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ORIGINAL STUDY

Radiographic Features Associated with Neurological Deficit in Thoracic and Lumbar Spine Fractures

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Abstract

Background: The thoracic and lumbar spine are the two most commonly fractured regions in the vertebral column. The role of various radiographic parameters in surgical decision-making is still controversial, with many studies trying to define thoracolumbar fracture stability by correlating it to the various radiographic parameters. This prospective cross-sectional study aims to extrapolate the relationship between neurological deficit and radiographic parameters in this cohort of patients.
Methods: We included patients with thoracolumbar fractures presenting to our emergency department between November 2018 and October 2019. Neurological deficit was reported according to the American Spinal Injury Association (ASIA) score. Radiographic evaluation included plain radiographs and computerized tomography (CT) scans. Radiographic parameters, including anterior vertebral height (AVH), middle vertebral height (MVH), posterior vertebral height (PVH), canal compromise (CC), and sagittal alignment using Cobb's angle, were measured.
Results: In total, 160 patients were included, with an average age of 35.01 ± 14.36 years. Moreover, 122 patients (76.2%) were neurologically free, and 38 (23.8%) had a neurological deficit. Neurological deficits showed a statistically significant difference between single and multiple fractures patients. Regarding the regression analysis, the Cobb angle statistically affects the ASIA score ($t = -3.64$; $p < 0.001$). Additionally, at 23.5%, the CC had 72% sensitivity and 70% specificity in predicting the neurological deficit.
Conclusion: The Cobb angle is the strongest predictor of neurological deficit. This parameter can be crucial in predicting neurological deficits in relevant clinical situations.

Keywords: Thoracolumbar spine, Spinal trauma, Radiographic parameters, Neurological deficit, Cobb angle

Introduction

The overall incidence of thoracic and lumbar fractures in all trauma patients is 6.9%, and 26.5% of these patients sustain a spinal cord injury [1]. Thoracic and lumbar spine injuries follow a standard distribution along the vertebrae in all age categories, with injuries most common at the thoracolumbar junction and rarely in the upper thoracic spine [2, 3].

The value of radiographic parameters affecting stability, consequently affecting the neurological status of patients with thoracolumbar fractures, was widely discussed. However, defining the criteria of stability and these parameters still needs to be made public.

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Holdsworth et al. [4] considered burst fractures stable because although the anterior and middle columns may be squashed down, the posterior usually remains mechanically intact. On the contrary, Denis [5] concluded that all thoracic and lumbar burst fractures are unstable. He stated that the involvement of the middle column was a sufficient criterion for instability. Krompinger et al. [6], Reid et al. [7], and Cantor et al. [8] stated that fractures without neurologic deficit, with kyphosis less than 30 degrees and height loss less than 50%, were defined as mechanically stable.

The main aim of the study was to determine which preoperative radiographic parameters are closely associated with vertebral fracture-induced neurological deficit in patients with thoracic and lumbar fractures. Consequently, these parameters can be used as an aid in surgical decision-making, especially in cases where an accurate neurological examination cannot be performed, for example, disturbed consciousness, lower extremity fractures, multiple-level spine fractures, preexisting neurological deficits, or peripheral neuropathy.

Patients and methods

A prospective cross-sectional study was conducted on 160 patients admitted to the emergency department of a level-one trauma center from November 2018 to October 2019. The study included skeletally mature patients (above 18 years old) with thoracic or lumbar spine fractures with or without neurological deficits. Patients suffering from preoperative neurological disorders that hinder proper neurological examination, like peripheral neuropathy or previous strokes, obtunded patients with disturbed levels of consciousness, and patients with fractures older than one month were excluded from the study. Additionally, patients with pathological or osteoporotic fractures (excluded based on the Hounsfield unit measured in CT scans) and those with type A0 fractures according to AO thoracolumbar fracture classification [9] were excluded from the study.

The sample size was calculated using Epi-Info 7 [10]. Based on a previous study by Meves et al. [11], the incidence of neurological deficit among thoracic and lumbar fracture cases was 23%. With confidence limits of 6% and a confidence level of 80%, the sample needed for the study was estimated to be about 81 cases. However, 160 cases met the inclusion criteria and were included during the study period. The Institutional Review Board (IRB) reviewed and accepted the study, and informed written consent was obtained from patients before enrollment.

Both radiographic and clinical parameters were subsequently evaluated. Radiographic evaluation included anteroposterior and lateral radiographs and computer tomography (CT) scans. The measured radiographic parameters were vertebral body compression measured by anterior, middle, and posterior vertebral height compression percentage (AVH, MVH, and PVH, respectively), canal compromise measured by canal compression percentage (CC), sagittal alignment measured by Cobb angle, and the type of fracture according to the AO classification. All parameters were digitally measured by RadiAnt®DICOM viewer [12] and Surgimap®measured CC [13]. In patients with multiple-level fractures, the level with the most severe injury type according to AO classification was selected for radiographic parameters measurement. Vertebral body compression percentage indicates the relative compression of the injured vertebra when compared to the adjacent vertebra, which was determined using a formula calculating the percentage of vertebral compression of the affected vertebra to the average vertebral height measured by the mean vertebral height of the vertebra cranial and caudal to the fractured one. This formula is as follows: vertebral height (VH) = $1–[V2/(V1+V3/2)] \times 100\%$. V2 is the VH at the fractured level, V1 is the VH at the above level, and V3 is the VH at the below level [14].

The compression percentage of CC is defined as the ratio of CC at the level of injury to the estimated average canal dimensions of the patient. The CC was calculated by measuring the cross-sectional area of the fractured vertebra relative to the mean cross-sectional area, calculated from the vertebra's cross-sectional area above and below (Fig. 1). Cobb's angle was measured between a line drawn parallel to the superior endplate of the vertebra cranial to the fractured one and a line drawn parallel to the inferior endplate of the vertebra caudal to the fracture [15]. Two independent reviewers (a senior spine surgeon and a radiologist) measured all the parameters and checked for interobserver reliability using the intraclass correlation coefficient (ICC). Neurological evaluation was reported according to the American Spinal Injury Association Impairment (ASIA) score [16].

Statistical analysis

Statistical analysis included descriptive statistics of patients' demographic and baseline data. Multivariable regression analysis was conducted between the radiographic parameters and the ASIA scale. Also, receiver operating characteristics (ROC) analysis was performed on the abovementioned parameters to determine their sensitivity, specificity, and cut-off point. Statistical significance was accepted at a P value of less than 0.05. Microsoft Excel 365®and SPSS®version 27 was used for data entry and statistical analysis.

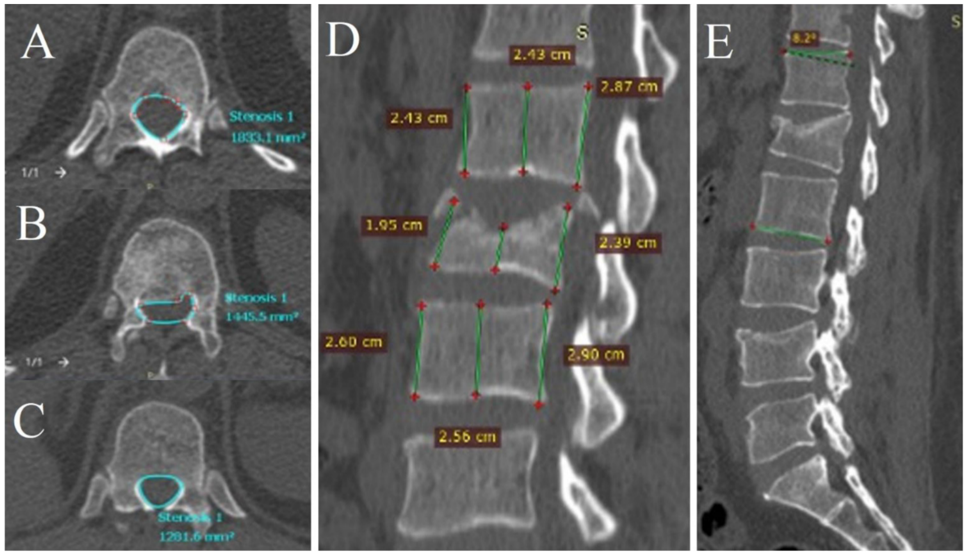

Fig. 1. MS CT scan images show the radiographic parameters measured by Surgimap Software. (A) The axial cuts of the vertebra cranial to the fracture, (B) the fractured vertebra, and (C) the vertebra caudal to the fracture. (D) A sagittal cut with the anterior vertebral height (AVH), middle vertebral height (MVH), and posterior vertebral height (PVH) as measured by RadiAnt software. (E) The sagittal alignment measured by the Cobb angle.

Results

Patient demographics and characteristics

Of the 283 patients who presented to the emergency department with thoracic and lumbar spine fractures between November 2018 and October 2019, 160 met the inclusion criteria, and 143 were excluded due to different exclusion criteria of our study. The mean age of patients was 35.01±14.36 years, ranging between 18 and 83 years; the majority (60%) were males. The most frequent pattern of trauma was falls from height (62.5%), followed by motorcar accidents (18.8%), falls downstairs (11.9%), motorbike accidents (5%), and hard object trauma.

In total, 122 patients (76.2%) were neurologically free, and 38 (23.8%) had a neurological deficit. L1 was the most frequent fractured vertebrae with 30 cases (18.75%), followed by L3 with 28 cases (17.5%), then L2 with 24 cases (15%), while the least frequent fractures were D3 and D5 (only two patients each). The majority (86.3%) of patients had single-level fractures, whereas 22 (13.8%) patients had multiple-level fractures. ASIA score was noticed to be high with type A1 (323.86 ± 12.45) and type A2 (308.88 ± 42.56), while the lowest AISA score was seen with type C (228.40 ± 85.43).

Neurological deficit was most evident at the thoracolumbar junction area (DV11-LV1), followed by lumbar vertebrae (LV2-LV5), then lower dorsal vertebrae (D6-D10), and the upper dorsal vertebrae (DV1–DV5). Neurological deficit was related to the number of fractured vertebrae as it was higher among those patients with single-level fractures than in patients with multiple-level fractures (309.51 ± 37.58 vs. 286.36 ± 72.01; p = 0.02) (Table 1).

Table 1. Summary of the patients' demographics and baseline characteristics (n = 160).

Parameters	Number (%)
Sex	
Male	96 (60)
Female	64 (40)
Mechanism of injury	
Fall from height	100 (62.5)
Motor car accident	30 (18.8)
Fall downstairs	19 (11.9)
Motorbike accidents	8 (5)
Hard object trauma	3 (1.8)
ASIA Score	
A	11 (6.9)
B	6 (3.7)
C	16 (10)
D	5 (3.1)
E	122 (76.2)
Level of injury	
D12	26 (16.25)
L1	30 (18.75)
L2	24 (15)
L3	28 (17.5)
Other levels	52 (32.5)
Type of fracture/(AO Classification)	
A1	60 (37.5)
A2	15 (9.4)
A3	46 (28.7)
A4	28 (17.5)
B1	3 (1.9)
B2	2 (1.3)
C	6 (3.8)

Table 2. Summary of the measured radiographic parameters.

Parameters	Mean ± standard deviation (SD)
Cobb angle in degrees/°	15.1 ± 8.84 (2–45)
Anterior vertebral height compression (AVH) percentage/%	30.12 ± 18.12 (8–72)
Middle vertebral height compression (MVH) percentage/%	29.82 ± 17.69 (6–76)
Posterior vertebral compression (PVH) millimetres/%	9.73 ± 13.08 (2–45)
Canal compromise (CC) percentage/%	28.49 ± 22.69 (0–48)

Radiographic parameters

The interobserver reliability using ICC showed good agreement for the Cobb angle, AVH, MVH, and PVH (0.78, 0.86, 0.81, and 0.89, $p < 0.001$). However, it showed moderate agreement for the CC (0.69, $p < 0.001$).

Multivariable regression showed that these radiographic parameters significantly affect neurological deficit ($F = 4.417$, $p = 0.001$, and $R^2 = 0.155$), suggesting that these radiographic parameters can predict 15.5% of the variation. The Cobb angle is the only significant predictor ($t = -3.64$, $p < 0.001$) with an adjusted odds ratio (OR) of 1.514 (Table 2).

The ROC analysis showed that out of the five radiographic parameters, the CC had the highest area under the curve (AUC) (AUC = 0.768). At a CC of 23.5%, it had a sensitivity of 72% and a specificity of 70% in detecting neurological deficits (Fig. 2).

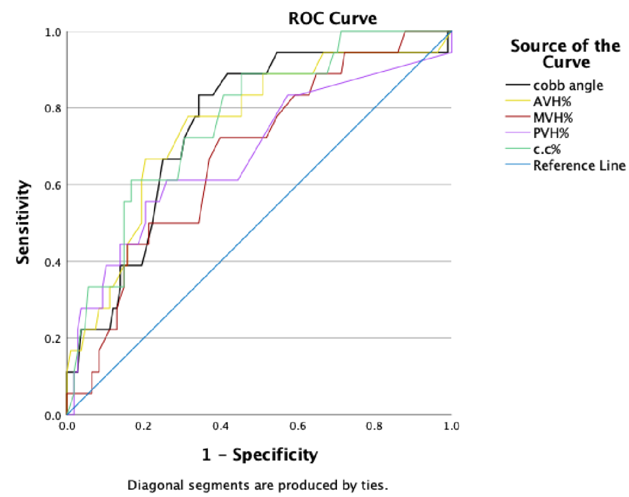

Fig. 2. ROC for the radiographic parameters. The CC had the highest area under the curve (AUC) (AUC = 0.768). At a CC of 23.5%, it had a sensitivity of 72% and a specificity of 70% in detecting neurological deficits.

Discussion

Many reports [9, 11, 17–19] were concerned about the correlation between CC and the severity of neural damage. However, only a few reports [20] discussed the correlation between different radiographic parameters like sagittal alignment, type of fracture, VH, and the severity of neurological damage. Furthermore, a few reports [21] measured CC by calculating the total canal cross-sectional area using a computer software program. Tang et al. [20] found a positive correlation between sagittal alignment (measured by Cobb angle) and neurological deficit in thoracolumbar fracture patients. This result concurs with the results of our study, as the Cobb angle was a significant predictor in the multivariate regression analysis with the ASIA score.

Our study used AVH, MVH, and PVH to measure vertebral compression. However, only the AVH showed a moderate correlation with the ASIA score, and the MVH and PVH were weakly correlated. The relationship between neurological deficit, sagittal alignment, and VH compression may be explained by the posterior ligamentous complex (PLC) injury, usually seen in fractures with a kyphosis angle of more than 30° and anterior height loss of more than 50% [22]. Additionally, the presence of PLC injury significantly influences the severity of nerve damage as its injury affects spine stability [23]. Therefore, the incidence of neurological deficit increases when the Cobb angle and AVH values increase as higher degrees of these factors are primarily associated with PLC affection [24].

When the spine is subjected to a high rate of axial loading, which is most evident in burst type, the impact produces a fracture that compromises the anterior and middle columns of the spine and subsequently drives a fragment of bone from the posterior wall of the vertebral body into the spinal canal [25, 26]. Many studies tried to find a relation between neurological deficit, spinal CC, or other parameters observed in CT. However, this relationship remains controversial. Fontiji et al. in 1992 [19], Tang et al. in 2016 [21], and Meves et al. in 2006 [11] reported a positive relationship between neurological deficit and CC in patients with thoracic and lumbar spine fractures. Also, Hashimoto et al. [17] measured 112 consecutive thoracolumbar burst fractures and found that there was a significant risk of neurologic injury as follows: at T11 to T12, there is a 35% risk of spinal injury; at L1, it is 45% and at L2 and below it is 55%. In 2001, Vaccaro et al. found the ratio of sagittal to the transverse diameter at the level of the injury to be significantly smaller in patients with neurologic deficits than in those who were neurologically intact [27]. On the contrary, Mohanty et al. [19] and Alpantaki K et al. [26] reported no relation between CC and neurological deficit in patients with thoracolumbar fractures. The findings are explained mainly by the biomechanical phenomenon described by Oxland et al. [28] who stated that encroachment was higher at the times of injury than the posttraumatic static state, which is shown on CT and later showed by high-speed video analysis by Hall and Wilcox et al. [29]. Several in vitro studies have been conducted to show the dynamic behaviour of the fracture-produced fragments [25, 29]. Results from these studies demonstrated that the final position of the fragment, which is the position observed on CT scans, has little correlation with maximum transient canal occlusion and the degree of neurological deficit.

One of the most important clinical implications of this study is predicting neurological injury in patients with thoracic and lumbar spine fractures who cannot be adequately examined. Examples of these patients are those with previous neurological deficits or peripheral neuropathy or patients with disturbed levels of consciousness or the presence of lower extremity fractures.

There are a few limitations to this study. The first limitation was the effect of patient positioning for the radiograph because loading can cause significant changes, as suggested by many studies [30]. Therefore, radiographic images should always be obtained upright or weight-bearing, which is difficult in acute trauma patients. Additionally, for predicting neurological deficit, we reported a low CC compression ratio, which can be explained by the inclusion of both thoracic and lumbar spine fractures in the study, which had different canal dimensions and a lower threshold for neurological deficit in the thoracic spine compared to the lumbar spine due to the distinct nature of the involved neurological tissues (spinal cord in the thoracic spine versus cauda equina in the lumbar spine). Last, measuring the kyphotic deformity by measuring the sagittal index would be more conventional as a universal parameter as it considers the differences in curvature across different spine regions.

Conclusion

Our results emphasize that the Cobb angle is the strongest individual predictor of neurological deficit. These parameters can be crucial in predicting neurological deficits in relevant clinical situations.

Ethical information

The manuscript submitted does not contain information about medical device(s)/drug(s).

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Conflict of interest statement

The authors declare that they have no conflicts of interest to disclose.

Abbreviation list

AO	Arbeitsgemeinschaft für Osteosynthesefragen
ASIA	American Spinal Injury Association
AUC	Area under the curve
AVH	Anterior vertebral height
CC	Canal compromise
CT	Computerized tomography
MVH	Middle vertebral height
PLC	Posterior ligamentous complex
PVH	Posterior vertebral height
ICC	Intraclass correlation coefficient
ROC	Receiver operating characteristic
VH	Vertebral height

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