

Risk Factor Analysis for Predicting Kyphosis Reoccurrence of Thoracolumbar Burst Fracture Patients Treated with Posterior Short-Segment Fixation

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Abstract

Background: The thresholds of risk factors of kyphosis recurrence in thoracolumbar burst fracture patients were still controversial. The aim of this multi-center study was to identify these thresholds.

Methods: 169 patients were included in this study. Upper intervertebral angle (UIVA), lower intervertebral angle (LIVA), Cobb angle (CA), anterior vertebral height ratio (AVH%), regional angle (RA), posterior vertebral height ratio (PVH%), vertebral wedge angle (VWA), anteroposterior ratio (A/P%), Clinical assessment included Load Sharing Classification (LSC) score, Thoracolumbar Injury Classification and Severity (TLICS) score, Visual Analogue Scale (VAS), and Body mass index (BMI) were perioperatively evaluated. Patients were divided into KR group and none KR (NKR) group according to whether the loss of CA correction was less than 15° or not. The risk factors of KR before or after implant removal were analyzed, respectively.

Result: There were significant improvements in postoperative parameters compared with preoperative parameters, such as AVH%, A/P%, VAS, CA, VWA, PVH% ($P < 0.001$, respectively), and UIVA ($P = 0.02$). Age (AUC = 0.828) and BMI (AUC = 0.846) were good predictors of KR before implant removal. BMI (AUC = 0.871) was a good predictor of KR after implant removal.

Conclusion: There were significant differences in risk factors of KR at different postoperative follow-up stages: age > 49 years, BMI > 24 were risk factors of KR before implant removal; BMI > 25.17 was a risk factor of KR.

1. Introduction

Thoracolumbar spine (T11-L2) is the most frequent site of vertebral fractures; the transition from the less mobile thoracic spine with support from the ribs and sternum to the more dynamic lumbar spine makes this junction a biomechanical weak point [1]. Therefore, most spinal injuries affect the thoracolumbar region, 17% of which are burst fractures [2].

The short-segment pedicle instrumentation with the screw insertion in the fractured vertebra (SSPI-f) usually provides sufficient fixation with good clinical outcomes [3]. However, it is also associated with common complications, such as failure of the instrumentation, the recurrence of kyphosis (KR) and sagittal spinal imbalance [4, 5]. Jang et al. [6] reported that predictors of vertebra re-collapse for thoracolumbar burst fracture were age and the loss of preoperative body height. Nevertheless, they combined long-segment pedicle instrumentation with short-segment pedicle instrumentation in the study. Because the follow-up time of their study is only one year, they did not fully discuss the influence of implant removal on spinal correction. In addition, they failed to discuss the KR after SSPI-f, which seemed to be of greater clinical significance than vertebral body re-collapse. Chen et al. [3] studied the effect of implant removal on KR after implant removal on KR after SSPI-f, and found that the loss of correction was associated with anterior vertebral height ratio (AVH%) < 50%, anteroposterior ratio and age. However, they did not fully analyze the factors influencing KR before implant removal. The thresholds of risk

factors in their study were based on experience and the results of previous studies; however, these were not analyzed by receiver operating characteristic (ROC) curve. Therefore, their research methods need to be improved.

In order to solve all the problems mentioned above, we analyzed the risk factors of KR before implant removal and after implant removal respectively in the present study. To identify the thresholds of the risk factors, we used logistic regression model and ROC curve in the analysis. Cases gathered from three health centers were studied in this research, which would make the results more convincing.

2. Materials And Methods

2.1 Ethics statement

Ethics Committee of the Xuanwu Hospital Capital Medical University approved this study. The approval number is Clinical study review [2018] 021. Written informed consent of each patient was obtained prior to the study.

2.2 Inclusion and Exclusion Criteria

We retrospectively reviewed 224 consecutive thoracolumbar burst fracture patients presenting to the hospitals (Xuanwu Hospital Capital Medical University; Beijing Chaoyang Hospital, Capital Medical University; Chui Yang Liu Hospital affiliated to Tsinghua University) between January 1, 2014 and January 1, 2016. All patients received SSPI-f within 3 days. The patients were older than 18 years. The follow-up time was two years. We removed the fixation device with about 12 months after SSPI-f. The inclusion criteria were as follows: Thoracolumbar Injury Classification and Severity (TLICS) score was more than 4; kyphosis was more than 15°; anterior vertebral height was less than 50%. The exclusion criteria were as follows: Multiple contiguous fractures or non-contiguous fractures; bone mineral density (BMD) of the thoracolumbar spine was at least 2.5 SD below the mean of young normal men; pathological fracture such as tumor, ankylosing spondylitis, inflammatory arthritis; posterior fusion or posterolateral fusion, and laminectomy in the operation; neurological deficit, obsolete thoracolumbar fracture, previous history of spinal surgery. Finally, 169 (90 men and 79 women) patients were included in this study.

2.3 Radiological Measurements

Whole-spine X-ray (Philips Digital Diagnost) and computed tomography (CT) (Philips Medical Systems) were used to evaluate the patients. Superior endplate (SE) fracture in the fractured vertebra was evaluated on CT images. Radiographic parameters were obtained, preoperatively or postoperatively. In addition, the parameters were collected before implant removal and at last follow-up. The following radiological parameters [3, 6, 7] were evaluated: Cobb angle (CA) was measured between the inferior endplate (IE) of the lower adjacent vertebra (LAV) and the SE of the upper adjacent vertebra (UAV); vertebral wedge angle (VWA) was the angle between the IE and the SE of fractured vertebra; regional angle (RA) was defined as the angle between the IE of the UAV and the SE of the LAV; posterior vertebral

height ratio (PVH%) was calculated by the ratio of posterior height of the fractured vertebra (PVH0) to the average between posterior height of the UAV (PVH1) and posterior height of the LAV (PVH2); anterior vertebral height ratio (AVH%) was calculated by the ratio of anterior height of the fractured vertebra (AVH0) to the average of anterior height of the UAV (AVH1) and anterior vertebral height of the LAV (AVH2); anteroposterior ratio (A/P%) was the ratio of AVH0 to PVH0; upper intervertebral angle (UIVA) was the angle between the IE of UAV and the SE of fractured vertebra; lower intervertebral angle (LIVA) was the angle between the SE of LAV and the IE of fractured vertebra.

2.4 Clinical Assessments

The extent of anterior column comminution was assessed in accordance with Load Sharing Classification (LSC) score [8]. Back pain was evaluated according to a Visual Analogue Scale (VAS). Thoracolumbar Injury Classification and Severity (TLICS) score [9] was used to weight the severity of fracture. Body mass index (BMI) was used to evaluate the body size of the patients. Whether the patients got diabetes or not was also recorded in this research.

2.5 Grouping Methods

Patients with the CA less than 15° were included in the KR group; however, patients with the CA more than 15° were included in the none KR (NKR) group [10]. The risk factors of KR before or after implant removal were analyzed, respectively.

2.6 Statistical Analysis

SPSS 17.0 (SPSS Inc, Richmond, CA, USA) was used to perform the statistical analysis. Mean ± standard deviations were used to represent continuous variables. Kolmogorov–Smirnov test was performed to the normal distribution of the data. Normally distributed values were analyzed with independent Student t test. Skewed values were analyzed with Kruskal-Wallis test. Categorical variables were reported as the number of cases and were evaluated in Pearson's χ^2 test. Candidate variables were identified for multivariate logistic regression model via univariate screening to identify the risk factors. ROC (receiver operating characteristic) curve was calculated by the results of multivariate logistic regression analysis. It was used to determine the predictability of the risk factors for KR. P value < 0.05 was considered of statistical significance.

3. Results

3.1 Demographics

The patients' mean age was 48.4 ± 11.0 years. In all of those patients, 6 (3.6%) patients got diabetes mellitus. Superior endplate fracture occurred in 78 (46.8%) patients. There were 6 (3.6%) fractures in T11, 66 (39.3%) in T12, 72 (42.8%) in L1, 24 (14.3%) in L2. The average preoperative BMI was 24.8 ± 2.9 . In addition, preoperative TLICS was 6.5 ± 1.0 , and LSC score was 5.9 ± 1.1 . The mean follow-up time was 27.5 ± 1.7 months.

There were significant improvements in postoperative parameters compared with preoperative parameters, such as VAS, CA, VWA, AVH%, A/P%, PVH% ($P < 0.001$, respectively), UIVA ($P = 0.02$) (Fig. 1). However, no significant difference was found between preoperative LIVA and postoperative LIVA ($P = 0.420$).

3.2 Risk factors of postoperative KR before implant removal

The average correction loss before implant removal was $4.3 \pm 3.0^\circ$. Kyphosis reoccurred in 78 (46.4%) patients. There were significant between-group differences among the number of females, age, BMI ($P < 0.001$, respectively), the number of cases with preoperative AVH%, preoperative VAS, preoperative LSC ($P = 0.001$, respectively), diabetes mellitus ($P = 0.009$), preoperative PVH% ($P = 0.007$), and preoperative A/P% ($P = 0.002$) (Table 1).

Table 1
Comparison of preoperative parameters between KR Group and NKR Group

Characteristic	KR Group		NKR Group		t/ χ^2 value		Pvalue	
	Before	After	Before	After	Before	After	Before	After
Implant removal								
Female (n)	48 (28.6%)	72 (42.9%)	30 (17.6%)	6 (3.6%)	13.365	39.908	< 0.001	< 0.001
Age (year)	54.2 ± 11.1	52.1 ± 10.3	43.4 ± 8.0	40.8 ± 8.1	-7.164	-7.089	< 0.001	< 0.001
BMI	26.6 ± 2.5	26.0 ± 2.7	23.3 ± 2.3	22.3 ± 1.3	-8.815	-12.166	< 0.001	< 0.001
Diabetes (n)	6 (3.6%)	6 (3.6%)	0 (0%)	0 (0%)	7.179	2.947	0.009	0.178
Upper endplate injury (n)	42 (25%)	60 (35.7%)	36 (21.4%)	18 (10.7%)	3.221	5.487	0.88	0.021
Preoperative CA (°)	20.8 ± 10.4	19.6 ± 9.1	19.1 ± 5.1	20.5 ± 4.9	-1.346	0.828	0.181	0.409
Preoperative RA (°)	9.4 ± 5.9	8.9 ± 5.6	9.3 ± 4.4	10.2 ± 3.8	-0.155	166	0.877	0.110
Preoperative VWA (°)	17.9 ± 6.8	17.6 ± 6.2	18.4 ± 4.4	19.3 ± 4.1	128.009	2.112	0.573	0.036
Preoperative UIVA (°)	-3.4 ± 2.4	-3.1 ± 3.0	-4.0 ± 3.5	-5.2 ± 2.6	-1.250	-4.552	0.213	< 0.001
Preoperative LIVA (°)	-4.9 ± 2.3	-5.1 ± 2.5	-5.5 ± 2.6	-5.5 ± 2.4	-1.475	-0.901	0.142	0.369
Preoperative AVH% (°)	55.6 ± 11.8	57.0 ± 10.7	63.0 ± 10.9	65.0 ± 12.5	4.222	166	< 0.001	< 0.001
Preoperative PVH% (°)	84.1 ± 5.8	84.6 ± 5.2	86.1 ± 2.9	86.2 ± 2.7	2.745	2.607	0.007	0.010
Preoperative A/P% (°)	53.3 ± 11.6	54.4 ± 10.3	58.3 ± 8.9	59.4 ± 10.2	3.118	2.994	0.002	0.003
Preoperative VAS	6.5 ± 0.8	6.4 ± 0.7	6.1 ± 0.7	6.0 ± 0.8	-3.259	-2.688	0.001	0.008
Preoperative TLICS	6.5 ± 0.6	6.5 ± 1.2	6.5 ± 1.3	6.4 ± 0.5	0.034	-0.224	0.973	0.823
Preoperative LSC	6.2 ± 1.0	6.1 ± 1.2	5.7 ± 1.2	5.7 ± 1.1	-3.355	-2.079	0.001	0.039

Characteristic	KR Group	NKR Group	t/ χ^2 value	Pvalue
Notice: CA, Cobb angle; RA, regional angle; VWA, vertebral wedge angle; UIVA, upper intervertebral angle; LIVA, lower intervertebral angle; AVH%, anterior vertebra height ratio; PVH%, posterior vertebra height ratio; A/P%, anteroposterior ratio; VAS, visual analogue scale; TLICS, thoracolumbar injury classification and severity score; LSC, load-sharing classification.				

Results of multivariable logistic regression analysis showed two significant risk factors of KR before implant removal: age and BMI ($P < 0.001$, respectively). However, preoperative AVH% ($P = 0.008$) and preoperative PVH% ($P = 0.008$) were protective factors for KR (Table 2).

Table 2
Results of Logistic regression analyzing risk factors of kyphosis recurrence

Implant removal	Characteristics	B value	Wals value	P value	Exp (B) value	Nagelkerke R ² value	Total percent
Before	Age	0.391	16.331	< 0.001	1.479	0.867	96.4
	BMI	2.522	16.388	< 0.001	12.459		
	Preoperative AVH%	-0.2038	6.954	0.008	0.816		
	Preoperative PVH%	-1.246	11.207	0.001	0.288		
	Constant	35.044	3.765	0.052	1.657x10 ¹⁵		
After	BMI	0.811	33.287	< 0.001	2.250	0.611	82.1
	Preoperative AVH%	-0.086	15.687	< 0.001	0.918		
	Constant	-13.380	18.419	< 0.001	< 0.001		

Notice: BMI, body mass index; AVH%, anterior vertebra height ratio; PVH%, posterior vertebra height ratio.

The ROC curve and the area under the curve (AUC) were used to analyze the predictability of the risk factors. The results showed that age (threshold value = 49.0, AUC = 0.828), BMI (threshold value = 24.0, AUC = 0.846) were good predictors; however, the predictabilities of preoperative AVH% (threshold value = 49.5, AUC = 0.348) and preoperative PVH% (threshold value = 85.5, AUC = 0.423) were unsatisfactory (Table 3).

Table 3
Results of ROC curve analyzing risk factors of kyphosis recurrence

Implant removal	Characteristics	Area under the curve	Cut-off value	Sensitivity	1-specificity	Youden index
Before	Age	0.828	49	0.769	0.200	0.646
	BMI	0.846	24.0	0.846	0.267	0.579
	Preoperative AVH%	0.348	49.5	0.615	0.933	-0.318
	Preoperative PVH%	0.423	85.5	0.385	0.667	-0.282
After	BMI	0.871	25.17	0.684	< 0.001	0.684
	Preoperative AVH%	0.317	61.5	0.3685	0.778	-0.409

Notice: BMI, body mass index; AVH%, anterior vertebra height ratio; PVH%, posterior vertebra height ratio.

3.3 Risk factors of postoperative KR after implant removal

The average correction loss after implant removal was $7.5 \pm 4.4^\circ$. Kyphosis reoccurred in 114(67.9%) patients (Fig. 2). There were significant differences between KR group and NKR group in the number of females, age, BMI ($P < 0.001$, respectively), the number of cases with preoperative AVH%, preoperative UIVA, preoperative AVH% ($P < 0.001$, respectively), diabetes mellitus ($P = 0.021$), preoperative A/P% ($P = 0.002$), preoperative VAS ($P = 0.008$), preoperative PVH% ($P = 0.007$), preoperative PVH% ($P = 0.010$), preoperative A/P% ($P = 0.003$), and preoperative LSC ($P = 0.039$) (Table 1).

Results of multivariable logistic regression analysis showed two significant risk factors of KR after implant removal: BMI ($P < 0.001$) and AVH% ($P = 0.008$). However, preoperative AVH% was a protective factor for KR (Table 2).

The ROC curves showed that BMI (threshold value = 25.17, AUC = 0.871) was a good predictor; however, the predictability of preoperative AVH% (threshold value = 61.5, AUC = 0.317) was unsatisfactory (Table 3).

4. Discussion

During daily activities, spinal posture and thoracic kyphosis influence the load distribution in vertebral body; repetitive cyclic loading will cause collapse of fractured vertebral body; these can lead to thoracolumbar kyphosis [11]. It has been reported postoperative KR may be of greater significance than postoperative vertebral body re-collapse [12, 13]. Therefore, our study analyzed the risk factors of postoperative KR. Our study showed that correction loss progressed most rapidly within 12 months after

surgery; correction loss progressed much slowly after implant removal. Therefore, it's necessary to separately discuss the risk factors of KR before or after implant removal.

Previous studies showed that age will primarily affect bone remodeling toward resorption; this was because vertebral body contained numerous trabecular bone [14, 15]. All these studies supported our results that age > 49 years was a risk factor of KR before implant removal. There was a lack of studies on the correlation between BMI and KR. Our study showed that BMI > 24.0 was a risk factor of KR before implant removal; BMI > 25.17 was a risk factor of KR after implant removal; these implied that BMI works differently at different stages after surgery. Bone healing of fractured vertebra has not been fully achieved before implant removal [16]. Therefore, a high BMI will increase the load on instruments and even lead to the deformation of implants. The fractured vertebra has healed after implant removal; therefore, the KR after implant removal may be mainly caused by the loss of UIVA correction; in this period, a higher BMI with longer action time is needed to result in space collapse, reduction of buffering capacity and degeneration of upper intervertebral discs [17]. Chung et al. [18] reported that diabetes mellitus could increase the risk of fragility fractures, which was often associated with osteoporosis. Our study showed that diabetes mellitus was not a risk factor of KR. This was because the most thoracolumbar fractures of patients with diabetes mellitus involved more than one vertebra, which was much severer than single-level thoracolumbar burst fractures. According to the inclusion and exclusion criteria, our study included a small number of patients with diabetes mellitus, which might influence our results.

Fractured endplates and nucleus pulposus were intruded into fractured vertebral body during burst fracture; this could result in collapse of the cancellous framework in the vertebral body [12]. During SSPI-f, annulus fibrosus of the collapsed intervertebral disc was distracted; then the wall of fractured vertebral body was reduced by the annulus fibrosus attached to the periphery of the endplate; however, because the annulus fibrosus was not sufficiently attached to the center of the endplate, the fragmented nucleus, endplates and collapsed cancellous framework were not sufficiently reduced [12]. Similarly, our study showed that AVH% > 49.5%, PVH% > 85.5% were protective factors of KR before implant removal. This was because low AVH% and low PVH% usually meant a severer vertebral body compression. These would lead to large bone defect created inside the fractured vertebra after reduction, which had been reported as an important reason of internal fixation failure and KR [19]. Additionally, the results in our study showed that AVH% > 61.5% was a protective factor of KR after implant removal, which implied that the loss of anterior vertebra height had a long-term impact on therapeutic effect. Preoperative CA, RA and VWA were not the risk factors of KR in our study. The possible explanation might be that thoracolumbar burst fractures usually involved anterior and posterior columns, both anterior and posterior walls of vertebra were fractured; therefore, compared with vertebra height, the variation of vertebra angle could not accurately reflect the severity of thoracolumbar burst fractures [20].

The fractured endplates and nucleus pulposus were intruded into the fractured vertebral body during burst fracture, which would result in collapse of the cancellous framework in the vertebral body [21]. Similarly, Oner et al. [22] reported that even with the fracture of end plates, the upper discs were intact in most of the patients. It could be seen from the trend of parameters in our study that the loss of correction

caused by the collapse of upper intervertebral disc of fractured vertebra was a slow process, which was not due to the adjacent disc injured by direct high-energy violence. Therefore, superior endplate fracture, the decrease of preoperative UIVA and preoperative LIVA were not the risk factors of KR.

Our results showed that preoperative VAS score could not be used to predict the risk of KR. The reason was that VAS score had strong subjectivity with many influence factors, which made its accuracy limited [3, 6]. Pellise et al. [23] pointed out that LSC score was positively correlated with correction loss. However, our study showed that LSC score was not a risk factor of KR. The possible explanation might be that most of the previous studies discussed the curative effect of skip-level fixation without inserting additional screws into the fractured vertebra. Our study analyzed the treatment effect of SSPI-f, which could increase stiffness and reduce the failure rate of instrumentation with the insertion of two screws in the fractured vertebra; this seemed to reduce the influence of LSC score on the treatment effect [19]. TLICS was comprehensive not only in determining injury prognosis, but also in guiding treatment [24]. Our study found that TLICS was not a risk factor of KR. The reason might be that the mean TLICS was more than 4 points in our study; the fractured vertebrae of patients with higher TLICS were highly unstable, which was usually treated with long-segment fixation and should be excluded from our research.

There were limitations in our study. First, it was a retrospective study that developed the detailed prediction model; however, our study was a multi-center study with strict inclusion and exclusion criteria, which was more meaningful compared with prior risk factor analysis. Second, magnetic resonance imaging (MRI) was not fully discussed in our study, which made the evaluation of soft tissue around fractured vertebra very difficult; this might lead to the omission of significant risk factors.

5. Conclusion

Our study proved that the effectiveness of SSPI-f in the treatment of thoracolumbar burst fractures was good; the correction loss was mainly found within 12 months after surgery. Therefore, patients should be carefully followed up within 1 year after surgery. There were significant differences in the risk factors of KR at different postoperative follow-up stages. Patients who have older age (> 49 years), higher BMI (> 24), lower AVH% ($< 49.5\%$) and lower PVH% ($< 85.5\%$) were more likely to suffer from KR before implant removal. These patients should be properly treated with conservative methods, such as wearing braces and doing rehabilitation exercises, to actively prevent the occurrence of KR before implant removal. KR before implant removal is more likely to occur in patients with higher BMI (> 25.17) and lower AVH% ($> 61.5\%$). In such patients, the removal time of internal fixation should be extended. Patients with poor physical conditions should maintain the internal fixation without removal. Among all these predictive factors, age and BMI were the most accurate factors.

6. Abbreviations

SSPI-f = short-segment pedicle instrumentation with screw insertion in the fractured vertebra, KR = the recurrence of kyphosis, AVH% = anterior vertebra height ratio, ROC = curve: receiver operating characteristic curve, TLICS score = Thoracolumbar Injury Classification and Severity score, BMD = bone mineral density, CT = computed tomography, NKR = none recurrence of kyphosis, CA = Cobb angle, RA = regional angle, VWA = vertebral wedge angle, AVH% = anterior vertebral height ratio, AVH0 = anterior height of the fractured vertebra, AVH1 = anterior height of the upper adjacent vertebra, AVH2 = anterior vertebral height of the lower adjacent vertebra, PVH% = posterior vertebral height ratio, PVH0 = percentage of posterior height ratio of the fractured vertebra, PVH1 = posterior height of the upper adjacent vertebra, PVH2 = posterior height of the lower adjacent vertebra, A/P% = anteroposterior ratio, UIVA = upper intervertebral angle, LIVA = lower intervertebral angle, VAS = Visual Analogue Scale, LSC score = Load Sharing Classification score, BMI = body mass index, OR = odds ration, CI = confidence interval, AUC = area under the curve, SE = superior endplate, IE = inferior endplate, UAV = upper adjacent vertebra, LAV = lower adjacent vertebra.

7. Declarations

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Compliance with Ethical Standards:

Ethics Committee of the Xuanwu Hospital Capital Medical University approved this study. The approval number is Clinical study review [2018] 021. Written informed consent of each patient was obtained prior to the study. All patients included in the study provided their informed consent at enrolment on the use of patients' data for research.

Conflict of interest statement:

The authors declare that they have no conflict of interest.

Authors' contributions:

XS, WS, HH and WW were responsible for designing the search strategy, evaluating the articles and writing this article. TTZ and CK were responsible for English editing. SS was responsible for designing the protocol. SL was responsible for interpreting results.

Availability of data and materials:

Please contact author for data requests.

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Figures

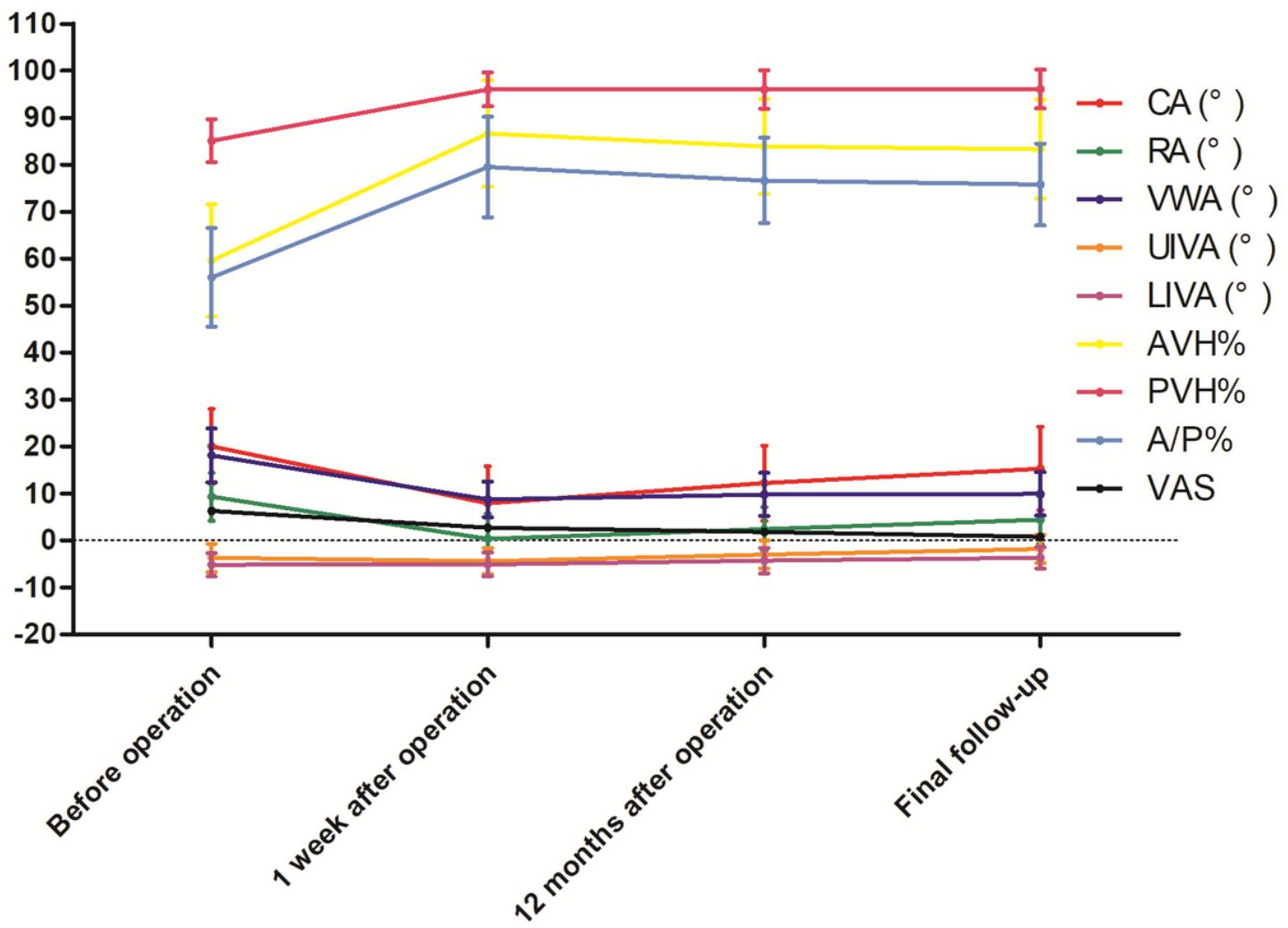


Figure 1

The trend of clinical and radiological parameters in patients with thoracolumbar burst fracture

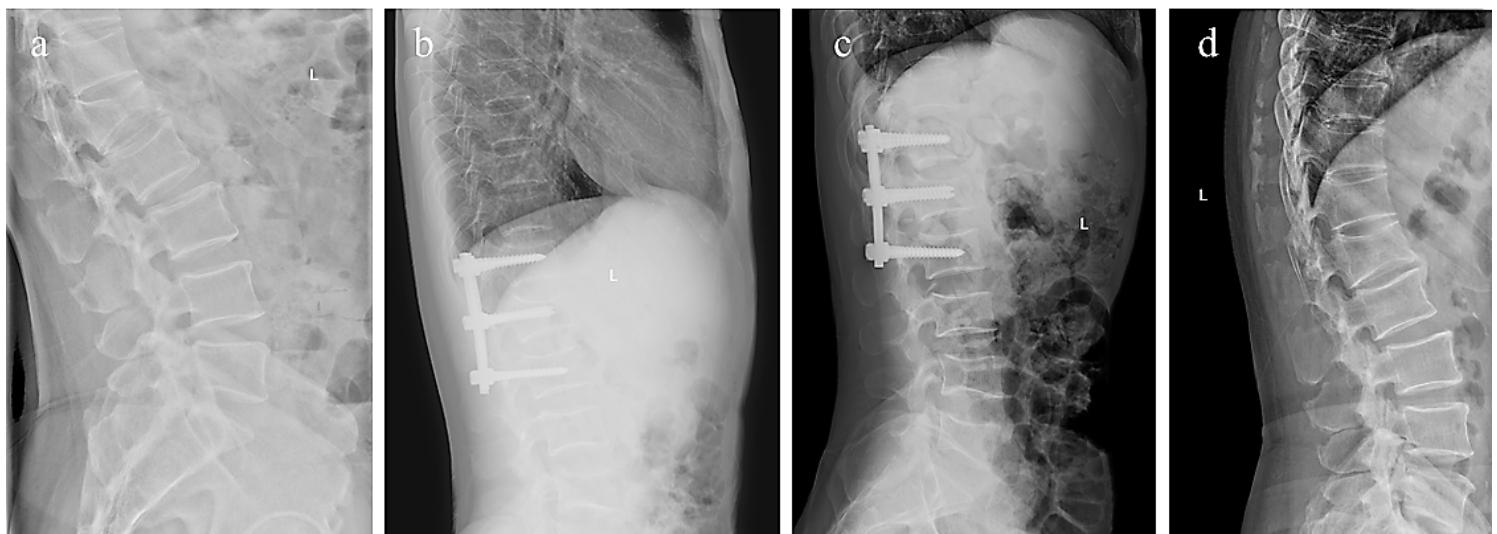


Figure 2

Radiographs of 39 years old male patient was obtained. (a) The preoperative Cobb angle (CA) of fractured segments was 27° . (b) one week after operation, the CA was 8° . (c) CA was 11° before the operation. (d) CA was 21° at last follow-up.