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# Characteristics of adolescent lumbar spondylolysis with acute unilateral fatigue fracture and contralateral pseudoarthrosis

Masaki Tatsumura[1], Shun Okuwaki[2], Hisanori Gamada[2], Fumihiko Eto[1], Katsuya Nagashima[1], Sho Iwabuchi[1], Takeshi Ogawa[1], Takeo Mammoto[1], and Atsushi Hirano[1]

[1]*Department of Orthopaedic Surgery and Sports Medicine, Tsukuba University Hospital Mito Clinical Education and Training Center/Mito Kyodo General Hospital, Japan*
[2]*Department of Orthopaedic Surgery, Faculty of Medicine, University of Tsukuba, Japan*

## Abstract

**Purpose:** This study aimed to examine the characteristics of lumbar spondylolysis with acute lumbar spondylolysis on one side and pseudoarthrotic spondylolysis on the other, relative to acute lumbar spondylolysis on one side only.
**Patients and Methods:** Short-tau inversion recovery images obtained through magnetic resonance imaging were used to diagnose 58 patients with acute lumbar spondylolysis with bone marrow edema on one side only. A total of 20 patients who had pars defects on the contralateral side (terminal-stage pseudoarthrotic spondylolysis) were included in the contralateral pseudoarthrosis group (P group). The remaining 38 patients with normal images for the contralateral pars interarticularis were included in the unilateral lesion group, in which the contralateral side was normal (U group). We investigated the union rate, age, sex, lesion laterality, vertebral level, pathological stage, and existing spina bifida occulta in both groups.
**Results:** The P group was characterized by a higher proportion of right-side cases, L5 lesions, more progressed pathological stage, and spina bifida occulta and a significantly lower union rate than the U group.
**Conclusion:** The union rate in patients with lumbar spondylolysis with acute lumbar spondylolysis on one side and pseudoarthrotic spondylolysis on the opposite side was only 15%. We should inform patients with acute unilateral spondylolysis lesions and contralateral pseudoarthrosis about this poor union rate and urge them to choose their therapy accordingly.

**Key words:** lumbar spondylolysis, union rate, contralateral pseudoarthrotic lesion, treatment failure, adolescent

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## Introduction

Lumbar spondylolysis is a stress fracture at the pars interarticularis. It is a major sports-related disorder and the most frequent cause of low back pain in adolescent athletes. Most cases of acute lumbar spondylolysis are cured by conservative therapy[1]; however, occasionally, the union may fail and result in pseudoarthrosis. Some athletes are forced to retire from their sport because of back pain caused by spondylolysis[2].

Delay in diagnosis occurs because the back pain caused by spondylolysis may not be severe and doctors may therefore inadequately examine the patients. Such delays can lead to unilateral pseudoarthrosis before the athlete is aware of the deterioration. Hence, we often detect an acute pars fracture on one side and pseudoarthrotic spondylolysis on the other at the athlete's initial visit to the hospital. However, imaging examinations can easily detect pseudoarthrotic spondylolysis although the detection of acute spondylolysis requires the use of magnetic resonance imaging (MRI). If an athlete who has pseudoarthrosis on one side is complaining of low back pain on the same side as that of pseudoarthrosis, the cause of pain is inflammation due to synovitis of the pseudoarthrosis[3]. On the other hand, if the athlete complains of pain on the opposite side, pain caused by acute

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Correnspondence: Masaki Tatsumura, Department of Orthopaedic Surgery and Sports Medicine, Tsukuba University Hospital Mito Clinical Education and Training Center/Mito Kyodo General Hospital, 3-2-7 Miyamachi, Mito, Ibaraki 310-0015, Japan
E-mail: tatsumura@md.tsukuba.ac.jp

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opposite spondylolysis should be suspected, and their MRI should be checked. It is known that when a bone defect occurs on one side of the vertebral arch, a fatigue fracture is likely to occur on the other side[4]. It implies that acute unilateral spondylolysis with contralateral pseudoarthrosis is hard to heal. This study aimed to examine the characteristics of lumbar spondylolysis with acute lumbar spondylolysis on one side and pseudoarthrotic spondylolysis on the other and compare them with acute lumbar spondylolysis on one side only.

## Patients and Methods

### Patients

From 2014 to 2017, 62 patients were diagnosed with acute lumbar spondylolysis with bone marrow edema on one side using short-tau inversion recovery (STIR) images obtained using MRI. We excluded 4 patients who had acute lumbar spondylolysis on both sides and who did not agree to receive conservative therapy. Thus, 58 patients were included in the study. The cleft in the contralateral pars interarticularis was evaluated. A total of 20 patients who had a pars defect on the contralateral side (terminal-stage pseudoarthrotic spondylolysis) were included in the contralateral pseudoarthrosis group (P group). As the control group, the remaining 38 patients with normal images for the contralateral pars interarticularis were included in the unilateral lesion group (U group). All patients presented to our institute with the chief complaint of low back pain.

### Methods

The conservative treatment strategy was to temporarily cease exercise, including physical education classes at school, and wear a hard back brace like a Knight brace. For the image-based evaluation, MRI STIR images were captured monthly. Conservative treatment was continued if MRI images showed bone marrow edema around the pedicle and discontinued when they showed a normal signal around the pedicle. Computed tomography (CT) was performed to confirm union or pseudoarthrosis with or without a bony bridge. Union was defined as bone filling the cleft in the pars in at least two of the three planes (sagittal, coronal, and axial). We retrospectively investigated the spondylolysis union rate in both groups.

In addition to the union rate, we investigated patient age, sex, lesion laterality, vertebral level, pathological stage, and existing spina bifida occulta (SBO). We defined SBO possession as having a neural arc cleft in either the lumbar spine or S1. Additionally, all the lesions were classified based on CT for sagittal pathological staging (stages 0, 1a, 1b, 1c, and 2)[5]. In the P group, we also investigated whether there was a history of low back pain that could be a symptom of contralateral spondylolysis in the past. The chi-square test was used for the statistical analysis of the union rate, sex ratio, lesion laterality, vertebral level, and pathological stage in both groups. The *t*-test was used for the analysis of age. A *P*-value <0.05 denoted a statistically significant difference. Informed consent was provided by all patients, and all procedures performed were approved by the institutional review board in this study.

## Results (Table 1)

Bony union was achieved only in 3 of 20 patients (15%) in the P group but 33 of 38 patients (89%) in the U group. The union rate in the P group was significantly lower than that recorded in the U group ($P<0.01$) (Figure 1a).

The P group comprised 15 males and 5 females with an average age of 14.2 years (11–17 years). The U group comprised 31 males and 7 females with an average age of 14.5 years (10–18 years) (Figure 1b). There was no significant difference in age ($P=0.45$) or sex ratio ($P=0.56$).

With respect to the laterality of the spondylolysis lesions, the P group had 15 lesions on the right side and 5 on the left side, whereas the U group had 10 and 28, respectively. The P group had significantly more lesions on the right side ($P<0.01$) (Figure 1c).

**Table 1** Clinical characteristics of the two study groups

| | | P group (N=20) | U group (N=38) | |
|---|---|---|---|---|
| Union (union rate) | | 3 (15%) | 33 (89%) | ** |
| Average age | | 14.2 | 14.5 | |
| Sex | Male | 15 (75%) | 31 (82%) | |
| | Female | 5 (25%) | 7 (18%) | |
| Laterality | Right | 15 (75%) | 10 (26%) | ** |
| | Left | 5 (25%) | 28 (74%) | |
| Level | L3 | 1 (5%) | 3 (8%) | |
| | L4 | 1 (5%) | 13 (34%) | |
| | L5 | 18 (90%) | 22 (58%) | * |
| Sagittal stage | 0 | 0 | 4 (11%) | |
| | 1a | 5 (25%) | 14 (37%) | |
| | 1b | 3 (15%) | 10 (26%) | |
| | 1c | 2 (10%) | 7 (18%) | |
| | 2 | 10 (50%) | 3 (8%) | ** |
| SBO exiting | (+) | 16 (80%) | 20 (53%) | * |
| | (–) | 4 (20%) | 18 (47%) | |

The union rate in the P group was significantly lower than that observed in the U group ($P<0.01$). There was no significant difference in age ($P=0.45$) or sex ratio ($P=0.56$) between the groups. The P group had a higher proportion of right-side lesions ($P<0.01$). The proportion of L5 lesions was significantly higher in the P group ($P=0.01$). The proportion of stage 2 lesions was significantly higher in the P group ($P<0.01$). The proportion of spina bifida occulta was significantly higher in the P group ($P=0.04$). *$P<0.05$; **$P<0.01$. All statistical tests were based on proportions and not absolute numbers.

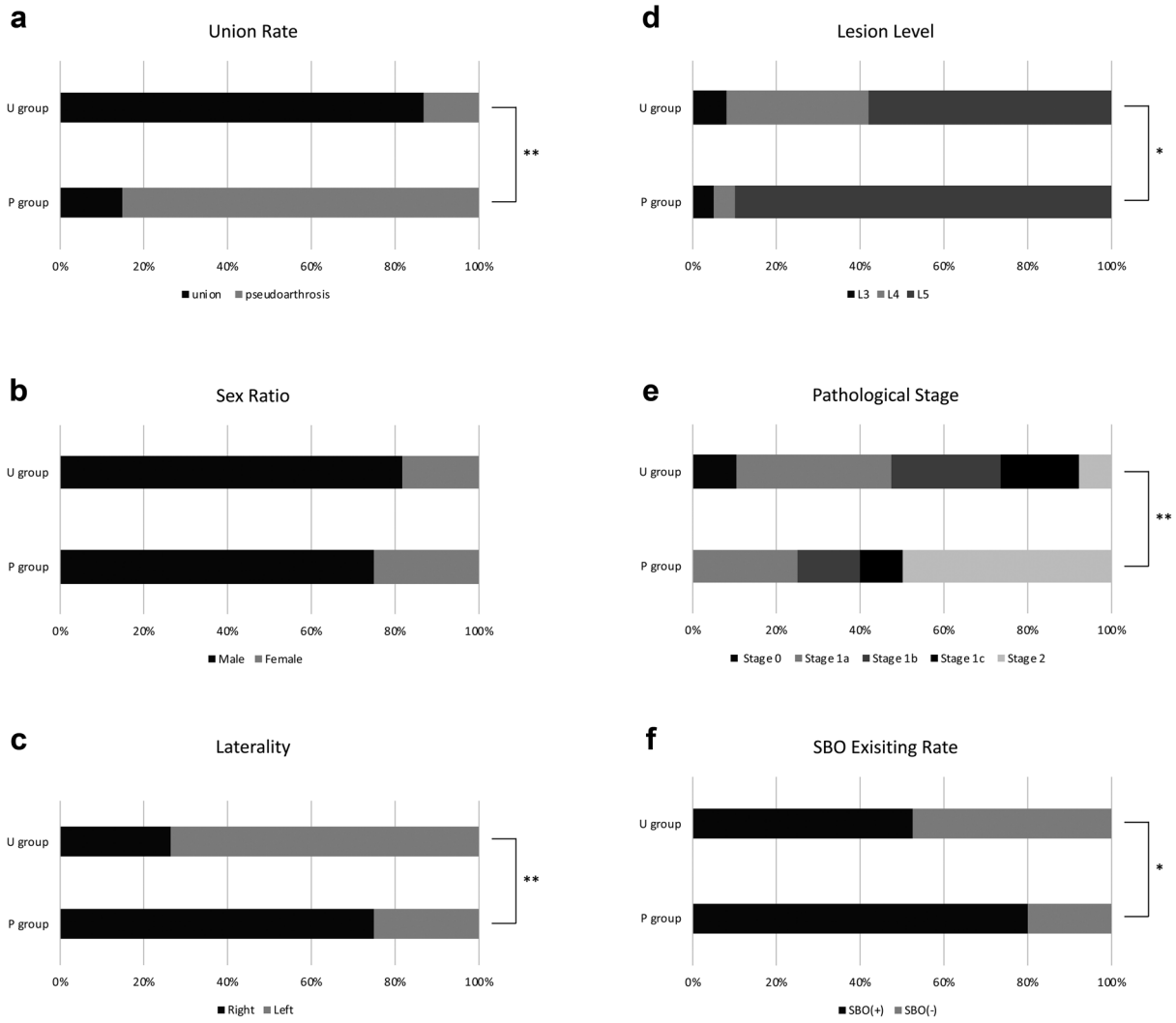


**Figure 1** Comparison of clinical characteristics of the two study groups.
a) The union rate was significantly lower in the P group than in the U group ($p < 0.01$). b) There was no significant difference in sex ratio. c) The P group had a higher proportion of right-side lesions ($p < 0.01$). d) The proportion of L5 lesions was significantly higher in the P group ($p = 0.01$). e) The proportion of stage 2 lesions was significantly higher in the P group ($p < 0.01$). f) The proportion of patients with spina bifida occulta was significantly higher in the P group ($p = 0.04$).

In the P and U groups, the presence of lesions in the lumbar vertebral level was as follows: L3, case 1 and 3; L4, case 1 and 13; and L5, case 18 and 22, respectively. The proportion of L5 lesions was significantly higher in the P group than in the U group ($P$=0.01) (Figure 1d).

Pathological staging of the fracture site was performed on the spondylolysis lesions. The sagittal stage classification in the P and U groups was as follows: stage 0, case 0 and 4; stage 1a, case 5 and 14; stage 1b, case 3 and 10; stage 1c, case 2 and 7; and stage 2, case 10 and 3, respectively. The proportion of stage 2 lesions was significantly higher in the P group than in the U group ($P$<0.01) (Figure 1e).

Existing SBO was observed in case 16 and 20 in the P and U groups, respectively. The proportion of cases with SBO was significantly higher in the P group than in the U group ($P$=0.04) (Figure 1f).

In the P group, 13 patients had a history of low back pain that may be a sign of contralateral spondylolysis. In other words, 7 patients had pseudoarthrotic spondylolysis without being aware of low back pain in the past.

Representative case 1 (P group)

A 15-year-old male baseball player with an L5 lesion recognized low back discomfort and then pain while running eight and two days, respectively, before his first visit to the hospital. At this visit, MRI STIR showed bone marrow edema on the right side only, around the pedicle (Figure 2a–2c). CT showed incomplete and complete bony clefts on the right and left sides, respectively (Figure 2d–2f). We

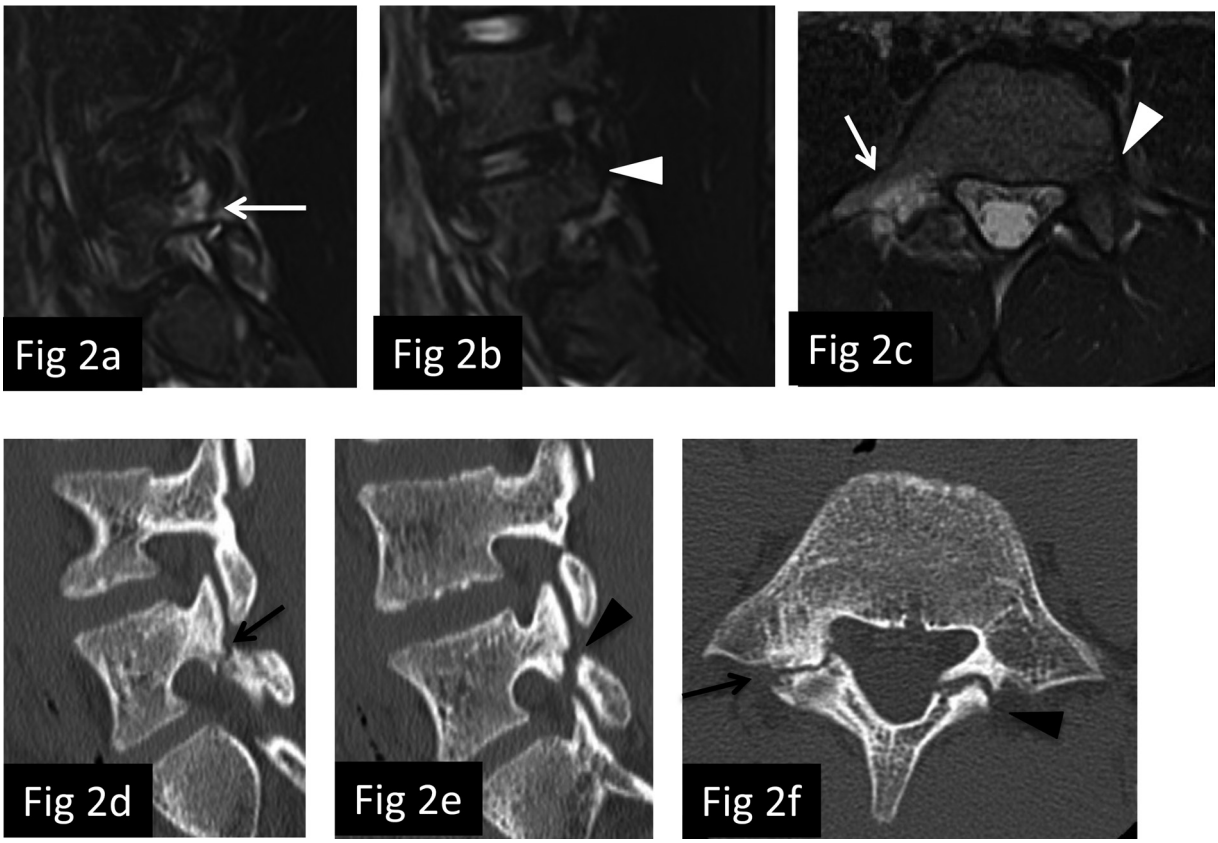


**Figure 2** Case 1 at his first visit to the hospital. a–c) MRI STIR showed bone marrow edema on the right side only, around the pedicle (white arrow), and was normal on the left side (white arrowhead). d–f) CT showed an incomplete bony cleft on the right side (black arrow) and a complete cleft on the left side (black arrowhead).
MRI STIR, magnetic resonance imaging short-tau inversion recovery; CT, computed tomography. (a and d: sagittal slices on the right, b and e: sagittal slices on the left, and c and f: axial slices on L5.)

diagnosed the patient with terminal-stage spondylolysis on the left side and acute spondylolysis on the right side. Conservative therapy with rest and the use of a hard back brace was prescribed. Five months after the first visit, MRI STIR showed a low signal, indicating that the bone marrow edema had reduced (Figure 3a–3c). In addition, CT showed a bilateral complete bony cleft (Figure 3d–3f). We concluded that the acute fracture at the pars had resulted in pseudoarthrosis.

Representative case 2 (U group)

A 14-year-old male baseball player with an L5 lesion became aware of back pain while playing catch two weeks before his first visit to the hospital. At this visit, MRI STIR showed bone marrow edema on the right side only, around the pedicle (Figure 4a–4c). CT showed incomplete and normal bony clefts on the right and left sides, respectively (Figure 4d–4f). Conservative therapy with rest and the use of a hard back brace was prescribed. Three months after the first visit, MRI STIR showed a low signal, indicating that the lesion had resolved (Figure 5a–5c), and CT revealed that bony union had been achieved (Figure 5d–5f).

## Discussion

In some athletes, spondylolysis develops on one side only[5]. Asymmetrical movement, such as throwing and kicking, is one of the causes of this effect. Hand and foot dominance results in asymmetrical movement that alters the frequency of the rotational direction of the lumbar spine. Some lumbar spondylolysis lesions exist on both sides at the same time, while others are present only on one side. Also, in bilateral spondylolysis, the pathological stage may be the same on both sides, or it may differ between sides. In this study, there were 38 cases of unilateral lumbar spondylolysis and 20 bilateral cases, including acute unilateral fracture and pseudoarthrosis on the opposite side. It is thought that mechanical distortion from unilateral spondylolysis increases the load on the opposite side, leading to the occurrence of a new spondylolysis on the contralateral side[6].

The vertebral body posterior surface, pedicle, and lamina arch form a bony ring structure in the normal lumbar vertebra and arch (Figure 6a). However, in cases with terminal-stage spondylolysis on one side, the bony ring structure

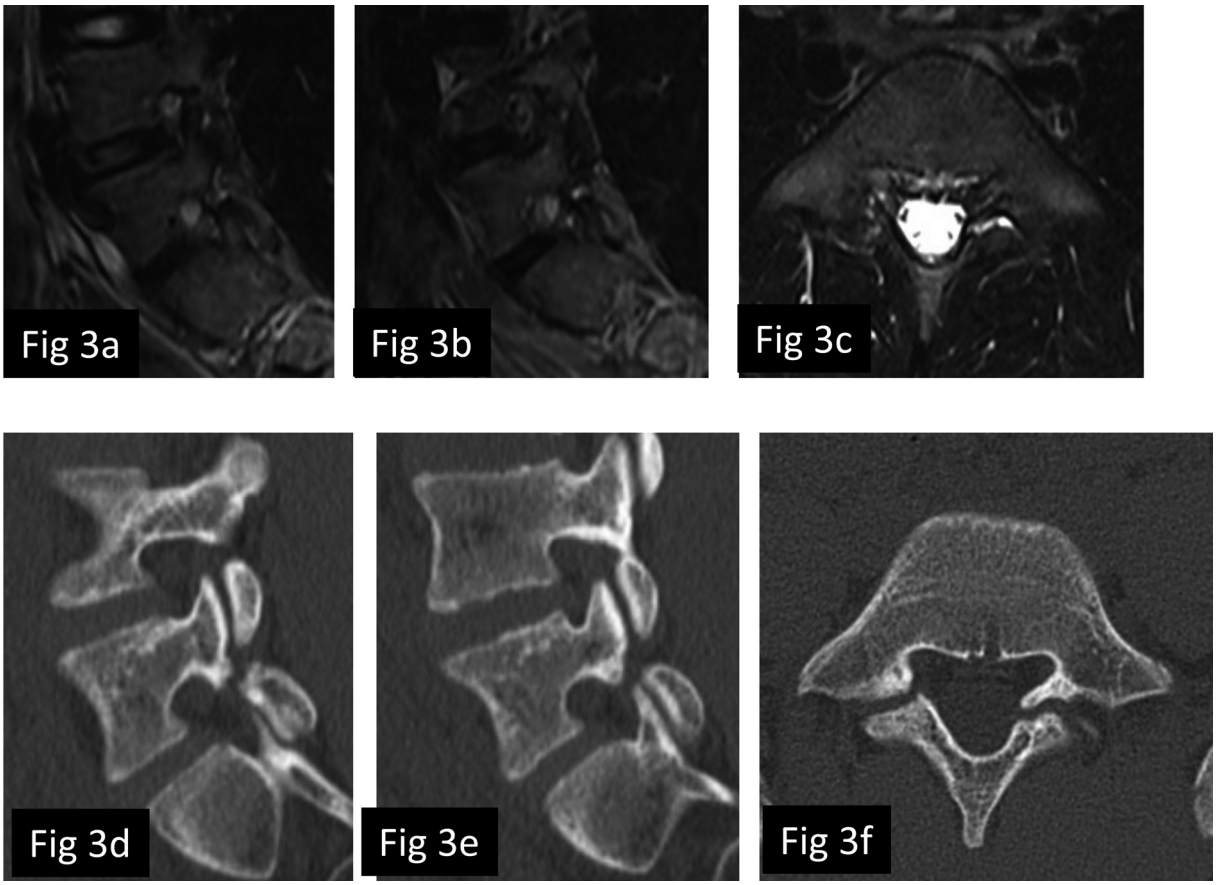


**Figure 3** Case 1 after conservative therapy. a–c) MRI STIR showed a low signal, indicating that the bone marrow edema had reduced. d–f) CT showed a complete bony cleft on both sides.
MRI STIR, magnetic resonance imaging short-tau inversion recovery; CT, computed tomography. (a and d: sagittal slices on the right, b and e: sagittal slices on the left, and c and f: axial slices on L5.)

fails (Figure 6b). Failure of the ring structure results in the concentration of stress at the pars interarticularis. Therefore, it seems likely that it requires only slight additional stress to cause spondylolysis. If new acute spondylolysis occurs when terminal-stage spondylolysis is already present on the contralateral side, it is caused by the asymmetrical mechanical load, which leads to the concentration of stress on the pars interarticularis[7]. If a bony cleft occurs on one side, even if exercise is temporarily ceased, the micromotions of daily life add to the stress on the contralateral side and make it difficult to achieve bony union.

With respect to laterality, the P group had a higher proportion of lesions on the right side. In other words, a high proportion of pseudoarthroses were noted on the left side in this group. Although the time of occurrence of the contralateral pseudoarthroses is unknown, it is certain that they occurred earlier than the lesions on the acute side. Combined with the fact that the proportion of lesions on the left side was higher in the U group, this suggests that lumbar spondylolysis is likely to occur first on the left side.

In the P group, L5 accounted for a large proportion of the presence of lesions in the lumbar vertebral level. It is considered that this is because the union rate by lesion level is low in L5 (our unpublished data). Thus, in L5, there is a high frequency of nonunion after unilateral spondylolysis. In other words, in L3 and L4, even if unilateral spondylolysis occurs, the probability of pseudoarthrosis is low, so L3 and L4 accounted for a small number in the P group.

Sairyo *et al.* suggested that the cause of pain in the terminal stage is communicating synovitis[3]. Pseudoarthrotic spondylolysis may cause low back pain. Hence, if plain X-ray examination or CT shows a visible bony cleft in the pars interarticularis, some doctors tend to conclude that the cause of low back pain is spondylolysis. In such cases, rest is ineffective because the lesion is pseudoarthrotic and cannot be cured by conservative treatment. However, if the patient complains of pain on the opposite side, it is possible that an acute fatigue fracture has occurred on the opposite side of the pseudo-joint. To avoid misdiagnosis, we should consider that the cause of the pain may be acute spondylolysis on

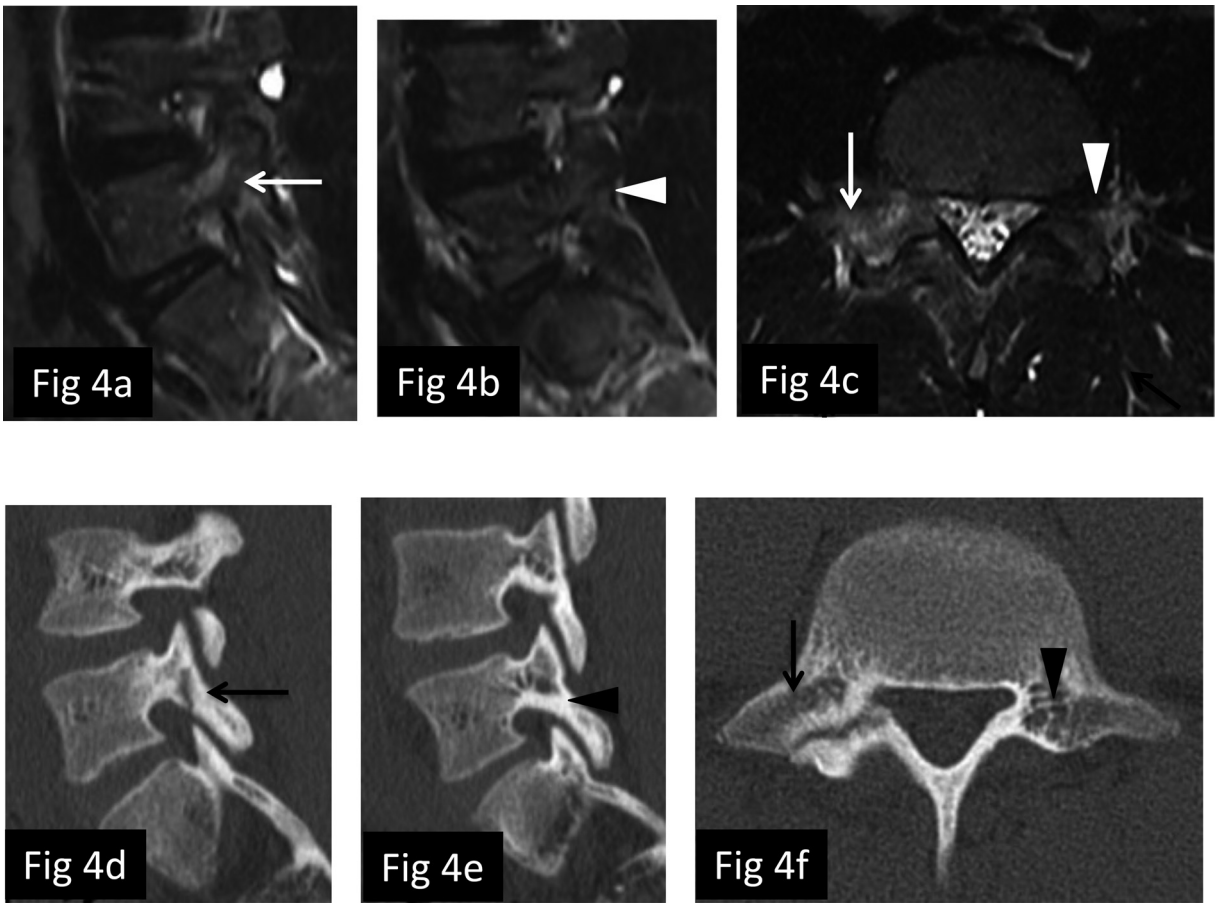


**Figure 4** Case 2 at his first visit to the hospital. a–c) MRI STIR showed bone marrow edema on the right side only, around the pedicle (white arrow), and was normal on the left side (white arrowhead). d–f) CT showed an incomplete bony cleft on the right side (black arrow) and was normal on the left side (black arrowhead).
MRI STIR, magnetic resonance imaging short-tau inversion recovery; CT, computed tomography. (a and d: sagittal slices on the right, b and e: sagittal slices on the left, and c and f: axial slices on L5.)

the opposite side to the pseudoarthrosis. In some clinical cases, plain X-ray examination or CT does not show a fracture line. Thus, it is necessary to perform MRI to check for bone marrow edema on the contralateral side. This indicates an acute fatigue fracture even in the presence of pseudoarthrosis on one side.

Some patients who had unilateral pseudoarthrotic lesions at their first visit to the hospital had not previously experienced low back pain. One reason for the absence of low back pain even with unilateral pseudoarthrosis is that instability between the vertebral body and lamina does not occur because there is still bony continuity on one side even if there is a bony cleft on the other (Figure 6b). However, it appears that the continuity of the lamina arch is impaired following the occurrence of an acute fatigue fracture in the pars interarticularis with contralateral pseudoarthrosis, leading to instability between the vertebral body and lamina, which induces strong pain.

With respect to the pathological stages, the proportion of stage 2 lesions was higher in the P group than in the U group. Stage 2 fractures penetrate up to two cortex bones. When spondylolysis occurs with contralateral pseudoarthrosis, we can say that the stage is likely to progress because the proportion of stage 2 lesions in cases where the lesions were obtained at the same time is higher in this study. The rapid progression from lesion occurrence to fracture means that delayed detection may often lead to pseudoarthrosis.

A high proportion of patients with SBO were noted in the P group. SBO is a risk factor for decreasing the union rate in spondylolysis[8], so it is likely that pseudoarthrosis occurs easily in these patients and the rate of unilateral pseudoarthrosis is higher.

Although the number of patients in this study was small (20 patients), we observed a distinctly low union rate in acute unilateral spondylolysis with contralateral pseudoarthrosis. The fact that the union rate in patients with unilateral lesions only was very high in this study implies that our conservative treatment strategy is appropriate. We believe

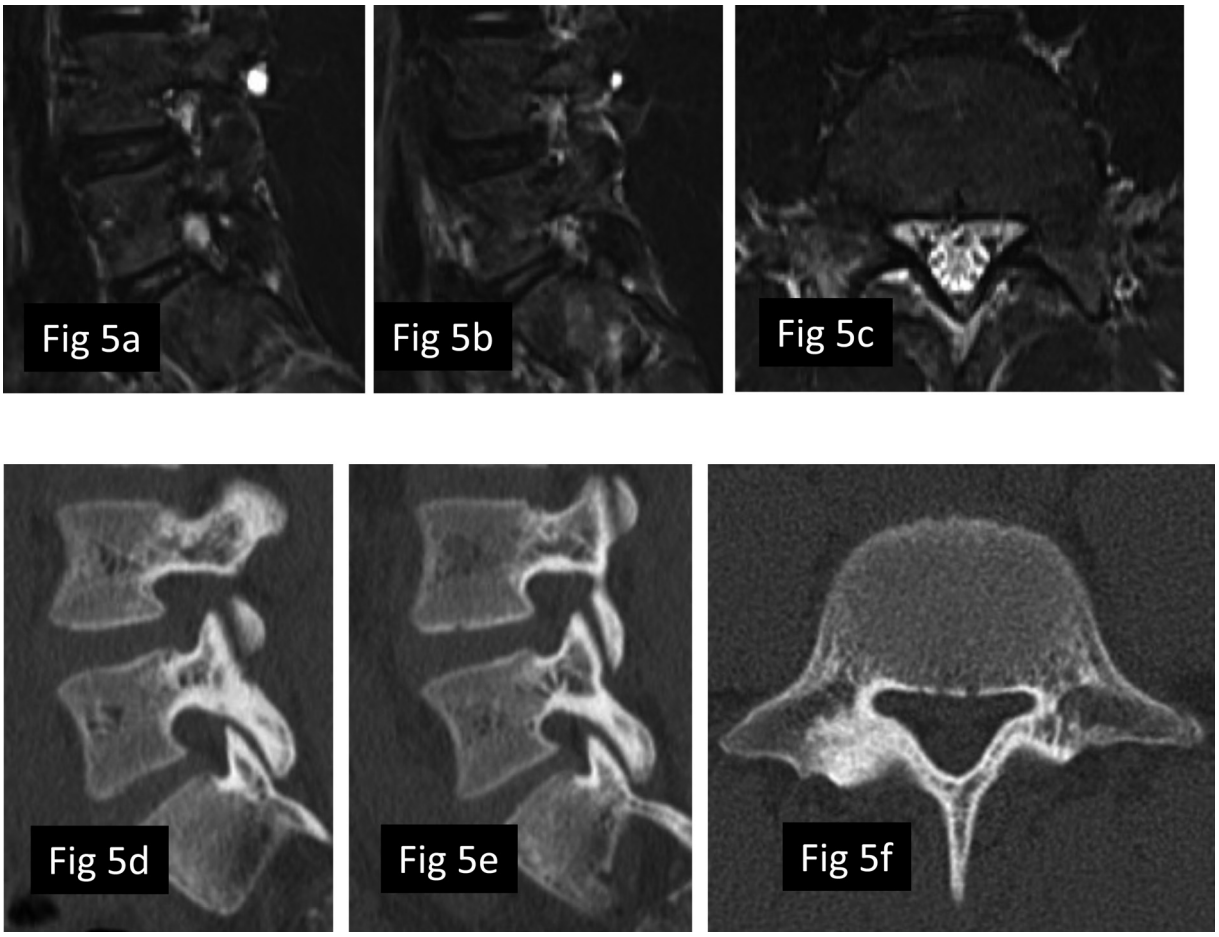


**Figure 5** Case 2 after conservative therapy. a–c) Three months after the first visit to the hospital, MRI STIR was normal. d–f) CT indicated bony union had been achieved.
MRI STIR, magnetic resonance imaging short-tau inversion recovery; CT, computed tomography. (a and d: sagittal slices on the right, b and e: sagittal slices on the left, c and f: axial slices on L5.)

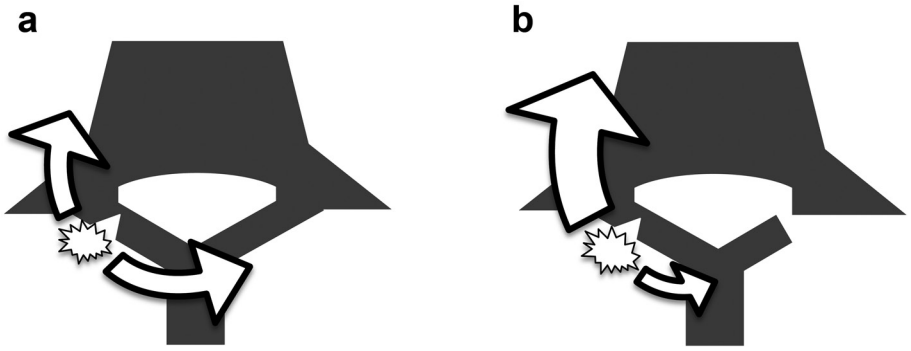


**Figure 6** The direction and magnitude of the mechanical load on the vertebral bodies, as indicated by arrows. a) In a normal spinal canal, the posterior wall of the vertebral body, pedicle, and vertebral arch form a ring structure, and the mechanical load is evenly distributed. b) Bone continuity is disrupted in patients with terminal-stage spondylolysis on the contralateral side. If an acute spondylolysis occurs, the mechanical load is uneven in the left and right directions, and stress concentrates on the acute side. This complicates the healing process.

that the reason for the low union rate in patients with contralateral pseudoarthrosis is the aforementioned mechanical effect. However, the proportions of patients with injuries at each vertebral level in the two groups differed, and the vertebral level may also affect the fusion rate.

Therefore, when treating acute spondylolysis with a contralateral pseudoarthrotic lesion, we should warn the patients and their families that with conservative therapy, the union rate is poorer than in unilateral lesions and urge them to choose their therapy accordingly. In addition, in cases where we treat spondylolysis with a unilateral pseudoarthrotic lesion, we try to prevent an acute spondylolysis lesion from occurring on the contralateral side. Since early detection is also important, spondylolysis is likely to occur in contralateral pseudoarthrotic cases, and therefore, when back pain occurs, an MRI is planned without waiting.

## Conclusion

We investigated the characteristics of lumbar spondylolysis with acute lumbar spondylolysis on one side and pseudoarthrotic spondylolysis on the opposite side. In patients with pseudoarthrosis on the contralateral side, the union rate on the acute fracture side was low. In addition, the proportion of cases with a more advanced pathological stage was higher in that group. When treating an acute spondylolysis lesion with contralateral pseudoarthrosis, patients and their families should be warned that the union rate under conservative therapy is poor and urged to choose their therapy accordingly. Since deterioration is rapid, prompt detection is crucial. In cases with spondylolysis with a unilateral pseudoarthrotic lesion, our aim is to prevent the occurrence of an acute spondylolysis lesion on the contralateral side.

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