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Imaging parameters and clinical significance of posterior ligament complex injury in thoracolumbar fracture

Zhiquan Guo, BD[a,*], Shouliang Shi, BD[a], Feifei Liu, BD[a], Ligong Wang, MD[a], Yunli Shi, BD[a], Xiaofang Peng, MD[a], Lei Zhang, BD[a], Chunsheng Liu, BD[a], Yingjie Liu, BD[a]

Abstract

This study aims to investigate whether the combination of radiographs and computed tomography (CT) images can be used as an alternative means of magnetic resonance imaging examination or a preliminary screening method before examination, so as to improve the accuracy of determining the degree of posterior ligament complex injury in thoracolumbar fracture patients. From May 2011 to May 2019, the patients with thoracolumbar fracture were collected. A total of 150 patients were enrolled. The reference standard was 1.5T magnetic resonance imaging examination and lipid suppression sequence was applied. All radiographs and CT imaging results were measured in the Picture Archiving and Communication System workstation. The upper endplate angle and lower endplate angle, the percentage of vertebral height drop, the difference of inter-spinous process distance on CT images and the translation distance were statistically significant between the 2 groups ($P < .05$). Receiver operating characteristic curve showed that the diagnostic performance was excellent (all area under the curve > 0.7). To sum, the results showed that endplate angle + inter-spinous process distance on CT images combination had relatively high-quality diagnostic value for posterior ligamentous complex injury in thoracolumbar fracture patients.

Abbreviations: CT = computed tomography, ISDFCT = inter-spinous process distance on CT images, $LOVBH_x$ = percentage of vertebral height drop, MRI = magnetic resonance imaging, PLC = posterior ligamentous complex, $SIEA_x$ = upper endplate angle.

Keywords: clinical significance, image parameters, posterior ligament complex injury, thoracolumbar fracture

1. Introduction

Biomechanical studies have shown that posterior ligamentous complex (PLC) plays a vital role in maintaining the stability of posterior column of the spine. With the gradual deepening of the understanding of the role of this structure, the integrity of PLC in the thoracolumbar fracture has become an important factor in deciding whether to operate. At present, the thoracolumbar injury classification and severity score, which guides the treatment of thoracolumbar fracture, takes the PLC injury or not as an important factor for the need for surgical intervention and has been widely used. At present, magnetic resonance imaging (MRI) is the most important means of examination for PLC injury. However, the prevalence rate of MRI in China is still insufficient. The missed diagnosis and misdiagnosis of PLC injury in primary hospitals seriously affect the prognosis of patients with thoracolumbar fracture. There are contraindications of MRI examination in some patients, so MRI examination cannot be performed.[1–5]

This study aims to explore whether the combination of X-ray film and computed tomography (CT) image can be used as an alternative means of MRI examination or a preliminary screening method before examination, so as to improve the accuracy of judging the PLC injury degree of patients with thoracolumbar fracture. In this paper, we firstly conduct anatomy on solid specimens to comprehensively understand and verify the structural characteristics of the thoracolumbar PLC, and analyze the injury mechanism of various types of thoracolumbar PLC injury and its influence on spinal stability. On this basis, several cases of patients with PLC injury of thoracolumbar fracture in our hospital from May 2011 to May 2019 were included and analyzed. The characteristics of preoperative X-ray, CT and MRI imaging findings were summarized and verified with the results of surgical exploration and neurological function damage. The specificity and sensitivity of X-ray, CT and MRI for the diagnosis of posterior ligamentum complex injury were comprehensively compared, and the orthopedic imaging parameters with significant statistical significance were obtained. Then, the results of surgical exploration were taken as the reference standard to compare the X-ray, CT, and MRI imaging features of patients with complete fracture of posterior ligamentum complex with partial injury

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The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

[a] Department of Radiology, The Second Hospital of Tangshan City, Tangshan, Hebei, China.

** Correspondence: Zhiquan Guo, Department of Radiology, The Second Hospital of Tangshan City, Tangshan, Hebei 063000, China (e-mail: zhiquanguo998@163.com).*

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and integrity. To evaluate the correlation between changes in imaging parameters and PLC injury after thoracolumbar fracture, select parameters with statistically significant differences for effective combination, use statistical tools to analyze and evaluate the diagnostic value of various combinations for PLC injury, find out the optimal combination, and provide a strong reference basis for clinical preliminary screening. Combined with the characteristics of vertebral and PLC injury to guide clinicians to the reasonable selection of treatment methods.

2. Materials and methods

2.1. General information

Patients with thoracolumbar fracture who were treated in the spinal surgery department of our hospital from May 2011 to May 2019 were collected. The inclusion criteria were: cases of thoracic or lumbar fracture; a clear history of trauma; X-ray, CT, and MRI examinations were completed within 5 days. Exclusion criteria: pathological fracture or old vertebral fracture; congenital or degenerative scoliosis; spinous process fracture of injured vertebra or its adjacent vertebra; typical or atypical chance fracture; fractures with obvious dislocation or rotation of the vertebral body; and 2 or more vertebral fractures. A total of 150 patients were enrolled. There were 85 males and 65 females, the age ranged from 16 to 67 (44.7 ± 16.7) years old. With regard to the injury types, 88 cases were injured by traffic, 43 by falling from height and 19 by crushing. With regard to the fracture site, 39 cases of thoracic vertebra, 71 cases of thoracolumbar, and 40 cases of lumbar vertebra. The study was approved by the Ethics Committee of the Second Hospital of Tangshan City and conducted in accordance with the Declaration of Helsinki.

2.2. PLC judgment standard

The reference standard was 1.5T MRI examination and lipid suppression sequence was applied. The PLC with high signal and black band interruption in the lipid suppression image and the involvement of the supraspinous ligament was considered to be completely or almost completely broken, which was defined as PLC integrity destruction. Patients were divided into 2 groups based on this criterion, one with intact or partial PLC damage (group A) and the other with complete PLC rupture (group B). It was determined by a radiologist and an orthopedist with good agreement.

2.3. Imaging parameter measurement methods

All radiographs and CT imaging results were measured in the Picture Archiving and Communication System workstation, measured by 2 orthopedic surgeons. The following parameters are measured on the basis of X-ray films and sagittal CT images: superior and inferior endplate angle (SIEA): the included angle of the extension line of the upper and lower endplate of the injured vertebral body; local kyphosis angle: the angle between the extension line of the upper endplate of the upper vertebral body and the extension line of the lower endplate of the lower vertebral body; loss of vertebral body height: the percentage of vertebral anterior margin decline in vertebral posterior margin height; vertebral translation distance: the vertical distance between the vertex of the upper posterior angle of the injured vertebral body and the tangent line of the lower posterior edge of the upper vertebral body; laminar distance: the distance between the superior edge of the injured vertebral body and the superior edge of the other vertebral body; inter-laminar distance: the distance between the upper edge of the injured vertebra and the lower edge of the injured vertebra; inter-spinous distance (ISD): the distance of the upper spinous process of the injured vertebra; and ISD difference (ISDF): the difference of the distance between the spinous process of an injured vertebra and that of a normal vertebra.

2.4. Statistical analysis

SPSS 22.0 software was used for statistical analysis. Normally distributed quantitative data are expressed as mean ± standard deviation. Independent samples t test was conducted for data meeting normality, and rank sum test was used for data not meeting normality. $P < .05$ was considered statistically significant. The predicted probability was taken as the analysis index, and SPSS 22.0 software was used to construct receiver operating characteristic (ROC) curve, determine the optimal critical value, calculate the corresponding sensitivity, specificity and Youden index of each combination, and compare the area under the curve.

3. Results

The measurement results of X-ray and CT imaging parameters in the 2 groups are shown in Tables 1 and 2. The percentage of vertebral height decline was measured on X-ray films, the local kyphotic angle, the percentage of vertebral height decline, and the distance between spines met the normal condition were measured on CT images. The upper endplate angle ($SIEA_X$) and lower endplate angle, the percentage of vertebral height drop ($LOVBH_X$), the difference of inter-spinous process distance on CT images ($ISDF_{CT}$) and the translation distance were statistically significant between the 2 groups ($P < .05$) (Tables 1 and 2). ROC curve was performed to evaluate the diagnostic performance, the diagnostic value of each parameter as shown in Table 3. The diagnostic value of different combination schemes as shown in Table 4. The area under the curve was compared by using Medcale 15.10 software. The z test showed that $SIEA_X + ISDF_{CT}$ was compared with $LOVBH_X + ISDF_{CT}$ and $LOVBH_X + SIEA_X$, and the difference was statistically significant ($z = 1.966$, $z = 2.051$). The combination of $SIEA_X + ISDF_{CT}$ and $LOVBH_X + SIEA_X + ISDF_{CT}$ showed no statistically significant difference ($z = 0.518$). The combination of $SIEA_X$, $LOVBH_X$, and $ISDF_{CT}$ were used to conduct ROC curve, and the results were shown in Figure 1.

Table 1

Parameter measurement results on X-ray plate.

Group	PLC complete rupture group (n = 63)	PLC intact or partial injuries group (n = 87)
The local kyphotic angle (°)	21.40 ± 10.11	18.93 ± 7.49
The superior and inferior endplate angle (°)	23.89 ± 8.50	16.47 ± 6.28*
Loss of vertebral body height	49.41 ± 19.78	32.41 ± 13.88*
Translation distance (mm)	3.32 ± 0.71	2.16 ± 0.37*

PLC = posterior ligamentous complex.

* Compared with PLC complete rupture group, $P < .01$.

Table 2

Parameter measurement results on CT images.

Group	PLC complete rupture group (n = 63)	PLC intact or partial injuries group (n = 87)
The local kyphotic angle (°)	19.41 ± 9.52	16.72 ± 8.37
The superior and inferior endplate angle (°)	22.48 ± 10.08	16.15 ± 7.19*
Loss of vertebral body height	40.41 ± 18.96	35.52 ± 15.78
Translation distance (mm)	3.27 ± 0.83	2.15 ± 0.39*
Laminar distance (mm)	31.18 ± 3.11	30.33 ± 3.57
Inter-laminar distance (mm)	17.89 ± 9.43	16.71 ± 10.18
Inter-spinous distance (mm)	11.44 ± 3.20	10.77 ± 2.20
Inter-spinous distance difference (mm)	3.31 ± 2.08	1.36 ± 1.87*

CT = computed tomography, PLC = posterior ligamentous complex.
* Compared with PLC complete rupture group, $P < .01$.

Table 3

Diagnostic value of the three methods for PLC damage.

Measured parameters	Cut off points	Sensitivity (%)	Specificity (%)	Area under ROC-curve (95%CI)	Youden index
$SIEA_X$	20.1	80.6	79.2	0.776 (0.663–0.904)	0.572
$LOVBH_X$	45%	62.8	83.6	0.735 (0.598–0.849)	0.458
$ISDF_{CT}$	2 mm	76.3	79.6	0.748 (0.643–0.871)	0.539

$ISDF_{CT}$ = inter-spinous process distance on computed tomography images, $LOVBH_X$ = the percentage of vertebral height drop, PLC = posterior ligamentous complex, ROC = receiver operating characteristic, SIEAx = upper endplate angle.

Table 4

Diagnostic value of different combinations of methods on PLC damage.

Measured parameters	Cut off points of prediction probability	Sensitivity (%)	Specificity (%)	Area under ROC curve (95%CI)	Youden index
SIEAx + $LOVBH_X$	0.379	79.8	82.2	0.828 (0.675–0.909)	0.578
SIEAx + $ISDF_{CT}$	0.403	76.1	85.4	0.783 (0.746–0.942)	0.668
$LOVBH_X$ +$ISDF_{CT}$	0.338	75.7	86.1	0.790 (0.732–0.919)	0.537
SIEAx + $LOVBH_X$ +$ISDF_{CT}$	0.426	75.6	90.5	0.836 (0.751–0.946)	0.655

$ISDF_{CT}$ = inter-spinous process distance on computed tomography images, $LOVBH_X$ = the percentage of vertebral height drop PLC = posterior ligamentous complex, ROC = receiver operating characteristic, SIEAx = upper endplate angle.

4. Discussion

Biomechanical studies on PLC show that complete PLC can protect the spine and spinal cord to some extent. At present, thoracolumbar injury classification and severity scores, which are widely used to guide the treatment of thoracic lumbar fractures, include PLC integrity into the scoring items. When PLC integrity is 0 point, suspicious injury is 2 points, and fracture is 3 points. When the total score reaches 4 points, surgical treatment should be considered. Therefore, the integrity of PLC plays an important role in determining the treatment plan for patients with thoracolumbar fractures.[6–8]

Since the concept of PLC was proposed in 1963, its role in the classification, treatment and surgical selection of thoracolumbar fractures has been paid more and more attention by the majority of scholars. The posterior ligament structure or bone structure of the spine is damaged, which is an unstable fracture. Anterior or middle column injuries that are accompanied by posterior column fractures such as laminae or PLC injuries show significant spinal instability. CT examination of spinal fractures has presented a relatively mature fracture classification method. The injury mechanism of the PLC is complex, the diagnosis of this disease follows the procedures and steps of the general disease diagnosis, and the anatomy, injury mechanism, and injury types of the PLC must be understood. The diagnosis rate of pure X-ray or CT imaging examination is low, which should be combined with MRI imaging examination. At present, the domestic research on the PLC injury is still in the preliminary stage, the research sample is small, and there is a lack of authoritative classification. Through this study, the correlation between its anatomy, injury mechanism, post-injury imaging parameter changes and PLC injury was systematically understood, and a reasonable combination of imaging parameters was found to provide a strong reference for clinical preliminary screening.[9–14]

At present, the diagnosis of PLC injury mainly relies on MRI, because it has the best resolution of soft tissue injury. The sensitivity of MRI was the highest at 98.5%, while in other studies, the sensitivity of MRI ranged from 80.8% to 91%. The high signal of PLC in the lipid suppression image is the damage. Although the sensitivity is high, the specificity is only 68.4%. Other researchers applied a new standard. They considered the presence of instability only when MRI lipid suppression images involved the supraspinous ligament with high PLC signal and black band interruption, and defined it as PLC integrity failure. Prospective studies have shown that MRI has a sensitivity of 91% and a specificity of 100% for PLC damage detection. This study made reference to the results of other scholars to establish MRI reference standards. However, MRI has its shortcomings that cannot be ignored: first, the popularity rate in our country is still insufficient, in some county and town hospitals there is no MRI or poor imaging quality, it is difficult to accurately judge the PLC damage. Because the appointment time of examination is long, if the patient cannot perform MRI examination within 5 days, it may cause false negative due to the decrease of signal intensity. Secondly, some patients with severe disease or contraindications of MRI examination cannot be performed. If

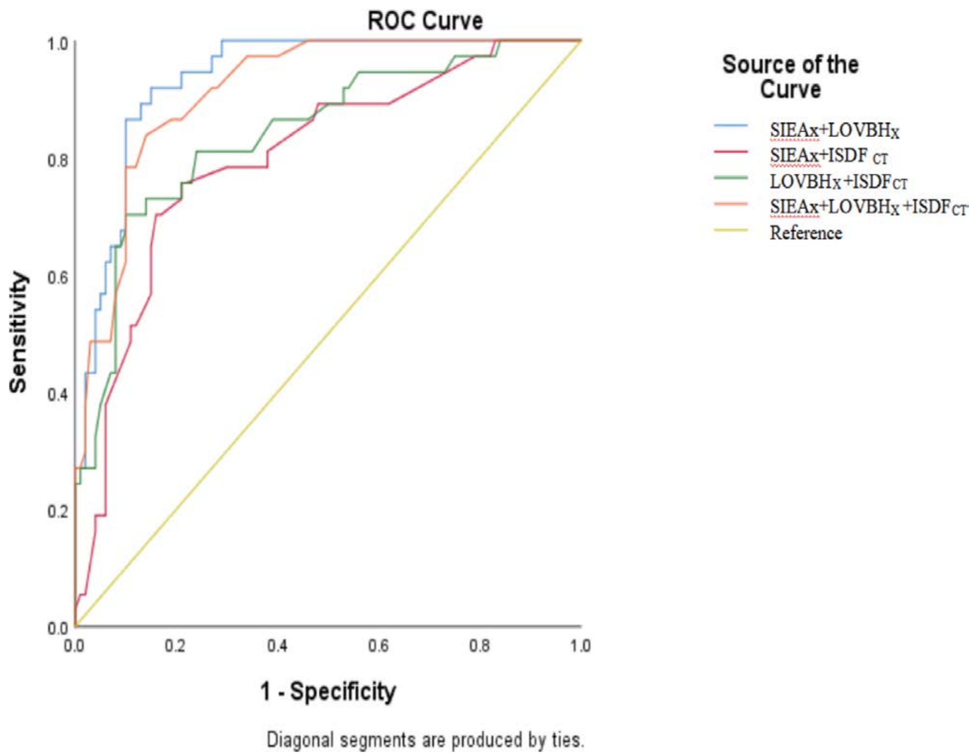

Figure 1. ROC curve of DF_{CT} combination, $SIEA_X$, $LOVBH_X$ and $ISDF_{CT}$. DF_{CT} = , $ISDF_{CT}$ = inter-spinous process distance on computed tomography images, $LOVBH_X$ = the percentage of vertebral height drop, ROC = receiver operating characteristic, $SIEA_X$ = upper endplate angle.

rapid and effective initial screening diagnosis can be carried out at an early stage, it will provide a reliable basis for early diagnosis and intervention strategy formulation, and thus improve the prognosis of patients.[15–17] As a fast, cheap, and easily available means of examination, combined X-ray film and CT were first used in the prediction of PLC damage. Different scholars come to different conclusions.

This study firstly understood and verified the structural characteristics of the thoracolumbar PLC and analyzed the injury mechanism of various types of thoracolumbar PLC injury and its influence on spinal stability. On this basis, a number of patients with thoracolumbar fracture PLC injury in our hospital from May 2011 to May 2019 were retrospectively analyzed. The specificity and sensitivity of X-ray, CT and MRI for the diagnosis of posterior thoracolumbar ligament complex injury were comprehensively compared, and the orthopedic imaging parameters with significant statistical significance were obtained. The correlation between the changes of imaging parameters and PLC injury after thoracolumbar fracture was evaluated, and the parameters with statistically significant differences were selected for effective combination to find out the optimal combination.

In conclusion, SIEA on X-ray and ISDF on CT images can be used as the primary screening criteria for PLC complete fracture. However, the number of cases included in this study was insufficient; it is necessary to further expand the sample size for verification.

Author contributions

Conceptualization: Ligong Wang, Yunli Shi, Xiaofang Peng, Yingjie Liu.
Data curation: Ligong Wang, Yunli Shi, Xiaofang Peng, Yingjie Liu.
Formal analysis: Ligong Wang, Yunli Shi, Xiaofang Peng, Yingjie Liu.
Funding acquisition: Ligong Wang, Yunli Shi, Xiaofang Peng, Chunsheng Liu, Yingjie Liu.
Investigation: Feifei Liu, Ligong Wang, Yunli Shi, Xiaofang Peng, Lei Zhang, Chunsheng Liu, Yingjie Liu.
Methodology: Feifei Liu, Ligong Wang, Yunli Shi, Xiaofang Peng, Lei Zhang, Chunsheng Liu, Yingjie Liu.
Project administration: Feifei Liu, Xiaofang Peng, Lei Zhang, Chunsheng Liu, Yingjie Liu.
Resources: Feifei Liu, Lei Zhang, Chunsheng Liu.
Software: Zhiquan Guo, Feifei Liu, Chunsheng Liu.
Supervision: Zhiquan Guo, Shouliang Shi.
Validation: Zhiquan Guo, Shouliang Shi.
Visualization: Zhiquan Guo, Shouliang Shi.
Writing – original draft: Zhiquan Guo, Shouliang Shi.
Writing – review & editing: Zhiquan Guo, Shouliang Shi.

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