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Research Article

Validity of radiographic measurements in classification of Thoracolumbar injuries: Statistical analysis

Abstract

Introduction: Although there are many classification systems for assessing the thoracolumbar injuries, it is of paramount importance to make the right clinical decision in treatment of thoracolumbar injuries is to precisely measure the radiographic vertebral parameters. Previous reports described the various radiologic parameters and the measuring techniques. The available radiologic parameters assess the following parameters in the injured spine: Sagittal alignment, vertebral body compression, and spinal canal dimensions. Another problem is different measuring techniques for those parameters which add more confusion in data collection that reflect on the decision making.

Aim: In this study, we criticize the role of the three columns theory in classification of thoracolumbar injuries, if the number of the columns affected correlate with the fracture type, instability and management results. Also, if the measured radiologic parameters from the lateral view of injured vertebra correlate with the type of the fracture.

Material and Methods: In this retrospective quantitative case study, X-rays, CTs and MRI of thoracolumbar injured spine in 74 patients in the period from 2012 to 2016 were evaluated. Pathologic spinal fractures or vertebral appendices fractures were excluded from the study. All fractures were classified using three columns theory by Denis. The radiographic parameters evaluated were: Sagittal alignment using Cobb's angle, vertebral compression, and spinal canal compression.

Results: Loss of vertebral heights especially anterior height was found to be significant in relation to the fracture type. Spinal canal narrowing and vertebral displacement and compression were found significance in relation to preoperative Frankel's grading.

Conclusion: Not all radiographic parameters previously used for assessment of thoracolumbar injuries were correlated with the fracture type, number of spinal columns or forces applied. The most important parameters that put into consideration in evaluation of thoracolumbar fractures are anterior vertebral height, percentage of spinal canal narrowing, percentage of vertebral displacement.

Introduction

Although there are many classification systems for assessing the thoracolumbar injuries, it is of paramount importance to make the right clinical decision in treatment of thoracolumbar injuries is to precisely measure the radiographic vertebral parameters. Previous reports described the various radiologic parameters and the measuring techniques [1-6]. The available radiologic parameters assess the following parameters in the injured spine: Sagittal alignment, vertebral body compression, and spinal canal dimensions. Another problem is different measuring techniques for those parameters which add more confusion in data collection that reflect on the decision making [7].

It was described previously that there were some relation between the degree of spinal deformity and clinical instability [8]. Some authors showed some relation between the radiological measurements and occurrence of instability [9,10].

Till now, the plain lateral radiographs still the best way for assessment despite the details offered by CT scan images.

In this study, we discuss the role of the three columns theory in classification of thoracolumbar injuries, if the number of the columns affected correlate with the fracture type, instability and management results. Also, if the measured radiologic parameters from the lateral view of injured vertebra correlate with the type of the fracture.

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Material and Methods

This quantitative case study was revised and approved by the ethical committee of our institution. Plain x-rays, CT scans and MRI of thoracolumbar injured spine in 74 patients in the period from 2012 to 2016 were evaluated. We included only patients less than 70 years of age to exclude osteoporotic fractures with major traumatic mechanisms. Exclusion criteria included pathologic spinal fractures, multiple vertebral fractures or vertebral appendices fractures. All fractures were classified using three columns theory by Denis. Sample studied power was calculated using sample size Post-Hoc power calculator and it was 100%.

The radiological parameters evaluated were

(1) **Sagittal alignment:** Cobb angle was the most reliable. It was measured from plain radiograph, lateral view.

(2) **Vertebral body compression:** Anterior/Middle/ and posterior Column Compression: It is measured from lateral view of plain radiograph, or computerized tomography. Vertebral body height was measured as the coefficient of the body height of the fractured vertebra divided by the sum of the heights of the vertebral body proximal and distal to the fractured vertebra.

(3) **Percentage of canal narrowing:** Measured from axial CT images. It is the ratio of canal stenosis at the level of injury to the estimated normal canal dimensions at that level [10].

(4) Frontal body height, Lateral body height, Interpedicular distance, Sagittal width, Kyphotic angle, Number of columns affected (according to Denis classification).

Results

Demographics

Patients age ranged from 18 to 67 years (mean 38.4 years, Females: Average: 45 ys, SD: 16.407, SD error: 3.421, males: Average: 42.7 ys, SD: 17.794, SD error: 2.468). Thirty patients (45%) were females and forty four (55%) were males (P= 0.6038: non significant). causal trauma was fall from a height, traffic accidents, or direct. The fracture was located at the T10 level in six patients, at T12 in 24, at L1 in 25, L2 in 14, L3 in three, L4 in 2, and L5 in one. There were forty seven burst fractures, thirteen compression fractures, eight fracture-dislocations, and four flexion distraction injuries. Neurologic deficit was assessed using the scale of Frankel et al. [11], with 19 patients being classified as Frankel E, 15 patients as Frankel D3, six patients as D2, 3 patients as Frankel D1, 3 patients as Frankel C, 3 patients as Frankel B, and 8 patients as Frankel A.

Radiographic parameters (Table 1)

1) **Loss of vertebral heights in relation to the fracture type:** Anterior loss% to Middle loss%, P<0.0001 (significant). (Figure 1).

Anterior loss% to Posterior loss%, P=0.5622

Table 1: Summary of radiographic parameters in relation to fracture types.

Radiographic parameter	Standard deviation	P value
Loss of vertebral heights		P<0.0001
Frontal body width	Burst fr.: SD: 9.911 Comp. fr.: SD: 9.410 Flex. Distr. Inj.: SD: 14.659 Fr. Disloc.: SD: 11.346	P=0.1990
Interpedicular distance	Burst fr.: SD: 19.529 Compr. Fr.: SD: 5.801 Flex. Distr. Inj.: SD: 10.587 Fr. Disloc.: SD: 25.190	P=0.1320
Lateral height	Burst fr.: SD: 8.535 Compr.fr.: SD: 13.27 Flex.Distr. Inj: SD: 8.914 Fr. Disloc.: SD: 14.840	P=0.3857
Sagital width	Burst fr.: SD: 11.059 Compr. Fr.: SD: 8.766 Flex. Dist. Inj: SD: 22.650 Fr. Disloc.: SD: 7.908	P=0.2510
Anterior height	Burst fr.: SD: 14.687 Compr. Fr.: SD: 12.841 Flex. Distr.: SD: 7.361 Fr. Disloc.: SD: 16.739	P=0.0018*
Middle height	Burst fracture: SD: 14.065 Compr. Fr.: SD: 13.233 Flex. Distr. Inj.: SD: 14.347 Fr. Disloc.: SD: 7.777	P=0.1001
Posterior height	Burst fr.: SD: 9.023 Comp. fr.: SD: 20.682 Flex.Distr. Inj.: SD: 9.690 Fr. Disloc.: SD: 14.249	P=0.2007
Pre-Op. Kyphotic angle to columns number		P=0.1605
Relation of number of columns failed to number of applied forces		P=0.3251
% of spinal canal narrowing and Frankel		P=0.0004*
% of compression and Frankel		P=0.0025*
% of vertebral displacement and Frankel		P<0001

(*significant P value).

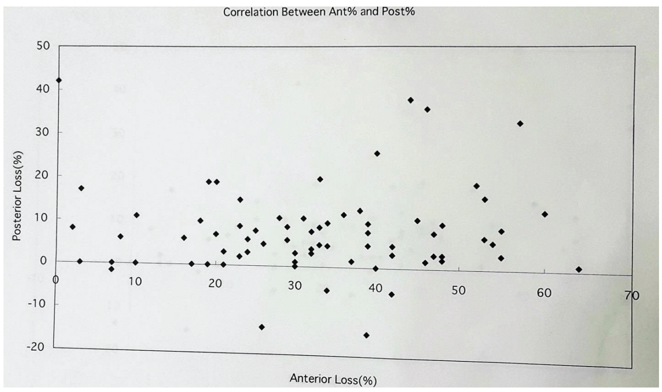

Figure 1: Correlation between anterior and posterior vertebral height loss.

Middle loss% to Posterior loss%, P<0.0001 (significant) (Figure 2).

Ant., Mid., Post%: P<0.0001

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2) **Frontal body width:** FBW ratio in relation to fracture type: P=0.1990 (not significant).

FBW to the fracture type: a) Burst fr.: SD: 9.911, S error: 1.494

b) Comp. fr.: SD: 9.410, S error: 2.515

c) Flex. Distr. Inj.: SD: 14.659, S error: 6.556

d) Fr. Disloc.: SD: 11.346, S error: 4.011

3) **Interpedicular distance:** IPD ratio in relation to fracture type: P=0.1320 (not significant)

IPD to the fracture type: a) Burst fr.: SD: 19.529, S error: 2.978

b) Compr. Fr.: SD: 5.801, S error: 1.550

c) Flex. Distr. Inj.: SD: 10.587, S error: 4.735

d) Fr. Disloc.: SD: 25.190, S error: 8.906

4) **Lateral height:** LH ratio to the fracture type: P=0.3857 (not significant)

LH to the fracture type: a) Burst fr.: SD: 8.535, S error: 1.302

b) Compr.fr.: SD: 13.27, S error: 3.54

c) Flex.Distr. Inj: SD: 8.914, S error: 3.987

d) Fr. Disloc.: SD: 14.840, S error: 5.609

5) **Sagital width:** SW ratio to the fracture type: P=0.2510 (not significant)

SW to the fracture type: a) Burst fr.: SD: 11.059, S error: 1.667

b) Compr. Fr.: SD: 8.766, S error: 2.431

c) Flex. Dist. Inj: SD: 22.650, S error: 10.129

d) Fr. Disloc.: SD: 7.908, S error: 2.796

6) **Anterior height:** AH ratio to the fracture type : P=0.0018 (significant) (Figure3).

AH to the fracture type: a) Burst fr.: SD: 14.687, S error: 2.322

b) Compr. Fr.: SD: 12.841, S error: 3.432

c) Flex. Distr.: SD: 7.361, S error: 3.292

d) Fr. Disloc.: SD: 16.739, S error: 5.918

7) **Middle height:** MH ratio to the fracture type: P=0.1001 (not significant)

MH to the fracture type: a) Burst fracture: SD: 14.065, S error: 2.120

b) Compr. Fr.: SD: 13.233, S error: 3.537

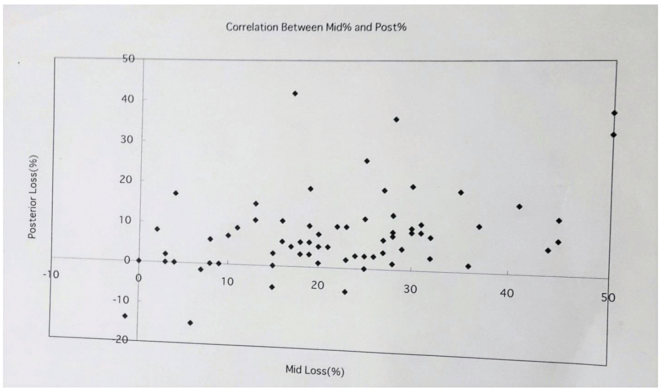

Figure 2: Correlation between middle and posterior vertebral height loss.

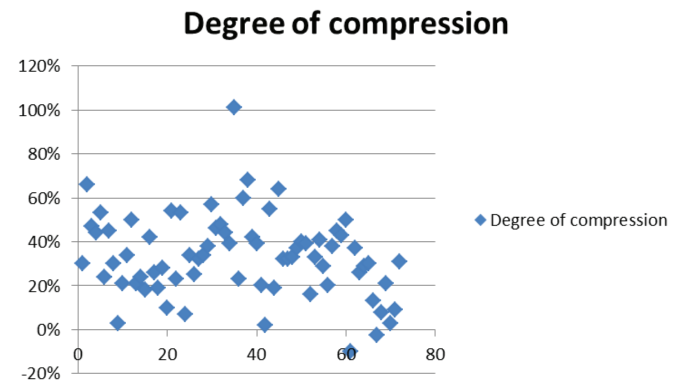

Figure 3: Degree of compression and fracture type.

c) Flex. Distr. Inj.: SD: 14.347, S error: 6.416

d) Fr. Disloc.: SD: 7.777, S error: 2.750

8) **Posterior height:** PH ratio to the fracture type: P=0.2007 (not significant)

PH to the fracture type: a) Burst fr.: SD: 9.023, S error: 1.360

b) Comp. fr.: SD: 20.682, S error: 5.527

c) Flex.Distr. Inj.: SD: 9.690, S error: 4.333

d) Fr. Disloc.: SD: 14.249, S error: 5.038

9) **Pre-Op. Kyphotic angle to columns number:** P=0.1605 (non significant) (Figure 4).

10) **Pre-Op. Frankel's grade to columns number:** P=0.4965 (non significant)

11) **Relation of number of columns failed to number of applied forces:** P=0.3251(using non-parametric Kruskal – Wallis test), P=0.1273 (using one-way ANOVA) (non significant)

12) **Anterior vertebral height loss with pre-Op. Frankel' grade:** P=0.0794 (non significant)

13) **Middle height vertebral loss with Pre-Op. Frankel' grade:** P=0.3280 (non significant)

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14) **Posterior height vertebral loss with Pre-Op. Frankel's grade:** P=0.3212 (non significant)

15) **Ant/Mid/Post. Vertebral height loss with Pre-Op. Frankel' grade:** P=0.3598 (non significant)

16) **Fracture level to fracture type:** P=0.2270 (non significant)

17) **Frankel (Preop) and fracture type:** P=0.0001 (Mann-Whitney: P=0.0625 insignificant).

18) **% of spinal canal narrowing and Frankel (Preop):** P=0.0004 (significant between 7 groups from A to E) (Figure 5).

19) **Canal narrowing more than 50% and Frankel (preop):** P= .0009 (significant).

20) **% of vertebral displacement and Frankel (preop):** P<0001 (significant) (Figure 6).

21) **Scoliotic angle (preop) and Frankel (preop):** P=0.9404 (non significant).

22) **Kyphotic angle (preop) and Frankel (preop):** P=0.5218 (no significant)

23) **% of compression and Frankel (preop):** P=0.0025 (significant).

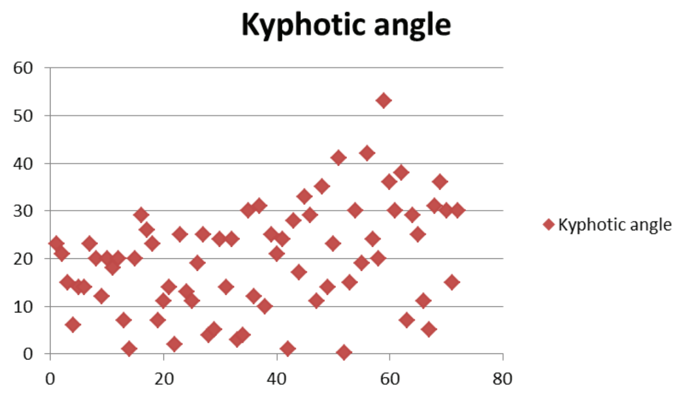

Figure 4: Kyphotic angle and fracture type.

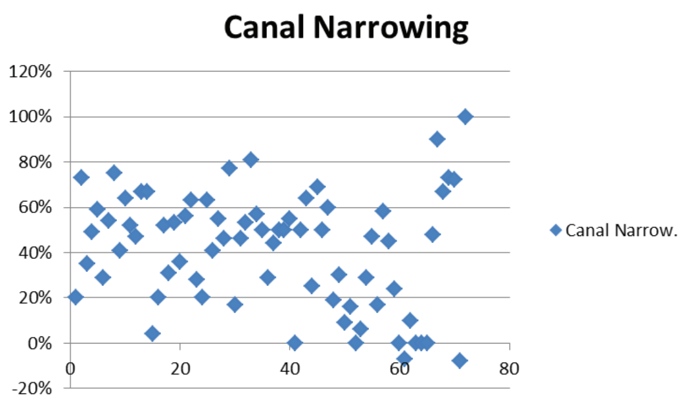

Figure 5: Spinal canal narrowing and fracture type.

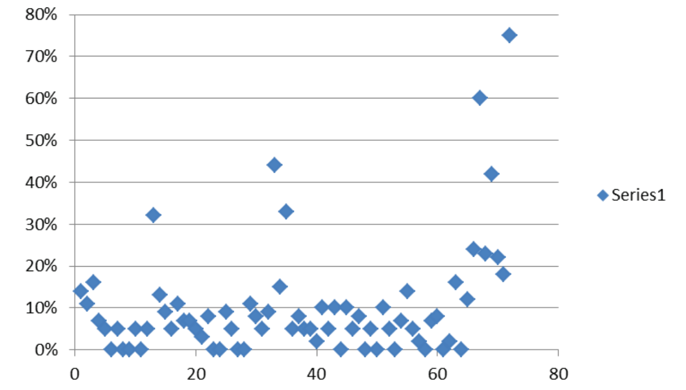

Figure 6: Degree of vertebral displacement and fracture type.

Discussion

The importance of radiographic measurements came from being a universal standard for collection of data, clinical evaluation and assessment of the fracture condition, decision making, and for results assessment.

But, because of drawbacks in measuring techniques leasing to inter and inra-observer variability, there were regular defining and validation to choose the best method for measurement of such parameters [12].

There were many classifications for thoracolumbar injuries, some were simple but the many others were difficult to understood or difficult to apply in everyday practice [13]. Earlier in the last century, the two columns theory was proposed dividing the spinal anatomy into anterior and posterior structures. Soon after, the three columns theory was provoked by Denis, where he joined the neurological status of the patient and injury mechanism to the fracture geometry and its stability [14-17]. Recently, The thoracolumbar injury classification system proposed by Vaccaro and colleagues providing point scale system for easier decision making [18,19].

There are different techniques in measuring radiographic parameters previously needed for evaluation of thoracolumbar fractures. This may depend in part on quality of imaging and ability of surgeon for interpretation. So, It is very important to detect the smallest number of radiographic parameters needed to evaluate the type of the fracture and detect type of intervention required either conservative or surgical.

The previous researchers concluded that Cobb angle provided the best inter and intraobserver reliability because the method of measurement reflect the bony deformity [7]. But in this study, relation between Cobb angle and number of columns affected (three columns theory), or the neurologic affection caused by the injury was non significant although loss of anterior vertebral height in relation to the fracture type was significant. This may be attributed to Cobb angle measure spinal deformity caused not only by vertebral fracture but also by traumatic disc space narrowing.

Regarding the anterior vertebral body compression, different methods were used for assessment. Some authors

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used a method correlating the ratio between the compressed part of the vertebra to the posterior vertebral height [7], while the others correlate the degree of compression of fractured vertebra to the normal one above and below (same as in this study) [10,20,21]. In this study, Anterior height ration was found to be significant in detecting the fracture type although had no significance in detecting the neurological injury. Also, correlation between anterior height with middle height and correlation between middle height with posterior height of the fractured vertebra were found to be highly significant in relation to the fracture type which represent the particular importance of the middle column as a main pillar in classification of thoracolumbar fractures.

Regarding the percentage of spinal canal occlusion, In this study, it was found that canal narrowing ≥50 is highly significant in correlation with neurologic injury although Hashimoto found that the percentage may differ at different spinal levels affected where it was ≥35% at T11 to T12, 45%at L1, and ≥55% at L2 and below [22].

From the previous literature it was known that each vertebral fracture type had a unique mechanism or combined mechanisms. For example, compression fractures occurred due to axial compression with flexion affecting mainly the anterior vertebral column with no involvement of posterior vertebral column. Burst fractures occurred as a result axial compression that maybe combined with flexion, extension or rotation with affection of middle and anterior columns [23]. Also, in flexion-distraction injuries, affection of the three vertebral columns occur, the anterior fails in flexion while middle and posterior columns fail in extension. But in this study, there were no correlation between number of columns affected and type of the fracture as measured by relation of different longitudinal and transverse measured heights.

In biomechanical studies, each force produce a peculiar type of injury [24] but in clinical practice detection of the causative force depends on history talking, clinical and radiographic evaluation and there is always combination of mechanisms causing the spinal injury. In this study, no correlation was found between number of applied forces and number of columns affected (or fracture types).

Interpedicular distance was previously correlated to the degree of neurological affection and was found not significantly correlated [25]. To our current knowledge, no previous studies correlate the interpedicular distance to the fracture type although most of the fracture types involve at least two vertebral columns. In the present study, no statistical correlation was found between the fracture type and change of interpedicular distance.

Many classifications had been proposed to classify the thoracolumbar injuries started with Holdsworth who introduced the two columns theory in 1963 dividing the spinal column into two columns anterior and posterior, then Denis in 1984 who introduced the importance of the middle column in his three columns theory [2,4]. Recently, the spine trauma study group developed the thoracolumbar injury severity score to classify the fractures as surgical or non surgical candidates according to three parameters: mechanism of injury, neurological status, and integrity of posterior ligamentous complex. A new comprehensive AO classification system was more recently proposed depending only on fracture morphology and neurological status [26,27].

The findings of this study were found to be nearly correlated with the parameters of AO classification system were percentage of spinal canal narrowing, percentage of vertebral displacement, percentage of compression and preoperative neurological affection (Frankel grades) were found to be significant.

In conclusion, not all radiographic parameters previously used for assessment of thoracolumbar injuries were correlated with the fracture type, number of spinal columns or forces applied. The most important parameters that put into consideration in evaluation of thoracolumbar fractures are anterior vertebral height, percentage of spinal canal narrowing, percentage of vertebral displacement.

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