Comparison between continuous and discontinuous multiple vertebral compression fractures

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Abstract *Background*The majority of multiple vertebral fractures (MVFs) occur under high-energy conditions; however, some cases occurring under minor-energy conditions exist. Fractures in successive vertebrae (continuous type) and in skipped vertebrae (discontinuous type) can exist. *Purpose*The objective of this study was to compare and evaluate the cause, level of injury, and relationship to osteoporosis between continuous and discontinuous MVFs. *Methods*We studied 77 subjects (173 vertebrae) who had presented with acute back pain between September 2007 and April 2010 and who received diagnoses of fresh MVFs through magnetic resonance imaging. Subjects with continuous and discontinuous fractures were evaluated based on age, sex, bone mineral density (BMD), level of affected vertebrae, and cause of injury. *Results*Subjects with discontinuous MVFs were significantly older and comprised more female patients. Mean BMD, measured by dual-emission X-ray absorptiometry, was 0.70 and 0.58 g/cm^3 for the continuous and discontinuous MVFs, respectively, demonstrating a significant difference. Of 34 patients with discontinuous MVFs, 32 (94%) exhibited vertebral fractures in the thoracolumbar junction. In subjects with continuous MVFs, the MVFs of 19 (44%) subjects were caused by high-energy trauma, whereas mild trauma and unknown cause were identified in 14 (41%) and 13 (38%) subjects with discontinuous MVFs, respectively. ConclusionsDiscontinuous MVFs generally caused by mild outer force, and often occurred at the thoracolumbar junction. Continuous MVFs, frequently, were caused by high-energy trauma.ently, were caused by high-energy trauma.

Introduction

In recent years, vertebral compression fractures (VCFs) caused by osteoporosis have become increasingly prevalent due to a disproportionate increase in the elderly population. VCFs cause many significant problems, including pain [1], spinal deformity [2], reduced pulmonary function [3], reduced mobility [4-6], and increased mortality [7]. Multiple vertebral fractures (MVFs) are often observed; however, statistical review of MVFs has not been reported. Generally, MVFs are caused by high-energy trauma, but cases occurring under low-energy conditions exist. There are fractures in both successive (continuous type) and skipped vertebrae (discontinuous type). The purpose of this study was to compare and evaluate the cause, level of injury, and relationship to osteoporosis between continuous and discontinuous MVFs.

Materials and methods

We defined MVFs in which fractured vertebrae are successive as continuous type, and MVFs in which intact vertebrae exist between the fractured vertebrae as discontinuous type (Fig. 1). We then investigated the differences between the two types.

This study included the MVFs of 173 vertebrae from 77 consecutive subjects who presented at our hospital between September 2007 and April 2010 reporting acute low back pain and/or thoracic pain and who were diagnosed with fresh vertebral fractures by magnetic resonance imaging (MRI). MRI was performed 0-24 days (mean 2 days) after plane radiography.

Imaging

MRI was performed with a 1.5 T system (Signa EXCITE; GE Healthcare, United Kingdom) using a spine-phased array coil. The imaging protocol included sagittal T1-weighted fast spin-echo images (400-575/9-12 [repetition time millisecond/ echo time millisecond]) and short inversion time inversion-recovery (STIR) images (4000-4,800/68/150 [inversion time millisecond]) with 3.0-mm section thickness. The matrix was 256 9 320, with a field of view of 300 mm. A fresh vertebral fracture was diagnosed when T1-weighted and STIR images exhibited low and high signals, respectively, as Baker and colleagues [8] reported. Additionally, we employed the MRI diagnosis criteria of T1-weighted images reported by Nakano and colleagues [9], and the change of high signal in the STIR images was used as a reference. Continuous MVFs comprised 97 vertebrae from 43 subjects and discontinuous MVFs comprised 76 vertebrae from 34 subjects.

We studied the following variables: sex, age, body weight, body height, cause of injury, bone mineral density (BMD), presence/absence of deformed vertebrae caused by old vertebral fracture, presence/absence of proximal or femoral fracture, time to pain relief, kyphotic angle of the thoracolumbar junction (T10-S1), lordotic angle of the lumbar vertebrae (T12-S1), type of vertebral fracture, and level of the affected vertebrae. BMDs were measured at the bilateral femoral neck by dual-energy X-ray absorptiometry (DXA) and the mean values were used for evaluation. The time to pain relief was defined as the disappearance of knocking pain and the completion of nonsteroidal anti-inflammatory use.

The cause of trauma

The traumas caused by traffic accidents, falling from a high place, sliding or rolling falls, and trauma while skiing or snowboarding were classified as high-energy trauma, while those caused by falling while walking, farm work, lifting, and standing movement were classified as mild trauma.

The data were analyzed by the Chi-square test and Student's ttest using SPSS software (SPSS Japan Inc., Tokyo, Japan), with $P < 0.05$ defined as significant. The types of fracture were compared using Fisher's exact test and post hoc testing using R Version 2.6.2, a free, open-source statistical analysis system; P values <0.05 were regarded as significant.

Results

Characteristics of patients with continuous MVFs

The continuous group comprised 25 men and 18 women with a mean age of 66.8 ± 18.9 years. BMD measurement was performed in 10 of the 43 subjects, and yielded a mean value of 0.748 ± 0.172 g/cm3 (Table 1). The fracture position in the continuous group comprised the thoracolumbar junction in 31 subjects, the cranial side of the thoracolumbar junction in 3 subjects, and the caudal side of the thoracolumbar junction in 9 subjects (Fig. 2). Many continuous MVFs were caused by high-energy trauma (19 subjects, 44.2%), followed by mild trauma (12 subjects, 27.9%), and unknown reasons (12 subjects,27.9%).

Characteristics of patients with discontinuous MVFs

The discontinuous group comprised 10 men and 24 women with a mean age of 76.6 ± 9.7 years. BMD measurement was performed in 12 of the 34 discontinuous subjects, and yielded a mean value of 0.571 ± 0.091 g/cm3 (Table 1). The affected vertebrae in the discontinuous group was at the thoracolumbar junction in 32 of 34 subjects (94.1%) (Fig. 2). Fewer cases of discontinuous MVFs were caused by high-energy trauma (7 subjects, 20.6%) and more cases were caused by mild trauma (14 subjects, 41.2%) or unknown reason (13 subjects, 38.2%).

Comparison between continuous and discontinuous MVFs

The discontinuous group comprised patients of a significantly higher age (P = 0.006) and included more women (P = 0.008). Mean time to pain relief for the discontinuous group tended to be shorter than that of the continuous group, but no significant difference was observed. There was no significant difference in the kyphotic angle of the thoracolumbar junction and the lordotic angle of the lumbar vertebrae between the two groups. BMD measurement demonstrated a significant difference (P = 0.032), with a lower BMD recorded in the discontinuous group (Table 1); however, this result should be considered only as a reference because measurement of BMD was not performed for all cases. The majority of higher-level vertebral fractures were concentrated at the thoracolumbar junction in both groups.

We carried out a Chi-square test (2 9 2; continuous or discontinuous, high- or minor-energy, plus unknown); Yates' continuity correction was used ($P = 0.0534$). Although the difference was not significant, the P value was near 0.05 and we observed the tendency for continuous and discontinuous types to include more high and minor energy, plus unknown causes of trauma, respectively.

The levels of fractured vertebrae, classified as due to high-energy trauma, mild trauma, and unknown cause, are shown in Fig. 3. Some continuous MVFs caused by high-energy trauma accompanied the fracture at the thoracic vertebrae; however, in the cases of mild trauma, the majority of vertebral fractures occurred at the caudal side of the thoracolumbar junction. Only small differences in the cause of injury were observed for the level of fractured vertebrae in the discontinuous group.

Analysis of old vertebral fracture

When deformed vertebrae, which did not exhibit signal change, were considered old vertebral fractures, such fractures existed in 22 of 43 continuous-type cases (51%) and 25 of 34 discontinuous-type cases (74%). The discontinuous group exhibited a larger number of old vertebral fractures, but the difference was not significant. The variables of patients with old vertebral fractures in the continuous and discontinuous groups were as follows: mean age (77.2 ± 7.4 vs. 78.5 ± 9.1 years, respectively), sex (8 male/14 female vs. 6 male/19 female, respectively), and mean BMD value (0.716 ± 0.156 vs. 0.575 ± 0.095 g/cm^3, respectively).

Fractures involving ≥3 vertebrae

Fractures involving ≥3 vertebrae in the continuous and discontinuous groups were detected in 9 of 43 cases (21%) and 6 of 34 cases (18%), respectively. The number of continuous fractures at each level was as follows: T3-5 (1 case), T4-6 (1 case), T11-L1 (1 case), T12-L2 (2 cases), L1-3 (3 cases), and L2-4 (1 case). There was a tendency (67%) for the fractures to occur at the thoracolumbar junction. The number of discontinuous fractures at each level was as follows: T7, T8, T11 (1 case); T9, T12, L1 (1 case); T10, T11, L1 (1 case); T10, L1, L3 (1 case); L1, L3, L4 (1 case); and L1, L4, L5 (1 case). The fractures occurred at a variety of levels and were not concentrated to the thoracolumbar junction.

Analysis of fracture morphology

The morphology of the fractures was classified into the following groups: insufficiency fracture, which could be diagnosed only by MRI; compression fracture, which exhibited greater compression of the anterior wall compared with the posterior wall; wedged vertebra, in which the anterior wall could not be observed; fish vertebra, which feature vertebrae with a depression in the center; flat vertebra, which exhibits compression of both the anterior and posterior walls; and burst fracture, which exhibits fractured bone from the posterior wall to the spinal canal. A comparison between continuous and discontinuous fractures in both groups was made (Table 2).

Fisher's exact test was performed and the level of significance was adjusted by Bonferroni's correction. Insufficiency fracture occurrence within the continuous and discontinuous groups was 54% (53/97) and 22% (17/76), respectively, with the continuous group exhibiting a significantly larger value ($P < 0.0001$). Compression fracture occurrence within the continuous and discontinuous groups was 28% (27/97) and 53% (40/76), respectively, with the discontinuous group exhibiting a significantly larger value ($P = 0.002$). Wedged vertebra occurrence within the continuous and discontinuous groups was 0% (0/97) and 11% (8/76), respectively, with the discontinuous group showing a significantly larger value ($P = 0.001$).

Evaluation of osteoporosis

BMDs were measured at the bilateral femoral neck by DXA and a T value <70% was defined as osteoporosis. The cause of injury was then analyzed. Sixteen patients had osteoporosis (continuous type, 5 patients; discontinuous type, 11 patients). High-energy trauma, minor-energy trauma, and unknown cause were determined in 0, 6, and 10 of these patients, respectively. Six patients yielded a T value ≥70% (continuous type, 5 patients; discontinuous type, 1 patient), and high-energy trauma, minor-energy trauma, and unknown cause were identified in 2, 3, and 1 patient, respectively. The Chi-square test of patients with a T value <70% demonstrated a significant difference ($P = 0.013$).

Discussion

Spinal compression fractures are often encountered in daily practice, and compression fractures are generally diagnosed by plane radiograph. However, diagnosis of fresh vertebral fractures by plane radiograph is difficult. MRI is the most reliable approach for the diagnosis of fresh vertebral fractures and there is a report that showed single and/or MVFs are frequently a cause of low back pain and/or thoracic pain in elderly patients [9]. In our hospital, many patients presented with acute low back pain and/or thoracic pain, and were diagnosed with fresh vertebral fractures by MRI. MVFs often were observed in the MRI diagnoses.

Osteoporosis is a decrease in bone mass most commonly seen in women in the post-menopausal period. It is a decrease not only in the mineral component (such as calcium and phosphorus), but also in the organic component (such as protein) of bone. Approximately 15-20 million people have osteoporosis, and more than one-half a million people suffer spinal fractures due to osteoporosis each year. These fractures can occur with minimal trauma or no trauma at all. Osteoporotic patients with thoracic or low back pain have a risk of compression fracture even if the cause of trauma is not clear, and multiple vertebrae can be affected. Multiple fractures can exist on skipped vertebrae. Osteoporotic patients with thoracic or low back pain should have their thoracic and lumbar spine examined by MRI. It is possible that patients with discontinuous fractures have severe osteoporosis, and face a higher risk of additional fractures compared to patients with continuous fractures. A detailed examination for osteoporosis should be made in patients with discontinuous vertebral fractures.

In this review, MRI diagnosed fresh MVFs. However, Ichimura [10] reported that the intravertebral signal change in MRI T1-weighted images returned to normal within 6 months in many cases. Black and colleagues [11] reported that only 33% of vertebral fractures were clinical fractures with pain, and there are morphological fractures that do not exhibit symptoms. Vogt and colleagues [12] reported that only 20-33% of vertebral fractures are presented for diagnosis. Based on these reports, we cannot rule out the possibility that the vertebral fractures in our study were caused by multiple injuries. However, as the center of gravity of the trunk moves to the frontal side in osteoporotic vertebral fractures, the vertebrae adjacent to the fractured vertebrae are exposed to higher mechanical stress [13], and one VCF raises the fracture risk of the adjacent vertebrae by five times or more [14]. Thus, it is unlikely that discontinuous MVFs are caused by multiple traumas. We predicted that the kyphotic deformity of elderly patients was the reason for many skipped vertebral fractures in osteoporotic patients; therefore, we evaluated the kyphotic angle of the thoracolumbar junction and the lordotic angle of the lumbar spine; however, we observed no significant difference between the continuous and discontinuous groups.

In this study, a larger number of old fractures—defined as vertebrae without T1 low signal or STIR high signal—was observed in the discontinuous group; however, the difference was not significant. This result suggests that a higher risk of compression fracture exists in osteoporotic patients. Patients with discontinuous MVFs complicated with old fractures should be treated aggressively for osteoporosis.

Although DXA was used to measure BMD in only 22 of 77 subjects, a T value <70% was defined as osteoporosis, and we analyzed the cause of injury for those patients. Osteoporotic patients had significantly larger numbers of discontinuous fractures, and mild trauma or unknown cause was significantly more common than high-energy trauma. From these results, discontinuous MVFs suggest the existence of osteoporosis, and aggressive treatment for osteoporosis should be indicated.

Limitations

In this study, the majority of patients did not have their BMD measured by DXA. In addition, the medical interview for compression fracture patients did not include questions to clarify the presence or absence of osteoporosis or secondary osteoporosis (e.g., steroid use). To identify the relationship between osteoporosis and discontinuous MVFs, a definitive diagnosis of osteoporosis, followed by a comparison between continuous and discontinuous MVFs would be necessary.

Moreover, as there is no method to determine whether the fractures of multiple vertebrae occurred at the same time, vertebral fractures diagnosed by MRI might include not only acute-phase fractures, but also fractures that occurred within the past 6 months.

Conclusions

A higher proportion of discontinuous MVFs might be caused by mild outer force, and osteoporosis might be a contributing factor. A higher proportion of continuous MVFs might be caused by high-energy trauma.

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Table 1 Comparison between patients with continuous and discontinuous multiple vertebral fractures

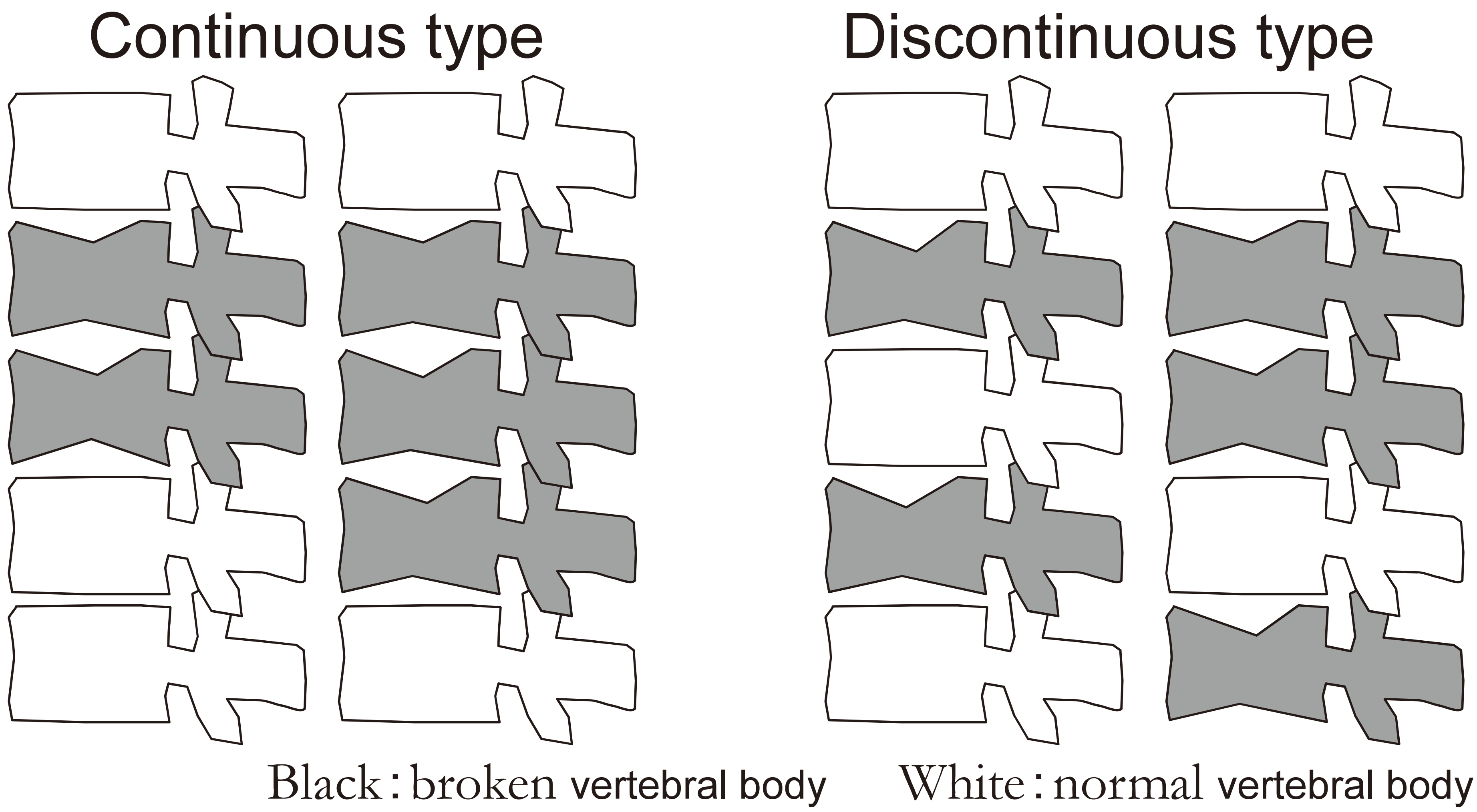
	Continuous(n = 43)	Discontinuous(n = 34)	P value
Male:female ratio	25:18	10:24	0.008
Age (years)	66.8 ± 18.5	76.6 ± 10.0	0.006
Body height (cm)	156.5 ± 11.8	153.0 ± 11.2	NS
Body weight (kg)	56.0 ± 12.6	51.3 ± 12.9	NS
Retrospective fractureof the proximal femur, no.	0	0	
Old vertebral body fracture, no. (%)	22 (51)	25 (73)	NS
Kyphosis of the thoracolumbar spine (T10-L2)	27.4° ± 14.9°	25.5° ± 13.0°	NS
Lordosis of the lumbar spine (T12-S1)	22.4° ± 12.1°	23.5° ± 15.0°	NS
Bone mineral density (g/cm^3) (no.)	0.748 ± 0.172 (10)	0.571 ± 0.091 (12)	0.016
Pain relief periods (days)	43.5 ± 28.5	39.8 ± 24.3	NS

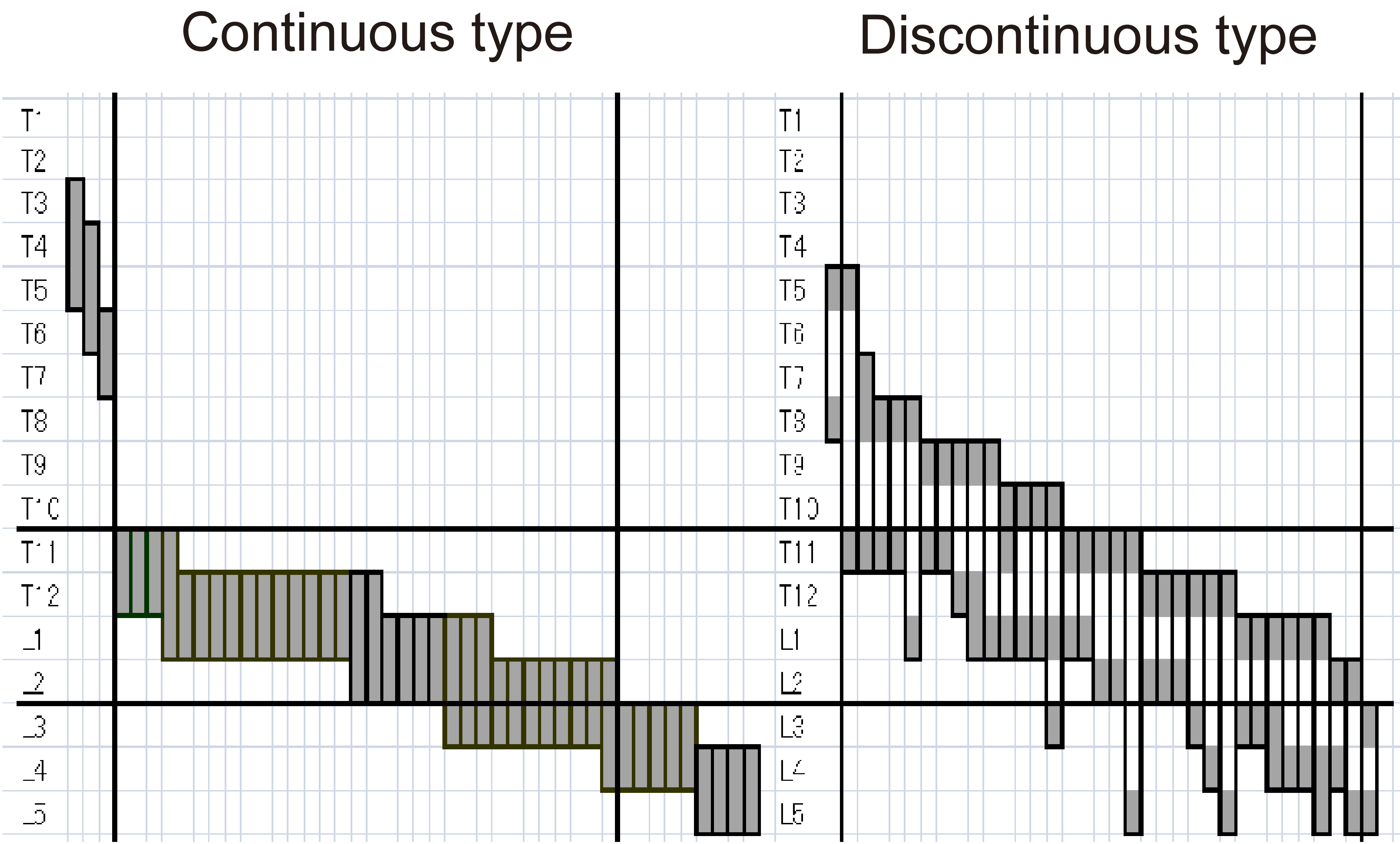
NS not significant

Table 2 Number of vertebral bodies classified by fracture type

Fracture type	Continuous, no. (%)	Discontinuous, no. (%)	P value
Insufficiency fracture	54 (56)	17 (22)	<0.0001
Compression fracture	27 (28)	40 (53)	0.002
Fish vertebra	8 (8)	2 (3)	NS
Flat vertebra	5 (5)	7 (9)	NS
Wedge vertebra	0 (0)	8 (11)	0.001
Burst fracture	3 (3)	2 (3)	NS
Total	97	76	

NS not significant


Continuous type
Discontinuous type
Black : broken vertebral body
White : normal vertebral body


Continuous type
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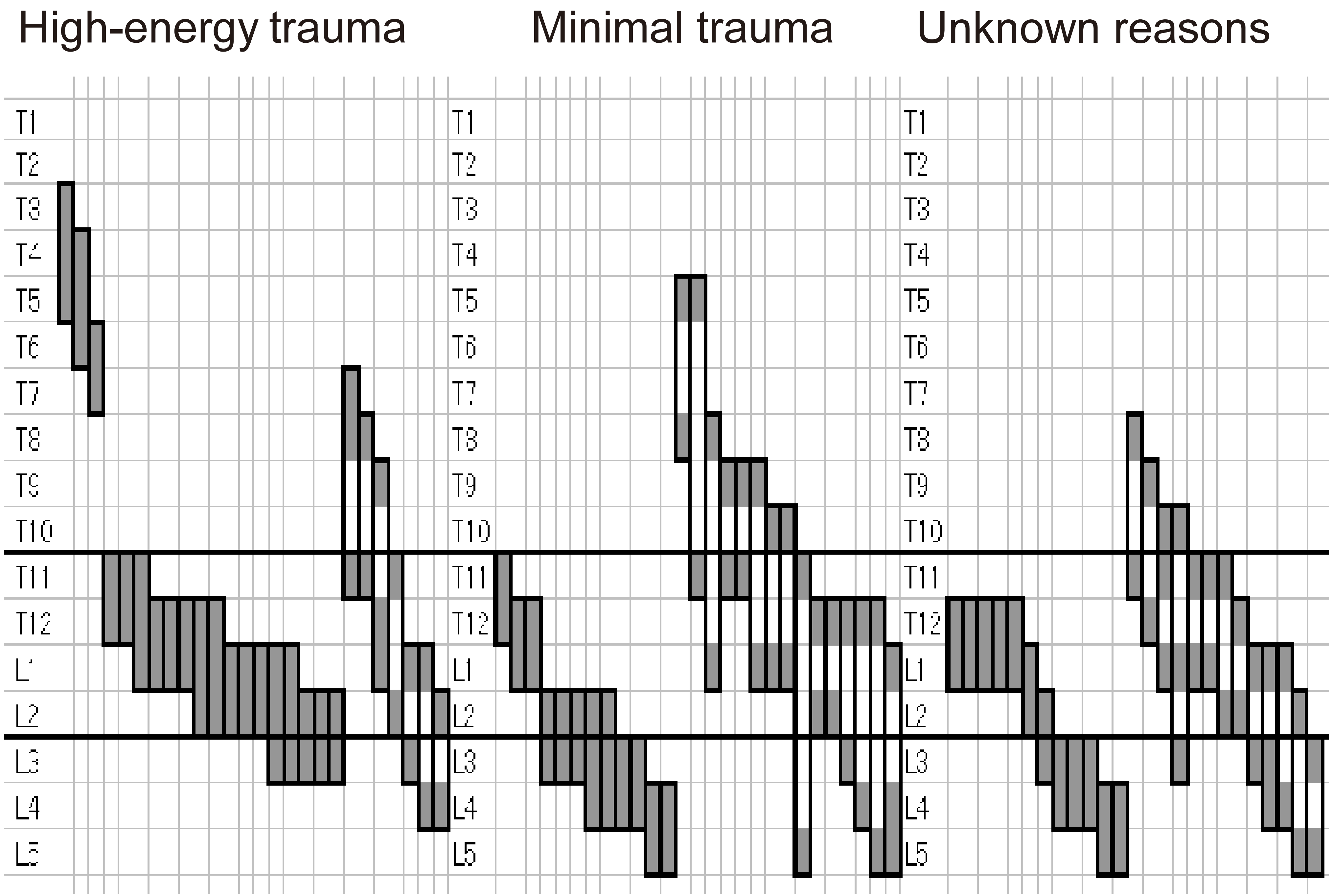
High-energy trauma
Minimal trauma
Unknown reasons
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