Clinical Characteristics and Intraoperative Reduction Technique of Thoracolumbar Fractures Combined with Posterior Column Injury

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ABSTRACT

Objective: To analyse the clinical characteristics of thoracolumbar fractures combined with posterior column injury, and explore its intra-operative reduction technique with clinical efficacy.

Study Design: Descriptive study.

Place and Duration of the Study: Department of Orthopaedics, Fuyang People's Hospital, Anhui, China, from December 2017 to 2021.

Methodology: A total of 60 patients met the inclusion criteria, they were divided into two categories according to injury mechanism and imaging characteristics: flexion-distraction injury (FDI) and burst fracture with lamina fracture (BFLF), and their clinical characteristics were analysed. All patients were treated with posterior pedicle screw internal fixation, and different intraoperative reduction methods were adopted for reduction. Measurements of anterior vertebral heights (AVH), local kyphotic angles (LKA), visual analog scale (VAS) and oswestry disability index (ODI) were evaluated preoperative, after operation, and the last follow-up.

Results: The two groups of thoracolumbar fractures combined with posterior column injury had different clinical characteristics, and there were significant differences in preoperative imaging related parameters ($p<0.05$). All patients in the two groups successfully completed the operation, and there were no direct complications related to the operation. The patients were followed up for 12-24 months. Compared with those before the operation, the AVH, LKA, VAS, and ODI immediately after the operation and at the last follow-up were significantly improved ($p<0.05$). Bone fusion was achieved in all patients.

Conclusion: Careful and comprehensive preoperative clinical data analysis is the key to diagnosis of thoracolumbar fractures combined with posterior column injury. According to the type of fracture, reasonable selection of intraoperative reduction technique can obtain satisfactory clinical results.

Key Words: *Burst fracture, Pedicle screw, Internal fixation, Thoracic, Lumbar.*

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INTRODUCTION

Since Denis proposed the famous three-column theory of thoracolumbar fractures,[1] the concept has been integrated into various types of thoracolumbar fractures (such as AO Spine Type, thoracolumbar injury classification, and severity score (TLICS).[2,3] The main anatomical structures of the posterior column can be very crucial in maintaining the stability of thoracolumbar fractures. Thoracolumbar fractures combined with posterior column injury can be divided into three categories. Thoracolumbar fracture with fracture dislocation is often associated with severe spinal sequence disorder and nerve injury. Proper preoperative planning and surgical expertise can optimise the outcome of patients.[4,5]

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Given that FDI and BFLF have similar clinical symptoms and signs, careful and comprehensive clinical examination and detailed analysis of imaging features should be distinguished to provide a guide in the treatment. The objective of this study was to analyse the clinical characteristics of thoracolumbar fractures combined with posterior column injury and explore its intraoperative reduction technique with clinical efficacy.

METHODOLOGY

A retrospective review of the Fuyang People's Hospital, Anhui, China, database from December 2017 to 2021 yielded 60 cases of FDI (Type B1 and B2 fractures) and BFLF (Type A3 or A4 fractures combined with lamina fractures) in the thoracolumbar segment (T_{11}-L_2). The inclusion criteria was single vertebral fracture ($T_{11} \sim L_2$), aged ≥18 years, and MRI result suggesting posterior ligament complex injury or CT reconstruction of the posterior column injury. The exclusion criteria was osteoporotic fracture, pathological fracture, incomplete data, low tolerance to surgery due to cardiopulmonary insufficiency, and displacement injury. The general character and distribution of fractured vertebra are demonstrated in Table I. The causes of injury on admission were analysed. If the preoperative examination indicated PLC injury, then top reduction technique was used. On the contrary, longitudinal spread reduction techniques were used for reduction of fracture. The surgery was performed by five equally qualified doctors. Microsoft Office was used to collect data. The PVH, AVH, IPD, LKA, CC, and Laminar fracture line of the two groups were measured and compared. The AVH, LKA, VAS, and ODI were collected and analysed before the operation, after the operation, and at the last follow-up.

LKA was the localisation angle between the two endpoints. CC was calculated as a ratio of the canal area of the injured level to the average of that of the two adjacent uninjured segments. IPD was calculated by comparing the widening between the pedicles of the fractured vertebrae with the mean of similar values obtained from levels above and below them. AVH was calculated by comparing the anterior vertebral height with the mean of similar values obtained from levels above and below them. PVH was calculated by comparing the posterior vertebral height of fractured vertebra with the mean of similar values obtained from levels above and below them.

The patients were placed in the prone position with the abdomen suspended to facilitate intraoperative reduction. Routine pedicle screw placement through an intermuscular approach was performed on patients who did not need decompression or fusion. The paraspinal muscles in patients who needed decompression or fusion were routinely dissected. Moreover, the injured vertebrae, the lamina, and the articular process of the upper and lower vertebral bodies were exposed. The pedicle screws were routinely inserted, and the lamina fenestration was performed.

The top reduction technique was used for the FDI group: the pedicle screws of the upper vertebral body of the injured vertebra deviated to the cephalad side. The pedicle screws of the lower vertebral body of the injured vertebra were skewed to the caudal side, and a set of screws were inserted into the proximal end if necessary. The prebent rods were placed, and the distal caps were first locked. Then, the proximal caps were locked one by one. The lever of the prebent rods was used to correct the local kyphosis by fracturing and resetting the top.

The BFLF group adopted longitudinal spread reduction techniques: in the injured vertebra and wounded vertebral fluctuation, two vertebral bodies were placed parallel to the vertebral pedicle screw. The connecting rods were installed. Distal locking was performed on the injured vertebral screws. Bilateral alternating with open longitudinal segment was conducted on open vertebral bodies. Then, the injured vertebral and proximal vertebral body screw end caps were locked to restore vertebral body height.

A unilateral posterior iliac incision was made. Each layer of tissue was cut layer by layer, and the posterior iliac external plate was stripped. Some iliac bone slices were shaved with an osteotome. The trimmed iliac bone slices were implanted between the posterior laminae of the injured vertebrae. Hemostasis was thoroughly stopped, irrigation was performed, negative pressure drainage was placed, and the wound was sutured layer by layer. Then, a sterile dressing was applied.

Antibiotics were applied within 48 h after the operation. Dehydration, fluid replacement, and symptomatic treatment with low molecular weight heparin were performed to prevent thrombosis. Then, the drainage tube was removed when the drainage volume was less than 50 ml. After 6–8 weeks, the brace was protected to allow patients to get out of the bed. Physical labour was avoided for 6 months.

The causes of injury on admission were analysed and PVH, IPD, LKA, and CC were measured and compared between the two groups. The AVH, LKA, VAS and ODI were collected and analysed before and after the operation, and at the last follow-up.

Statistical analysis was performed using SPSS 26.0. All measurement data were collected by an independent observer and expressed as mean ± SD for descriptive data. Paired sample t-test was used for intra-group comparison, and independent sample t-test was used for inter-group comparison. $\chi 2$ test was used for comparison of count data between groups. The level of statistical significance was defined as $p<0.05$.

RESULTS

The causes of FDI injury included traffic accidents in 14 cases, falling from height in 5 cases, heavy object injury in 6 cases, and others in 7 cases. Nine patients had neurological symptoms. The causes of BFLF injury included traffic accidents in 3 cases, falling from height in 14 cases, heavy object injuries in 3 cases, and others in 8 cases. Eleven patients had neurological symptoms. The causes of injuries between the two groups were statistically significant ($p = 0.007$). The injuries in the FDI group mainly involved longitudinal and flexion violence. They were mainly caused by traffic accidents, accounting for 14 cases (43.8%). Vertical violence was mainly involved in the BFLF group. The main cause of the injuries from this group was falling from a height, accounting for 14 cases (50%). The analysis of the imaging-related parameters for the two groups indicated that the PVH, IPD, LKA, and CC had significant differences ($p<0.05$), as shown in Table II. All 60 patients completed the operation. Three cases of cerebrospinal fluid leakage (all caused by fracture) were found during the operation and cured after corresponding treatment. All patients were followed up for 12-24 months, averaging 17.3 months. No internal fixation loosening, displacement, and nail or rod breakage occurred. All bone grafts achieved bony union. Typical cases are shown in Figure 1 and 2. Compared with those before the operation, the AVH and LKA after the operation and at the last follow-up showed significant differences ($p<0.001$). Compared with those before the operation, the VAS and ODI 3 months after the operation and at the last follow-up were at significant differences ($p<0.001$), as shown in Table III.

Table I: Overview of patient demographic and distribution of two fracture types ($\bar{x}\pm s$).

	FDI (n=32)	BFLF (n=28)	t/χ^2	p-value
Age	48.66±9.73	47.43±10.95	0.46/	0.647
Gender (Male/Female)	21(65.6%)/11(34.4%)	15(53.6%)/13(46.4%)	/0.905	0.431
Fracture sites (T11/T12/L1/L2)	3(9.4%)/8(25.0%)/ 9(28.1%)/12(37.5%)	1(3.6%)/7(25.0%)/ 12(42.9%)/8(28.6%)	/1.998	0.589

Table II: Clinical characteristics of the two fracture types ($\bar{x}\pm s$).

Imaging	Observation indicators		FDI (n=32)	BFLF (n=28)	t/χ^2	p-value
X-ray	AVH		54.81±12.86	52.68±9.91	0.72/	$^{(1)}$p=0.472
	PVH		84.16±13.78	74.46±8.85	3.28/	$^{(1)}$p=0.002
	IPD		99.88±5.96	105.50±5.20	3.91/	$^{(1)}$P<0.001
	LKA		11.40±5.13	8.70±2.91	2.54/	$^{(1)}$p=0.016
	CC		26.66±25.80	43.36±22.49	2.66/	$^{(1)}$p=0.01
CT-examination	Laminar fracture line	Lengthways	9(28.1%)	17(60.7%)		
		Crosswise	15(46.9%)	6(21.4%)	/6.77	$^{(2)}$p=0.036
		Without	8(25.0%)	5(17.9%)		
MRI-examination	PLC injury		9(28.1%)	17(60.7%)		-
Causes of injury	Traffic accident/Falling from height/ Heavy object injury/Other		14(43.8%)/5(15.6%)/ 6(18.8%)/7(21.9%)	3(10.7%)/14(50%)/ 3(10.7%)/8(28.6%)	/12.264	$^{(2)}$0.007

Data were compared (1) using the independent sample t-test; (2) using the Chi-squared test.

Table III: Comparison of the imaging and clinical results between the two groups ($x\pm s$).

		FDI	BFLF	$t^{(1)(2)}$ / $t^{(1)(3)}$ FDI / BFLF	$p^{(1)(2)}$ / $p^{(1)(3)}$
AVH	Before operation$^{(1)}$	54.81±12.86	52.68±9.91		
	After operation$^{(2)}$	94.44±5.25	96.00±3.17	18.426/20.635	<0.001
	Last follow-up$^{(3)}$	93.66±3.70	95.11±3.67	4.070/20.620	<0.001
	Before operation$^{(1)}$	11.40±5.13	8.70±2.91		
LKA	After operation$^{(2)}$	1.32±1.23	1.86±1.58	11.312/13.774	<0.001
	Last follow-up$^{(3)}$	1.54±1.07	2.09±1.65	11.746/12.423	<0.001
VAS	Before operation$^{(1)}$	7.00±1.19	6.96±1.20		
	3 months after operation$^{(2)}$	1.28±1.25	1.18±1.28	20.079/18.163	<0.001
	Last follow-up$^{(3)}$	0.69±0.90	0.64±0.91	21.331/19.420	<0.001
ODI	Before operation$^{(1)}$	95.31±2.95	95.36±3.08		
	3 months after operation$^{(2)}$	24.06±7.41	24.07±7.69	45.301/40.539	<0.001
	Last follow-up$^{(3)}$	3.38±3.02	3.21±3.00	136.22/125.515	<0.001

Data from (1) were compared with those from (2) and (3) using the paired sample t-test.

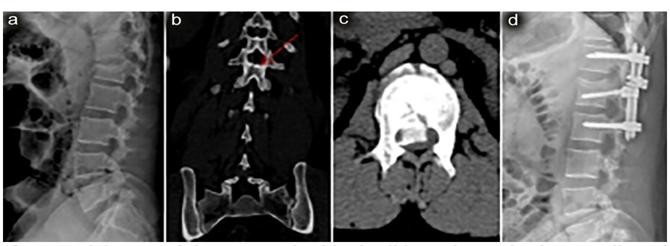

Figure 1: (a) BFLF of the L1 vertebral body. (b) CT shows the fracture line of lamina lengthways. (c) The cross-sectional place of CT shows the retropulsed bone fragment invasion of the spinal canal. (d) The height of the vertebral body recovered well after the immediate postoperative reduction by longitudinal spread reduction techniques.

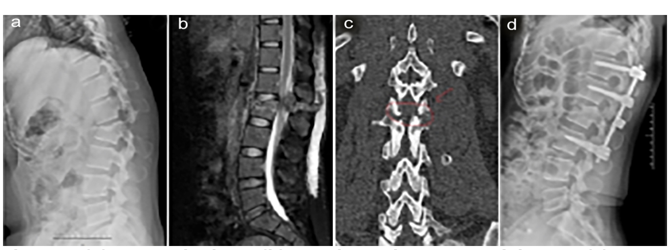

Figure 2: (a) L1 vertebral FDI. (b) MRI shows the rupture of the PLC. (c) Crosswise laminar fracture line indicated by CT. (d) The height and LKA of the vertebral body recovered well immediately after the operation employing the top reduction technique.

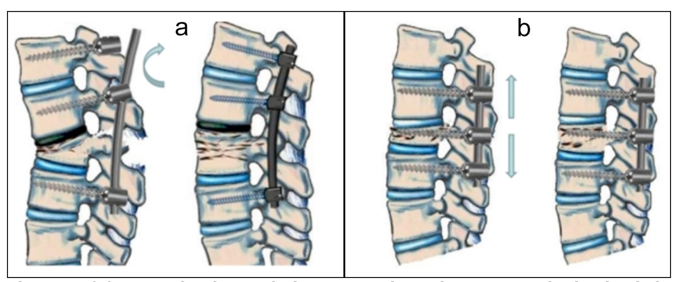

Figure 3: (a) Top reduction technique was adopted to correct the kyphosis in FDI group. (b) Longitudinal spread reduction technique was adopted to restore vertebral height in BFLF group.

DISCUSSION

Thoracolumbar fractures combined with posterior column injury are not rare in clinical practice. Their two common types are FDI and BFLF. Classic FDI for belt damage is rare. At present, the injury mechanism of FDI is mostly caused by longitudinal violence combined with buckling violence, which is common in traffic accidents and fall from height. It is usually accompanied by posterior ligament complex injury or transverse fracture of lamina and spinous process, which is unstable fracture. The injury mechanism of BFLF is mostly vertical violence. Its posterior ligament complex is relatively complete. Some of them are stable fractures. Therefore, the two types of fractures should be distinguished to provide a guide in the treatment. The two types of thoracolumbar fractures with different imaging characteristics because of different injury mechanisms, as shown in Table II. For FDIs, CT showed that the degree of vertebral body burst was often not serious. Some vertebral body bone mass invaded the spinal canal. CT and MRI commonly showed the fracture of the posterior ligament complex or vertebral lamina and the spinous process fracture with a horizontal fracture line. In the x-ray examination, traumatic kyphosis was obvious. Moreover, the spinous process spacing was increased. For BFLFs, the imaging often shows vertebral body bursts and the loss of anterior and middle column height; however, the x-ray can show the widening of pedicle spacing. The local kyphosis is not obvious but is often combined with a longitudinal fracture of the lamina.[5] In this present study, the imaging data of 32 patients with FDI and 28 patients with BFLF were retrospectively analysed. Significant differences were found between the imaging-related parameters ($p<0.05$).

FDI and BFLF should be distinguished by analysing the injury mechanism and imaging characteristics of thoracolumbar fractures combined with posterior column injury to provide a guide in the treatment. FDI is an unstable thoracolumbar transverse fracture through the three columns. It is prone to secondary spinal instability and progressive kyphosis in the long term. At present, most scholars tend to perform surgical treatment.[6] However, BFLF does not injure the posterior ligament complex and is often a stable fracture, some patients can be treated conservatively.[7,8] However, the degree of vertebral body comminution is often severe when burst fracture combines with a lamina fracture. Moreover, bone invasion of the spinal canal commonly occurs. Even without neurological symptoms, the risks of local kyphosis and secondary nerve injury can significantly increase in long-term conservative treatments.[9] Studies showed that CC, IPD, and the large LKA in stable vertebral burst fractures are related factors leading to the failure of nonsurgical treatment.[10,11] In the present study, all BFLF cases without nerve injury were treated by surgery. The clinical efficacy was satisfactory. Surgical treatment is currently recognised as the treatment plan for BFLF with neurological symptoms. Surgical decompression can create the best conditions for the recovery of neurological function. No destruction of the posterior ligament complex occured in BFLF. Thus, bone graft fusion was unnecessary during the operation.[12,13]

The posterior pedicle screw internal fixation is a classic surgical method for treating thoracolumbar fractures. It uses the mechanism such as prebent rods to reduce the fractured vertebral body and correct the kyphosis. In this method, the three-column fixation through the pedicle screw is realised to restore the physiological sequence of the spine and stabilise the spine. FDI and BFLF exhibit distinct imaging features because of their different injury mechanisms. According to the principle of reverse injury mechanism of fracture reduction, FDI mainly adopts the fracture top reduction technique (Figure 3a). In comparison, BFLF mainly adopts longitudinal spread reduction techniques (Figure 3b). Different reduction techniques are beneficial to the reduction of thoracolumbar fractures with different injury mechanisms and to restore the physiological sequence of the spine.

Given the involvement of flexion violence in the process of FDI, the injury result is mainly manifested as local kyphosis. If the traditional nail rod longitudinal support technique is used, the three columns will be supported at the same time, and the rear column will be supported to the largest extent, resulting in the further separation of the PLC that has been damaged, thereby reducing the effect of the tension band, which is not conducive to the reduction of the fracture and the correction of the kyphotic deformity, and maybe lead to the failure of internal fixation. The lever of the bending rod is mainly relied on to reduce the top through its strength against flexion injury, achieve the physiological sequence restoration of the FDI spine, and realise the purpose of stretching the anterior column and closing the posterior column.[14] Some scholars used precompression reduction with a lordotic bending rod and open reduction with a straight rod to treat Type A3 fracture with kyphosis.[15] They found that it showed obvious advantages in restoring the height of the injured vertebra, correcting the kyphosis deformity, and reducing the loss of postoperative correction. For FDI patients with large kyphosis angles, a proximal segment must be extended and fixed to increase the lever arm and obtain great orthopedic force.[16] In a biomechanical study, pedicle screw internal fixation in the treatment of thoracolumbar fractures can further lock the facet joints to increase stability and restore the sagittal plane sequence of the spine through posterior screw rod compression.[17] Some scholars studied kyphosis loss of correction in patients with burst fractures within 6 months after pedicle screws fixation.[18] In this group, 10 patients with FDI were treated with the proximal extension of fixation. The AVH, LKA, VAS and ODI were satisfactory. However, the injury mechanism of BFLF was mainly longitudinal vertical violence. Moreover, the injury results were mainly manifested as the compression and bursting of the anterior and middle columns and the reduction of vertebral height. The force of intraoperative reduction mainly resisted the external force of vertical compression to restore the height of the vertebral body. The longitudinal distraction reduction technique can achieve this purpose. The posterior approach for treating thoracolumbar fractures has recently achieved satisfactory clinical results through the injured vertebra short segmental six-screw structure fixation.[19] The injured vertebrae and their adjacent spaces can be lengthened at multiple points during the operation by placing screws on them to establish a fulcrum. The anterior and posterior longitudinal ligaments can be tightened well. This approach is conducive to the recovery of the height of the injured vertebrae. All BFLF patients in this group were treated with short-segment fixation of six screws through the injured vertebra. Significant improvements in imaging and clinical results were observed after the operation and at the last follow-up. The limitations of this study are that MRI is not the gold standard for PLC injury.[20] An extended follow-up is also needed to evaluate the clinical efficacy of both surgical reduction methods.

CONCLUSION

FDI and BFLF showed different imaging characteristics because of their different injury mechanisms. A careful and comprehensive clinical data analysis should be performed before an operation to make an accurate diagnosis. Proper reduction techniques can be adopted for satisfactory clinical efficacy and imaging results.

ETHICAL APPROVAL:
This study was reviewed and approved by the Medical Ethics Committee of Fuyang People's Hospital, Fuyang, China (No. 202011).

PATIENTS' CONSENT:
The authors obtained patients' consent to publish the data concerning this study. Patients were ensured that efforts will be made to conceal their identity.

COMPETING INTEREST:
This manuscript has not been published or presented elsewhere in part or entirety and is not under consideration by another journal. The authors read and understood the journal's policies, and believed that neither the manuscript nor the study violated any of these. The authors declared no conflict of interest. This research was supported by the Natural Science Key Project of Bengbu Medical College (No. BYKY2019227ZD).

AUTHORS' CONTRIBUTION:
JC, KW, HY: Study conception, design, material preparation, data collection, and analyses.
WY: Plotted the graph, designed the study.
CL: Performed operations, designed the study.
LS, CL: Designed the study and surgery plan, and wrote the manuscript.
All authors approved the final version of the manuscript to be published.

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