fractures occurred in all patients and led to disc degeneration in 24 patients. Caudal endplate injuries happened in two cases without development of disc degeneration. Natural occurrence of disc degeneration is limited at the duration of 9–12 months after surgery. Endplate injuries are main factor to cause degeneration of damaged disc.

The spinal cords were normal in all cases, and there were no disc herniations found in any of the patients.

No intra or postoperative complications were noted in any of the patients in 26 patients. This refers to potential complications, such as incorrect screw positioning, infections or neurological symptoms occurring preoperatively. No significant kyphosis of the fracture area was diagnosed in all patients. At latest follow-up, average Cobb angle was improved from 15.0° to 2.1° in 26 patients. All pre and postoperative outcome variables had statistical significance by using Student *t* test ($P < 0.01$) (Table 3).

Table 2 Pfirmann disc scores at levels adjacent and next adjacent to the fractured vertebra

Fractured vertebra	Level	Preoperative MRI		Second postoperative MRI	
		N	Average score	N	Average score
T11	T9–T10	1	2	1	2
	T10–T11	1	2	1	4**
	T11–T12	1	2	1	2
	T12–L1	1	2	1	2
T12	T10–T11	7	2.3	7	2.3
	T11–T12	7	2.3	7	3.3**
	T12–L1	7	2.3	7	2.4
	L1–L2	7	2.3	7	2.3
L1	T11–T12	16	2.2	16	2.2
	T12–L1	16	2.2	16	3.1**
	L1–L2	16	2.2	16	2.3
	L2–L3	16	2.3	16	2.4
L2	T12–L1	2	2	2	2
	L1–L2	2	2	2	3**
	L2–L3	2	2	2	2
	L3–L4	2	2	2	2
Sum of cranial disc		26	2.1	26	3.4

* $P < 0.05$, ** $P < 0.01$ **Table 3** Preoperative and postoperative Cobb angle (°) of 26 patients

Fractured vertebra	Preoperative Cobb angle (°)		Postoperative Cobb angle(°)	
	N	Average angle	N	Average angle
T11	2	15.3	2	5.7**
T12	7	17.1	7	3.8**
L1	16	15.9	16	2.2**
L2	2	11.7	2	−3.4**
Overall	26	15.0	26	2.1**

* $P < 0.05$, ** $P < 0.01$

Discussion

The goal for treatment of the thoracolumbar burst fracture is to restore the vertebral height, alignment, and lordosis, decompress the spinal canal, and restore spine stability. Minimally invasive techniques are potentially desirable and chosen to decrease the morbidity of the operative access and to protect the paravertebral musculature. Fusion may lead to adjacent segment disease at long-term follow-up [9]. All implants were removed from 9 to 12 months after surgery to reduce implant failure and adjacent segment degeneration in our case series.

Trauma has been considered one of the major reasons for disc degeneration, although the etiology of disc degeneration is multifactorial. In the year 2000, Kerttula et al. [7] published radiological follow-up data on MRI findings in young patients with previous wedge-shaped

compression fracture and age-matched and sex-matched control subjects. It was found that wedged compression fractures of vertebrae in children might cause disc degeneration, especially when both adjacent endplates were fractured. These changes do not usually cause symptoms, at least at a young age. In the study reported by Oner et al. [6], lack of consistent signal changes after a major traumatic event to the motion segment does not support the idea of a traumatic origin to degenerative disc disease. Fracture of the endplate alone was not sufficient to cause disc degeneration. There was no evidence for a correlation between spine trauma and disc degeneration. In contrast, Hsu et al. [10] analyzed MRI images from 379 patients with back pain and/or leg pain to evaluate disc degeneration in the higher lumbar spine. They found that isolated high lumbar disc degeneration was associated with fractures below or above the respective intervertebral discs. Similarly, Vornanen and co-workers [11] have analyzed 2-year follow-up MRI data from patients with spine fractures after Harrington rod stabilization. They found that 16 intervertebral discs adjacent to the fractured vertebral body in 11 patients showed decreased signal intensity in T2-weighted images. None of the uninjured intervertebral discs showed any detectable signal decrease. Annulus tears and endplate fracture are common lesions in human intervertebral discs. Endplate fracture can cause degenerative change both in humans [12] and in animal models [13]. Przybyla et al. [14] found that outer annulus tears have less (immediate) effects on intradiscal compressive stresses than endplate fracture and concluded that endplate fracture provides a greater stimulus for disc degeneration.

Our main findings were that there was obvious relationship between thoracolumbar fracture and disc degeneration. Of 26 patients with AO type A3 thoracolumbar fractures, cranial endplate fractures occurred in all patients, and caudal endplate injuries in two cases. Occurrence and development of disc degeneration were only found in 24 patients with cranial endplate fractures. Zhao et al. [15] found that when vertebrae are compressed naturally by adjacent intervertebral discs, cranial endplates usually fail before caudal endplates, because they are thinner and supported by less dense trabecular bone. Osseous endplate consists of perforated cortical bone with a layer of hyaline cartilage. The vertebral endplate contains a radiating anastomosing network of marrow cavities which allow bone marrow to lie adjacent to calcified hyaline cartilage, and this is widely regarded as an important route for metabolite transport into the avascular intervertebral discs [16]. As the gateway of nutrient supply, the vertebral endplate is essential to maintain the integrity and function of the avascular IVD. It seems reasonable to suppose that the endplate fracture results in disc degeneration due to calcification and blocking of the endplate nutritional route. The etiology and pathogenesis of disc degeneration are still controversial, but impaired nutrition is believed to have an important role.

Two discs caudal to the fracture endplate demonstrated no changes of disc degeneration. One possible explanation is that the endplate injuries were too mild to cause degeneration of damaged disc. This is also reason why different grades of disc degeneration occurred in all patients. The degree of vertebral and endplate injury seemed to have reasonable correlation with the occurrence of disc degeneration, although most of these patients with endplate fracture had disc degeneration. MRI was successful in finding disc degeneration of thoracolumbar burst fracture after hardware removal. The degeneration of IVD occurred during the period of temporary fixation of thoracolumbar spine for 9–22 months, but the discs caudal to the fractured vertebra did not degenerate further. This demonstrated that short segment instrumentation without fusion did not induce the degenerative process detectable on MRI in the patients within a follow-up period of 23.5 months with the minimum follow-up of 15 months.

The study is retrospective and non-controlled. The number of patients is small. More studies with larger sample size and long-term follow-up results would be interesting for determining whether the patients with disc degeneration will later have more degenerative findings and more symptoms. In conclusion, the present study indicates that endplate fractures of vertebrae in patients with thoracolumbar burst fractures may cause disc degeneration, especially in cranial endplate.

Conflict of interest None.

Ethical standard The clinical study proposal was approved by the medical ethical committee of the authors' institution. The written informed consents were obtained from all patients at study entry.

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