Retrospective Study

Multifactor Analysis of Costal Pain in Osteoporotic Fracture of Thoracic Vertebra

Jun Xin, MD[1], Xiaoyang Liu, PhD[2], Xingzhi Jing, PhD[2], Cheng Su, MD[3], Yi Mao, MD[4], Feifei Chen, PhD[2], Wenchao Wang, MD[3], and Xingang Cui, PhD[1]

From: [1]Shandong Province Hospital, Shandong University School of Medicine: Shandong University Cheeloo College of Medicine, Jinan, PR China; [2]Shandong Provincial Hospital, Jinan, PR China; [3]Shandong First Medical University,Tai'an Campus, Jinan, PR China; [4]People's Hospital of Quzhou, Jinan, PR China

Address Correspondence: Xingang Cui, PhD Shandong First Medical University as the Shandong Provincial Hospital Affiliated to Shandong First Medical University, Shandong Provincial Hospital Affiliated to Shandong University, No 9677, Jingshi Road, Jinan 250013, PR China E-mail: xinhuadegege@163.com

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Background: The costal pain is common in thoracic osteoporotic fracture patients. It is unclear why vertebral fracture patients without any specific nerve impingement on magnetic resonance imaging (MRI) present with costal pain.

Objectives: The aim of this study was to investigate the potential causes of costal pain in patients with osteoporotic fracture of thoracic vertebra.

Study Design: A retrospective study.

Setting: Shandong province, China.

Methods: In this retrospective study, 100 patients with thoracic osteoporotic fractures were collected and assigned into 2 groups on the basis of pain patterns noted during medical history and physical examination. Group A was comprised of 50 patients with costal pain. Group B was comprised of 50 patients without costal pain. The Visual Analog Scale and Oswestry Disability Index scores were recorded to assess the pattern and severity of pain. The gender, age, presence or absence of trauma, time of fracture, fracture segments, and analgesic application were recorded. Computed tomography data including changes in fracture vertebral body shape (height, width, and length), intervertebral foramen shape (height and width), wedge shape of fractured vertebral body, and local kyphosis angle were recorded. The fracture edema signal was determined by MRI. Multivariate analysis was performed for all the above parameters.

Results: There was a statistically significant difference in the vertebral body width between the 2 groups.

Limitations: The number of patients enrolled is not large enough. We also have limitations in interpreting all pains resulting from osteoporotic vertebral compression fractures, because all pain mechanisms are not fully understood. Further work is needed to improve the accuracy of locating pain sources and distinguishing pain patterns which may result from other spinal structures.

Conclusion: The incidence of costal pain is significantly and positively associated with the width of the fractured vertebra in patients with osteoporotic thoracic vertebrae fracture.

Key words: Osteoporosis fracture, thoracic vertebrae, costal pain, nonmidline pain, intervertebral foramen, sympathetic nerve

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Osteoporosis is a severe worldwide public health problem due to its high morbidity and mortality. As one of the most common complications of osteoporosis, osteoporotic spine fractures mainly occur in the thoracolumbar segment, and patients often complain of severe low back pain in the corresponding fracture area (1,2). Local tenderness over the spinous processes of the fractured vertebra and magnetic resonance imaging (MRI) signals of bone marrow edema is common in patients with osteoporotic spine fracture (3,4). However, several studies have reported that certain vertebral fractures have no focal tenderness and local pain over the fractured level, but with nonmidline pain in the chest, lower back, near the iliac crest, the groin, and the trochanteric region (5-8). It is unclear why vertebral fracture patients present with distal pain without any specific nerve impingement on MRI (9). In the previous studies, a variety of causes have been mentioned, including sympathetic nerve injury, vertebral body height decline, foramen narrowing, facet changes, disc tearing, and paravertebral muscle overload (6,9). However, to our knowledge, the relationship between nonmidline pain and fracture morphology still remains elusive. The diversity of clinical manifestations of nonmidline pain makes it difficult to analyze its causes. Thoracic vertebra fractures are relatively common in osteoporotic fractures. In this study, we chose the costal pain to study the cause of nonmidline pain of thoracic vertebra osteoporotic fractures. We also measured the relevant data of the morphological changes of fractured vertebra and intervertebral foramina to elucidate its possible causes and mechanisms.

Methods

Patient Selection

One hundred patients with single-segment thoracic osteoporotic fractures, admitted to Shandong Provincial Hospital from 2017 to 2020, were enrolled and retrospectively studied, including the youngest 51 years old and the oldest 95 years old. Institutional review board approval was granted for the study. The patients were selected according to the following inclusion criteria: 1) Thoracic osteoporotic fracture was confirmed by thoracic x-ray and MRI, and the fracture time was less than 3 weeks. 2) All patients had osteoporosis (vertebra or femoral neck T-score <-2.5). The criteria for exclusion: 1) burst vertebral fractures with spinal cord injury, patients with significant lower limb nerve damage symptoms and signs; 2) Accompanied by rib or sternal fractures; 3) a history of shingles or thoracotomy; and 4) patients with primary and metastatic bone tumors or myeloma.

Costal pain refers to radiating pain of both sides or one side along the intercostal space. Patients were divided into Group A (costal pain) and Group B (noncostal pain) according to the presence or absence of costal pain. The Visual Analog Scale (VAS) score (in the range of 0 = no pain to 10 = worst pain) for pain evaluation and the Oswestry Disability Index (ODI) score (sexual activity excluded) were conducted for functional assessment. The fracture types of the vertebral body were classified into 3 types: 1) wedge, 2) biconcave, and 3) crush deformities (8).

Considered Parameters

The following data were recorded: sex, age, bone mineral density of the vertebral body, type of fracture, presence or absence of trauma, time of fracture, and the analgesic application. They were obtained from the patients' medical records and MRI. The level and type of fractures were divided into 3 categories (less than 1/3, 1/3-2/3, more than 2/3) according to the signal scope and intensity of T2-weighted image in the MRI.

Computed tomography (CT) data were collected to evaluate the morphology of fractured vertebral body and intervertebral foramen. GE Medical Systems' measurement was conducted to avoid personal error on the film.

Measurement of Vertebral Body

Firstly, after locating the center of the injured vertebral sagittal position, we selected the lower edge of the injured vertebral pedicle as the baseline to locate the coronal plane of the injured vertebra and measured the maximum width of the injured vertebra. If the fracture involved only the upper or lower part of the vertebral body, the 3 physicians jointly discussed and decided to select a more appropriate coronal plane and record the maximum width of the injured vertebral body. Changes in vertebral body width were calculated by the ratio of fractured vertebral body width to [(upper adjacent body width + lower adjacent body width)/ 2]. Locating the sagittal center of the injured vertebra, and measuring the height of the anterior, middle, and posterior edges of the fractured vertebra and the corresponding height of the adjacent normal vertebra. Changes in the vertebral height were calculated in the corresponding ratios: fractured vertebral height / [(upper adjacent vertebral height + lower adjacent vertebral height)/ 2]. The middle part of the vertebral body is generally selected to measure the length. If the fracture only involved the upper part or the lower part of the vertebral body, an appropriate position was chosen to measure the length of the vertebral body. The length of the adjacent normal vertebrae was measured at the same position as the injured vertebrae. Changes in vertebral length were described by corresponding ratios: fractured vertebral length / [(upper adjacent vertebral length + lower adjacent vertebral length)/ 2] (Fig. 1).

Measurement of Intervertebral Foramen Size

Because the changes of the morphology of the injured vertebra will affect the upper and lower intervertebral foramen of the injured pedicle, the 2 intervertebral foramens were analyzed separately. The length of the intervertebral foramen refers to the distance between the upper and lower 2 pedicles. The width is the distance from the lower angle of the posterior margin of the upper vertebral body to the apex of the superior articular process of the lower vertebral body. The change in foramen was described by the corresponding ratio: foramen length above the vertebral pedicle of the fractured vertebra / [(foramen length above the pedicle of upper adjacent vertebra + foramen length below the pedicle of the lower adjacent vertebra)/ 2]. Foramen length of lower pedicle of fractured vertebra / [(foramen length above the pedicle of upper adjacent vertebra + foramen length below the pedicle of the lower adjacent vertebra)/ 2]. The change in the width of the intervertebral foramen was calculated in the same way (Fig. 2).

Measurement of Kyphosis and Vertebral Wedge Formation

Local kyphosis was evaluated by the Cobb angle between the superior endplate of the upper vertebra and the inferior endplate of the lower vertebra adjacent to the fracture. The Cobb angle between upper and lower endplates of the injured vertebra was measured to evaluate the wedge shape of the injured vertebra. Changes in the vertebral body were described by the corresponding ratio: fracture vertebral wedge / [(upper adjacent vertebral wedge + lower adjacent vertebral wedge)/ 2] (Fig. 3).

The measurements were performed twice to the nearest 0.1 mm. If the 2 measurements showed a difference of more than 1 mm, a third measurement was taken and the average of all was used.

We collected as much data as possible to reflect the morphological changes of the vertebral body, and analyzed them separately, trying to find the relationship between costal pain and fracture morphology.

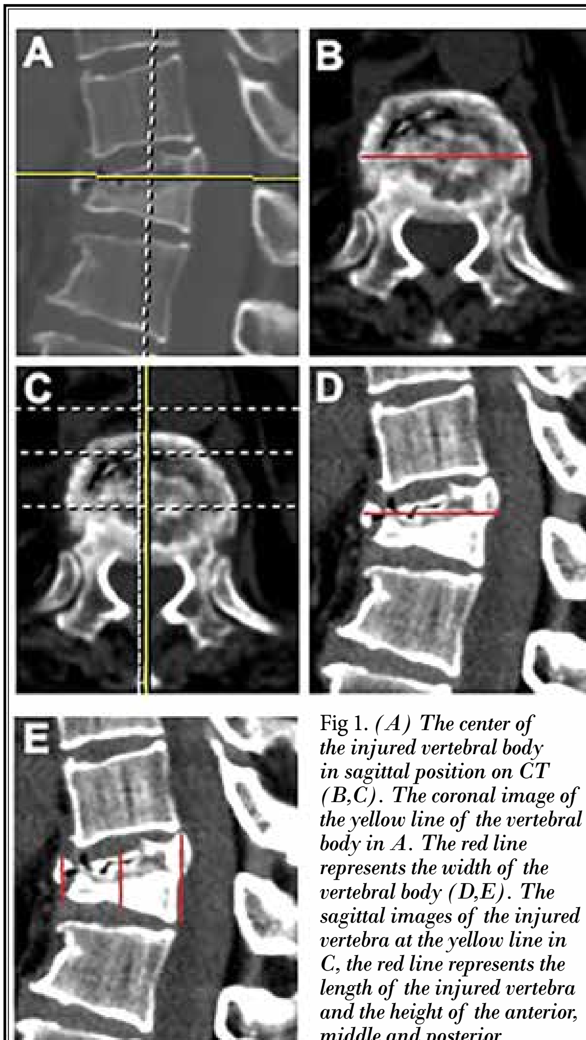

Fig 1. *(A) The center of the injured vertebral body in sagittal position on CT (B,C). The coronal image of the yellow line of the vertebral body in A. The red line represents the width of the vertebral body (D,E). The sagittal images of the injured vertebra at the yellow line in C, the red line represents the length of the injured vertebra and the height of the anterior, middle and posterior.*

Statistical Analysis

Statistical analysis was performed using SPSS 25.0 (SPSS Inc, Chicago, IL, USA). The data of patients with and without costal pain in osteoporotic fracture of thoracic vertebra were compared using t test or Chi square test. Any significant difference ($P < 0.05$) was also analyzed using binary logistic regression analysis, and then P value < 0.05 was considered to be statistically significant.

Results

Demographic Data

The clinical characteristics of patients are shown in Table 1. The average ages in the costal and noncostal groups were 68.8 ± 6.9 and 69.8 ± 9.0 years, respectively.

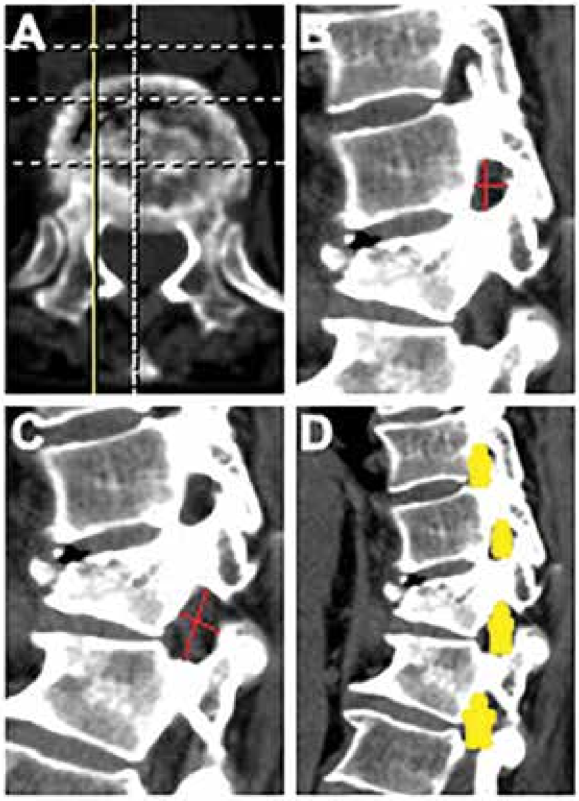

Fig 2. *(A) The coronal image of the vertebral pedicle plane of the fractured vertebra (B,C). The sagittal image of the yellow line in A. (B) The red line represents the height and width of the intervertebral foramen. (C) The red line shows the height and width of the intervertebral foramen below the pedicle. (D) Yellow arrows show the middle 2 intervertebral foramina affected by the fracture, and the mean height and width of the 2 foramina at both ends.*

In both groups, the lower thoracic segment (T10-T12) was the most common level of fracture site (Table 1).

There was significant difference in trauma or not, analgesic or not, and the VAS between the 2 groups ($P < 0.05$).

No statistical significance in the fracture level, magnetic resonance edema signal size, classification of fracture types, symptom duration or ODI ($P > 0.05$) were observed between the 2 groups.

Comparison of Parameters

There was significant difference in vertebral fracture width, anterior, and middle height between the 2 groups ($P < 0.05$). While there was no significant difference in vertebral length or posterior height ($P > 0.05$) (Table 2).

There was significant difference in width of left upper intervertebral foramen or width of right upper intervertebral foramen between the 2 groups ($P < 0.05$). There was no significant difference in the other parameters of the intervertebral foramen between the 2 groups ($P > 0.05$) (Table 3).

No significant difference in the wedge angle and local kyphosis angle was observed between the 2 groups ($P > 0.05$) (Table 4).

Our t test or Chi square test results showed significant differences in the changes of the vertebral fracture width, anterior, and middle height, the width of left and right upper intervertebral foramen, trauma or not, analgesic or not, and the VAS between the 2 groups. To further analyze the correlation of the 8 factors, binary logistic regression analysis was conducted. Binary logistic regression analysis showed that the change of the vertebral body width was a constant significant predictor of costal pain for all patients ($P = 0.00$, Exp (B) = 4.531E + 50). Following binary logistic regression analysis, the other 7 factors were no longer predictors of costal pain ($P > 0.05$). The incidence of costal pain was higher in patients with increased fracture vertebral width after adjusting for the other 7 factors in binary logistic regression model (Table 5).

The vertebral width in patients with costal pain was significantly higher

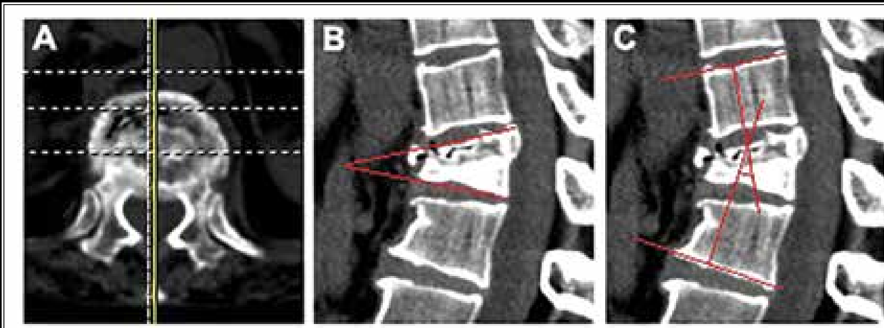

Fig 3. *(A) The coronal image of the injured vertebral body. (B,C) The sagittal image of the vertebral body at the yellow line of A. The wedge shape and local kyphosis angle of the vertebral body were measured, respectively.*

Table 1. *Characteristics of osteoporotic thoracolumbar vertebral fracture patients.*

	Total (n = 100)	Group A (n = 50)	Group B (n = 50)	*P* value
Age (years)	69.3 ± 8.0	68.8 ± 6.9	69.8 ± 9.0	0.51
Female gender	16/84	9/41	7/43	0.59
Fracture level	100	50	50	0.33
T6	1	1	0	
T7	6	3	3	
T8	8	3	5	
T9	7	3	4	
T10	18	5	13	
T11	17	10	7	
T12	43	25	18	
Magnetic resonance edema signal	100	50	27	0.90
< 1/3	15	8	7	
1/3-2/3	32	15	17	
> 2/3	53	27	26	
Fracture classification	100	50	50	0.44
Wedge	46	20	26	
Biconcave	42	24	18	
Crush	12	6	6	
Symptom duration (days)	11.8 ± 5.7	13.5 ± 5.1	10.1 ± 5.8	0.48
Trauma or not	45/55	29/21	16/34	0.01
Analgesic or not	42/58	28/22	14/36	0.01
VAS	6.4 ± 1.3	5.8 ± 1.2	6.9 ± 1.1	0.00
ODI	67.4 ± 12.8	64.3 ± 12.6	70.6 ± 12.3	0.13

The continuous variables are expressed as mean ± SD; the categorical variables are expressed as frequency.
Abbreviations: VAS, visual analog scale; ODI, Oswestry disability index.

than that without costal pain (*P* < 0.05). The incidence of costal pain is significantly and positively associated with the width of the fractured vertebra in patients with osteoporotic thoracic vertebrae fracture (Fig. 4).

Discussion

Several studies have reported that patients with certain vertebral fractures have no focal tenderness and local pain over the fractured level (5-8). Patients with vertebral fractures may present with nonmidline pain in the chest, lower back, near the iliac crest, the groin, and the trochanteric region (6,7). It is unclear why vertebral fracture patients without any specific nerve impingement on MRI present with nonmidline pain (9). In the previous studies, a variety of causes have been mentioned, including sympathetic nerve injury, vertebral body height decline, foramen narrowing, facet changes, disc tearing, and paravertebral muscle overload (6,9).

Table 2. *Results of the relationship between fracture intercostal neuralgia and vertebral height and width.*

	Group A (n = 50)	Group B (n = 50)	*P* value
VFW (%)	1.18 ± 0.11	1.01 ± 0.02	0.00
VFL (%)	1.05 ± 0.08	1.03 ± 0.05	0.14
AVH (%)	0.73 ± 0.19	0.82 ± 0.18	0.02
MVH (%)	0.64 ± 0.19	0.73 ± 0.20	0.03
PVH (%)	0.91 ± 0.10	0.92 ± 0.09	0.50

The results are expressed as mean ± SD.
Abbreviations: VFW, vertebral fracture width; VFL, vertebral fracture length; AVH, anterior vertebral height; MVH, middle vertebral height; PVH, Posterior vertebral height.

Table 3. *Results of the relationship between fracture intercostal neuralgia and bilateral intervertebral foramen.*

	Group A (n = 50)	Group B (n = 50)	*P* value
ULFH (%)	0.91 ± 0.13	0.88 ± 0.14	0.30
ULFW (%)	1.04 ± 0.18	0.94 ± 0.19	0.01
URFH (%)	0.90 ± 0.11	0.89 ± 0.12	0.70
URFW (%)	1.03 ± 0.18	0.96 ± 0.18	0.04
LLFH (%)	0.99 ± 0.16	0.96 ± 0.14	0.26
LLFW (%)	1.01 ± 0.23	1.05 ± 0.24	0.45
LRFH (%)	0.94 ± 0.13	0.92 ± 0.12	0.40
LRFW (%)	1.03 ± 0.21	0.98 ± 0.22	0.28

The results are expressed as mean ± SD.
Abbreviations: ULFH, left of upper intervertebral foramen height; ULFW, width of left upper intervertebral foramen; URFH, right upper intervertebral foramen height; URFW, width of right upper intervertebral foramen; LLFH, left of lower intervertebral foramen height; LLFW, width of left lower intervertebral foramen; LRFH, right lower intervertebral foramen height; LRFW, width of right lower intervertebral foramen.

Table 4. *Results of the relationship between fracture intercostal neuralgia and local kyphotic angle and wedge-shaped vertebral body.*

	Group A (n = 50)	Group B (n = 50)	*P* value
LKA (°)	16.33 ± 9.64	13.5 ± 9.57	0.15
WVB (%)	3.60 ± 3.97	3.10 ± 3.96	0.53

The results are expressed as mean ± SD.
Abbreviations: LKA, local kyphotic angle; WVB, wedge-shaped vertebral body.

Table 5. *Associations between the occurrence of intercostal neuralgia in the intercostal neuralgia and clinical factors, determined by binary logistic regression analysis.*

Parameters	B	Exp (B)	(95%CI) for Exp (B)	Sig
MVW (%)	116.6	4.531E+50	4.693E+17-4.374E+83	0.00
Trauma or not	-	-	-	0.93
Analgesic or not	-	-	-	0.72
VAS	-	-	-	0.56
AVH (%)	-	-	-	0.67
MVH (%)	-	-	-	0.15
ULFW (%)	-	-	-	0.40
URFW (%)	-	-	-	0.25

Abbreviations: MVW, middle vertebral width; VAS, visual analog scale; AVH, anterior vertebral height; MVH, middle vertebral height; ULFW, width of left upper intervertebral foramen; URFW, width of right upper intervertebral foramen.

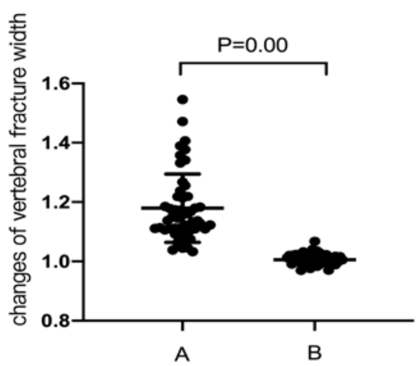

Fig 4. *Scatter plots for the changes of the vertebral body width between the 2 groups.*

In 1991, Patel et al (10) found that "radiation to the flanks and anteriorly was common" by investigating 30 patients with acute vertebral compression fractures. In a 2006 study, they found that pain caused by the vertebral fracture in the thoracolumbar region was mainly in the lumbosacral gluteal area which could confuse the surgeon in choosing treatment strategy (11). O'Connor et al (12) commented on thoracic radiculopathy in a bandlike distribution to the anterior thorax, chest, or abdomen. The pain pattern might result from the ventral rami of the thoracic. The explanation given for the referred pain is that the ventral rami of the thoracic spine run anterolaterally between the ribs to innervate the chest and abdominal wall (12).

Doo et al (8) reported that the decreased vertebral body height could damage the surrounding zygapophyseal joint and narrow the intervertebral foramen, thus irritate the posterior branches of the spinal nerve at T12, L1, and L2. Remarkably, their study showed a significant association between the nonmidline pain and deformity index (height of vertebral bodies). Moreover, they found that pain was extended from the anterior chest to the lowest height of the vertebral body as the height of vertebral bodies decreased (8). However, our study showed that the occurrence of costal pain was not significantly associated with changes in vertebral body height ($P > 0.05$). Wilson et al (13) found that the facet joints may play important roles in the generation of pain in most vertebral fracture patients. Biomechanical instability caused by an adjacent wedge fracture, and subsequent sagittal imbalance as well as overload of facet joints and paraspinal muscles, were the reasons for which patients felt pain at several vertebral segments away from the fractures identified on imaging (13). Choi et al (14) believed that the costal pain developed more frequently in nonwedge deformities compared to wedge-type fractures, which indicated that middle column injuries could be an important contributor to costal neuralgia following costal nerve injury, the intervertebral foramen could also affect the costal nerve and induce costal pain at the concordant vertebral fracture level (14). In our study, however, there was no significant correlation between costal pain and foramina changes. Niu J et al (9) found that kyphoplasty had a superior effect in relieving the nonmidline pain caused by thoracolumbar vertebral fractures. In their opinion, by means of the expansion of the balloon and injection of cement, kyphoplasty could restore the vertebral height, correct local kyphosis, eliminate micromotion within fractured vertebrae, and decrease the mechanical load pressed on the facet joints, which all decrease the irritation or compression of the sympathetic ganglion or dorsal ramus (9). But the authors did not analyze the pain pattern and its relation with the fracture region.

The results of our study indicated that nonmidline pain is common in patients without imaging findings of specific nerve impingement. The number of patients with nonmidline symptoms may be understated, as some patients who answered "no" to the question regarding nonmidline symptoms lacked a pain location diagram. Because patients often answered "no" when asked if they had pain in other areas, but they would answer "yes" when asked if they have pain in the anterior chest or the lateral ribs, these symptoms were often ignored. Some of these patients may have nonmidline pain to the side or elsewhere which was not addressed in the questionnaire (7).

Our study showed that the occurrence of costal pain in osteoporotic thoracic vertebrae is related to the change in the width of the vertebral body, the incidence of costal pain in patients with the vertebral body bulging to both sides of the fractured vertebra is relatively high. Anatomically, sympathetic nerve chain is distributed on the side of the vertebral body, consisting of thoracic sympathetic ganglion and the sympathetic trunk. There are communication branches between the sympathetic chain and the intercostal nerve. The range of costal pain was roughly the same as that of sympathetic nerve innervation. Therefore, we speculated that the cause of costal pain was the expansion of the fractured vertebra to both sides, and the compression of the sympathetic nerve by fracture block. Jinkins et al (15) described in detail the mechanism of vertebra-induced referred pain. They explained that the referred pain was elicited through the sympathetic nerve pathways and the pain was radiated to the regions corresponding roughly to the somatic distribution of the afferent fibers of the spinal nerve with which the afferent sympathetic fibers entered the spinal canal. However, they did not explain the mechanism of costal pain in osteoporotic thoracic vertebrae.

Our results also indicate that costal pain is common in patients with osteoporotic vertebral compression fractures (OVCFs). For patients with OVCFs, pain location may not accurately reflect the fracture site. Both physical examination and radiological image analysis are required for correct diagnosis. Thus, for aged patients with the pain radiating to both or one side along the intercostal space or to the chest, their thoracic vertebra should be examined, regardless of their trauma history in this region.

A major limitation of this study is that the number of patients enrolled is not large enough. Significant limitation being the need for prospective studies in patients with vertebral fractures with multiple variables. We also have limitations in interpreting all pains resulting from OVCFs, because all pain mechanisms are not fully understood (9,16). In addition, nonmidline pain has many locations and manifestations, which are relatively complex and need further clarification.

Conclusion

The relationship between costal pain and fracture morphology has not been previously reported. We believe that our classification of pain pattern may be useful in finding the pain sources from OVCFs, and hence facilitate in the pain management of these patients. We are conducting a study of nonmidline pain in lumbar osteoporotic fractures. They have similar pain characteristics. We are also conducting a prospective study to further confirm the reliability of this conclusion. We believe that this study may further elucidate the mechanism of nonmidline pain in osteoporotic fractures of the spine.

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