Is the Scotty Dog Sign Adequate for Diagnosis of Fractures in Pediatric Patients with Lumbar Spondylolysis?

Masatoshi Morimoto[1)], Toshinori Sakai[1)], Tsuyoshi Goto[2)], Kosuke Sugiura[1)], Hiroaki Manabe[1)], Fumitake Tezuka[1)], Kazuta Yamashita[1)], Yoichiro Takata[1)], Takashi Chikawa[1)] and Koichi Sairyo[1)]

1) Department of Orthopedics, Institute of Biomedical Sciences, Tokushima University Graduate School, Tokushima, Japan
2) Department of Rehabilitation, Tokushima University Hospital, Tokushima, Japan

Abstract:

Introduction: Recent advances in diagnostic imaging, such as computed tomography (CT) and magnetic resonance imaging (MRI), have allowed early diagnosis of lumbar spondylolysis (LS). However, few outpatient clinics are equipped with such imaging apparatuses and must rely on plain radiographs for the diagnosis of LS. The aim of this retrospective study was to identify how accurately fracture lines can be detected on plain radiographs in patients with LS.

Methods: Patients with a diagnosis of LS were staged as early, progressive, or terminal. We evaluated whether fracture lines could be detected on plain radiographs and compared the detection rates under the following conditions: two directions including anteroposterior and lateral views (2 views), four directions including both oblique views (4 views), four directions including dynamic lateral views (4-D views), and all six directions (6 views).

Results: In early LS, the fracture line detection rate was 11.4% using 2 views, 20.5% using 4 views and 4-D views, and 22.7% using 6 views. In progressive LS, the fracture line detection rate was 54.2% using 2 views, 70.8% using 4-D views, 75.0% using 4 views, and 79.2% using 6 views. The respective detection rates for terminal LS were 85.0%, 100%, 100%, and 100%.

Conclusions: Although terminal LS was diagnosed accurately on plain radiographs in all patients, the detection rates were only 22.7% and 79.2% in patients with early and progressive LS, respectively. These results suggest that plain radiographic films can no longer be considered adequate for early and accurate diagnosis of LS. Advanced imaging procedures, such as MRI in the early diagnosis or CT for persistent cases, are recommended to obtain an accurate diagnosis of early stage LS in pediatric patients requiring conservative treatment to achieve bony healing.

Keywords:

low back pain, lumbar spine, pediatric stress fracture, spondylolysis

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Introduction

Lumbar spondylolysis (LS) is a bony defect of the pars interarticularis that occurs in approximately 6% of the general population and is identified more frequently in athletes[1-3)]. Although several factors may contribute to the occurrence of LS, it is generally considered to be a stress fracture resulting from low-grade trauma, such as repetitive extension or rotation of the lumbar spine while playing sports[4)]. The outcomes of conservative treatment in terms of bony healing have been reported. Moreover, recent advances in diagnostic imaging and treatment have allowed early diagnosis and improved the bony healing rates in patients with LS[5)].

Historically, Millard's "Scotty dog" sign, that is, bilateral pars defects on oblique projection plain radiographs that resemble a Scottish Terrier with a collar around its neck, has been used to diagnose LS[6)]. Nowadays, computed tomography (CT) and magnetic resonance imaging (MRI) are often used for early diagnosis of LS and decision-making regarding the treatment strategy[3,7,8)]. However, outpatient clinics are not usually equipped with such imaging apparatuses because of the high costs and maintenance involved, and therefore tend to rely on plain X-ray imaging alone.

Corresponding author: Toshinori Sakai, norinoridowluck@yahoo.co.jp
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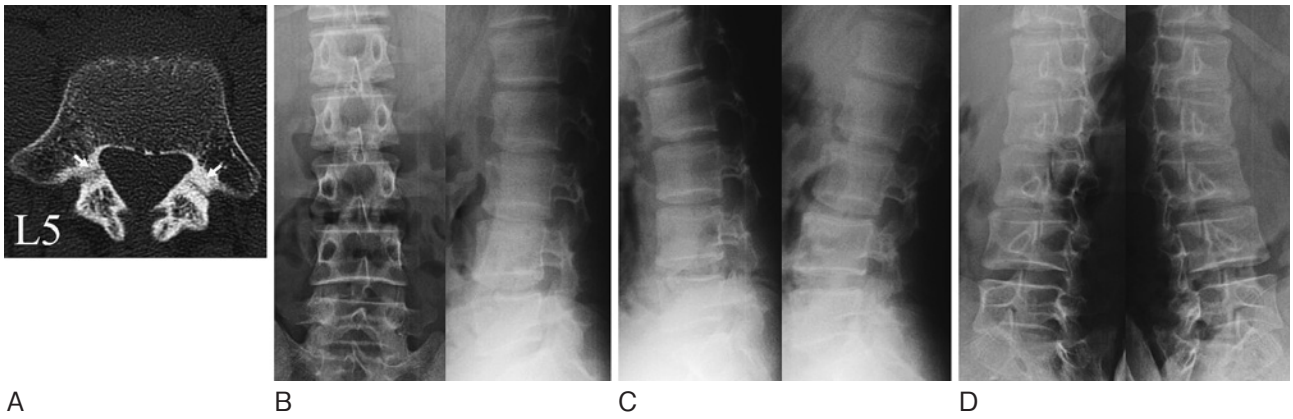

Figure 1. A reconstructed CT scan and plain radiographs for a 16-year-old boy with early spondylolysis. Staging of the fracture line was based on CT findings using reverse-gantry angles on the plane parallel to the pars interarticularis. (A) An oblique-axial CT scan shows a fissure-like hairline fracture in the pars interarticularis (arrow). (B-D) Plain radiographs including anteroposterior, lateral (B), dynamic lateral views (C) and oblique views (D), on which the fracture line is barely discernible.

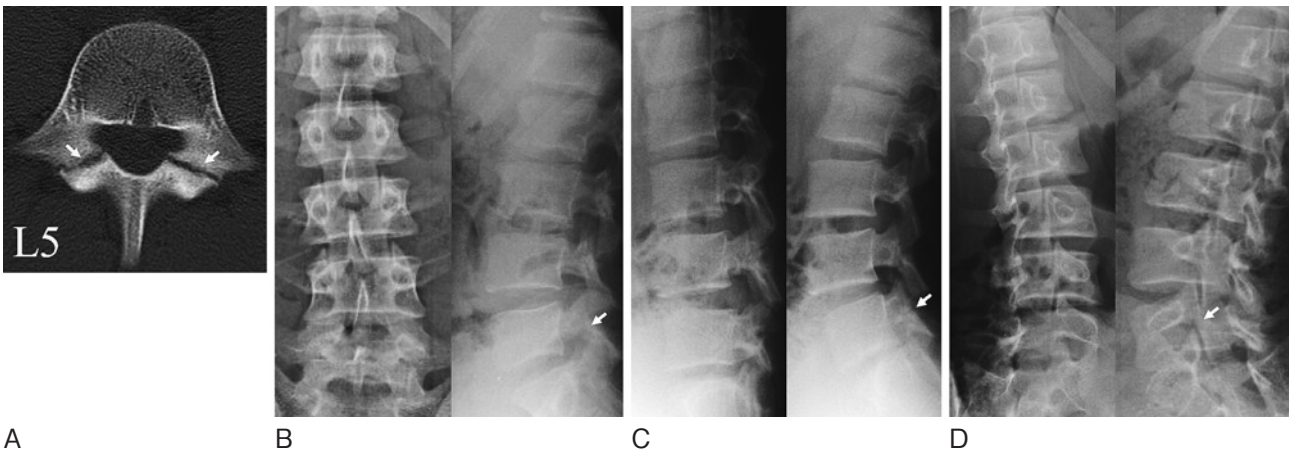

Figure 2. A reconstructed CT scan and plain radiographs for a 16-year-old boy with progressive spondylolysis. (A) An oblique-axial CT scan shows an obvious fracture line in the pars interarticularis (arrow). (B-D) Plain radiographs including anteroposterior, lateral (B), dynamic lateral views (C) on which the fracture line is not detectable, but dynamic lateral views (C) and oblique views (D), on which the fracture line is barely discernible.

The aim of this study was to determine the fracture line detection rate on plain radiographs in patients with LS already confirmed on CT.

Subjects and Methods

Subjects

We retrospectively searched our medical records database from January 2012 to January 2017 to identify pediatric patients who had been diagnosed as having early-, progressive-, or terminal-stage LS and in whom a fracture line had been detected on multi-detector CT. Following the previously reported criteria, early LS was defined as a fissure-like hairline fracture, progressive LS as an obvious fracture, and terminal LS as pseudoarthrosis[8-10] (Fig. 1-3). In all cases, the same certificated spine surgeon (TS), who had more than 20 years' experience, had made the definitive diagnosis and staged the fracture lines. Radiologic data of 52 pediatric patients comprising 42 boys (mean age 14.1 [range 9-17] years) and 10 girls (mean age 14.6 [range 12-17] years) were reviewed.

Methods

We assessed whether the fracture lines detected on CT could be seen on plain radiographs. Both the CT and the plain radiographs were taken at same day. The detection rates were compared under the following conditions: two directions, including anteroposterior and lateral views (2 views); four directions, including both oblique views (4 views); four directions, including dynamic lateral views (4-D views), and all six directions (6 views). The standard exposure conditions of the plain X-ray images in our institution were as follows (anterior view; 74 kV, 400 mA, 80 ms: lateral view and dynamic lateral view; 86 kV, 320 mA, 125 ms: oblique view; 80 kV, 400 mA, 80 ms). On the CT

Figure 3. A reconstructed CT scan and plain radiographs of a 15-year-old boy with terminal spondylolysis. (A) An oblique-axial CT scan shows pseudoarthrotic changes in the pars interarticularis (arrow). (B-D) Plain radiographs including anteroposterior, lateral (B), dynamic lateral views (C) and oblique views (D), on which fracture lines are clearly identified (arrow heads).

Table 1. Distribution of Lumbar Spinal Level.

Level	n	%
L3	1	1.1
L4	24	27.3
L5	63	71.6
Stage		
Early	44	50
Progressive	24	27.3
Terminal	20	22.7

scans, patients were scanned with 120 kV, 160-200 mA and 300-400 slices. However, these exposure conditions were changed according to the patient's physical constitution by two radiological technicians. Two general orthopedic surgeons (MM, KS) examined the plain radiographs taken at each patient's initial visit to determine whether the fracture line could be detected, and one (MM) conducted a second examination of the radiographs at an interval of more than 1 month.

Statistical analysis

Intra-class correlation coefficients (ICCs) were calculated to determine the levels of inter-observer and intra-observer agreement as well as the agreement between findings on plain radiography and those on advanced (gold standard) imaging. ICC of >0.81 indicates almost perfect, an ICC of > 0.61 represents substantial perfect and an ICC of >0.41 is considered moderate agreement. All statistical analyses were performed using SPSS version 21.0 (IBM Inc., Armonk, NY, USA).

Results

During the study period, 88 pars defects were detected in 52 pediatric patients. Sixty-three (71.6%) of the defects were at L5, 24 (27.3%) were at L4, and 1 (1.1%) was at L3 (Table 1). From the initial CT data, 44 (50.0%) of the defects were staged as early, 24 (27.3%) as progressive, and 20 (22.7%) as terminal (Table 1).

The fracture line detection rate in patients with early LS was 11.4% using 2 views, 20.5% using 4 views and using 4-D views, and 22.7% using 6 views. The detection rate in patients with progressive LS was 54.2% using 2 views, 70.8% using 4-D views, 75.0% using 4 views, and 79.2% using 6 views. The respective detection rates in patients with terminal LS were 85.0%, 100%, 100%, and 100%. The inter-rater reliability was 0.775 using 2 views, 0.864 using 4 views, 0.841 using 4-D views, and 0.886 using 6 views; the respective intra-rater reliability values were 0.864, 0.909, 0.909, and 0.888 (Table 2).

Discussion

In this study, fracture lines could only be identified on plain radiographs in 22.7% of patients with early LS and in 79.2% of those with progressive LS, even though the films were reviewed retrospectively. In terminal LS, 4 views or 4-D views allowed a 100% detection rate.

Millard recommended the Scotty dog sign, whereby the outline of a dog with a collar around its neck is seen in the oblique view of the lumbar spine[6] The collar corresponds to a bone fracture in the pars interarticularis, that is, a pars defect (spondylolysis). Although this sign is well-known and has been used to diagnose LS, Beck et al. reported that there was no difference in sensitivity or specificity between 4 views (anteroposterior, lateral, and bilateral oblique) and 2 views (anteroposterior and lateral)[11]. Amato et al. reported that LS was best detected on the collimated lateral view[12], whereas Gehweiler and Daffner and Libson et al. found that oblique views were necessary for diagnosis in only 12% and 20% of cases, respectively[13,14]. However, those reports were based on results obtained in patients with terminal LS and did not include patients with early or progressive LS. To the best of our knowledge, this is the first report that describes how well lines indicating impending fracture can be detected

Table 2. Diagnostic Rate of Each Stage of Lumbar Spondylolysis Using Plain X-ray Films.

	Stage				Reliability	
	Early [n (%)]	Progressive [n (%)]	Terminal [n (%)]	Total [n (%)]	Inter-rater	Intra-rater
2-views	5 (11.4)	13 (54.2)	17 (85.0)	35 (39.8)	0.775	0.864
4-views	9 (20.5)	18 (75.0)	20 (100.0)	47 (53.4)	0.864	0.909
4-D-views	9 (20.5)	17 (70.8)	20 (100.0)	46 (52.3)	0.841	0.909
6-views	10 (22.7)	19 (79.2)	20 (100.0)	49 (55.7)	0.886	0.888

on plain radiographs in patients with early or progressive LS.

Beck et al. reported that 2 views (anteroposterior and lateral) were adequate for diagnosis of LS, which might be terminal LS[11]. However, we found that even when plain radiographs for patients with terminal LS were evaluated retrospectively, the diagnostic rate was only 85% using 2 views but increased to 100% using 4 views or 4-D views. Based on our results, 2 views were not adequate for diagnosis of LS, and the diagnostic rate using 6 views was similar to those using 4 views or 4-D-views, though radiation exposure increases as the number of X-ray films increase. It should be recognized that 6 views do not provide a diagnostic benefit over 4 views and 4-D views for diagnosis of LS.

There have been several reports on the significance of early diagnosis in terms of bony healing in pediatric patients with LS. In 2012, Sairyo et al. reported their outcomes of conservative treatment in children with LS, which included bony healing rates of 90% and approximately 60% in patients with early and progressive LS, respectively[15]. Moreover, Sakai et al. have recently reported an 80% bony healing rate in patients with progressive LS[16]. Thus, although the importance of early diagnosis and optimal treatment has been emphasized for bony healing in these patients, our study findings suggest that the Scotty dog sign on plain radiographs is inadequate for diagnostic purposes and confirm that early and accurate diagnosis of LS is only possible on CT and MRI scans. However, the cost of the apparatus required and the examination fees are much higher for CT and MRI than for plain radiography. Furthermore, given that radiation exposure is much higher with CT, the frequency of examination needs to be kept as low as possible, particularly in children, who are more radiosensitive than adults[15,17]. Recently two systemic reviews of LS imaging were reported, and it is concluded that CT examination improves the diagnostic rate of LS compared to plain X-ray imaging, but radiation exposure may be concerned[16,18]. Therefore, the scan range should be limited to the level affected when performing follow-up CT studies[19].

We acknowledge that there are several limitations to this study because of its retrospective design. Quality of the X-rays might not be uniform although all of the X-rays were taken by only two radiological technicians because they usually change the exposure conditions based on each patient's physical constitution. We could detect the fracture line on plain radiographs in only 22.7% of patients with early LS and only 79.2% in those with progressive LS, even though the study was performed retrospectively. Therefore, even if the study had been prospective, the diagnostic rates would be unlikely to be higher than those reported here.

In conclusion, the Scotty dog sign can no longer be considered adequate for an early and accurate diagnosis of LS in pediatric patients.

Conflicts of Interest: The authors declare that there are no relevant conflicts of interest.

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Author Contributions: MM and TS wrote and prepared the manuscript, and all of the authors participated in the study design. All authors have read, reviewed, and approved the article.

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