Characteristics Associated With Active Defects in Juvenile Spondylolysis

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Abstract

Diagnosis is crucial in early-stage lumbar spondylolysis, as osseous healing can occur with conservative treatment. Single-photon emission computed tomography (SPECT) traditionally has been the most sensitive modality for diagnosing active (early) spondylolysis. More recently, high signal change (HSC) in the pedicle or pars interarticularis on fluid-specific (T2) magnetic resonance imaging (MRI) has been shown to be important in the diagnosis of early spondylolysis.

We conducted a study to determine the clinical and radiographic characteristics associated with the diagnosis of early or active spondylolysis. Fifty-seven patients with a total of 108 pars defects and a mean age of 14.6 years were retrospectively identified. Defects with a positive SPECT or HSC on T2 MRI were classified as active. There were 49 active and 59 inactive defects.

The active and inactive groups did not differ in age, body mass index, symptom duration, lumbar lordosis, pelvic incidence, slip percentage, or laterality. There was a difference in sex (35 vs 19 males; $P < .0001$) and presence of listhesis (16 vs 35; $P = .006$).

Active or early juvenile spondylolysis appears to be associated with male patients and the absence of listhesis, which may be important in identifying patients with a higher potential to experience osseous healing with nonoperative treatment.

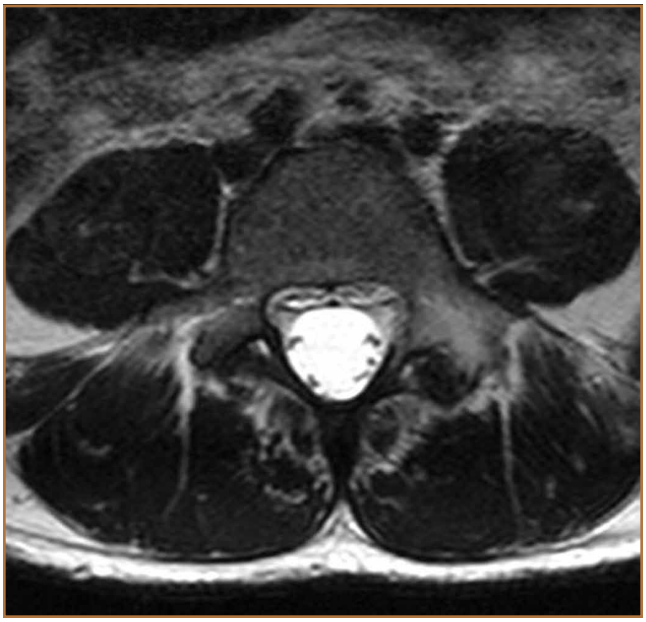
Spondylolysis, a defect in the pars interarticularis, is the single most common identifiable source of persistent low back pain in adolescent athletes.[1,2] The diagnosis of spondylolysis is confirmed by radiographic imaging.[3] However, there is controversy regarding which imaging modality is preferred—specifically, which to use for first-line advanced imaging after plain radiographs are obtained.[3] Single-photon emission computed tomography (SPECT) consistently has been shown to be the most sensitive modality, and it is considered the gold standard.[4-7] Patients with a positive SPECT scan are then routinely imaged with computed tomography (CT) for bone detail and staging of the pars defect.[8] This imaging or diagnostic sequence yields organ-specific radiation doses (15-30 mSv) as much as 50-fold higher than those of plain radiography.[9] Recent epidemiologic studies have shown that this organ dose results in an increased risk of cancer, especially in children.[10]

Diagnosis is crucial in early-stage lumbar spondylolysis, as osseous healing can occur with conservative treatment.[11,12] High signal change (HSC) in the pedicle or pars interarticularis (**Figure 1**) on fluid-specific (T2) magnetic resonance imaging (MRI) sequences has been shown to be important in the diagnosis of early spondylolysis and, subsequently, a good predictor of bony healing.[13,14] We conducted a study to determine the clinical and radiographic characteristics associated with the diagnosis of early or active spondylolysis.

Materials and Methods

The study was reviewed and approved by the local institutional review board. Using the *International Classification of Diseases, Ninth Revision* (*ICD-9*) diagnosis code for spondylolysis (756.11), we retrospectively identified patients (age, 12-21 years) from 2002–

Figure 1. Axial magnetic resonance imaging shows reactive edema of left pedicle adjacent to active pars defect.



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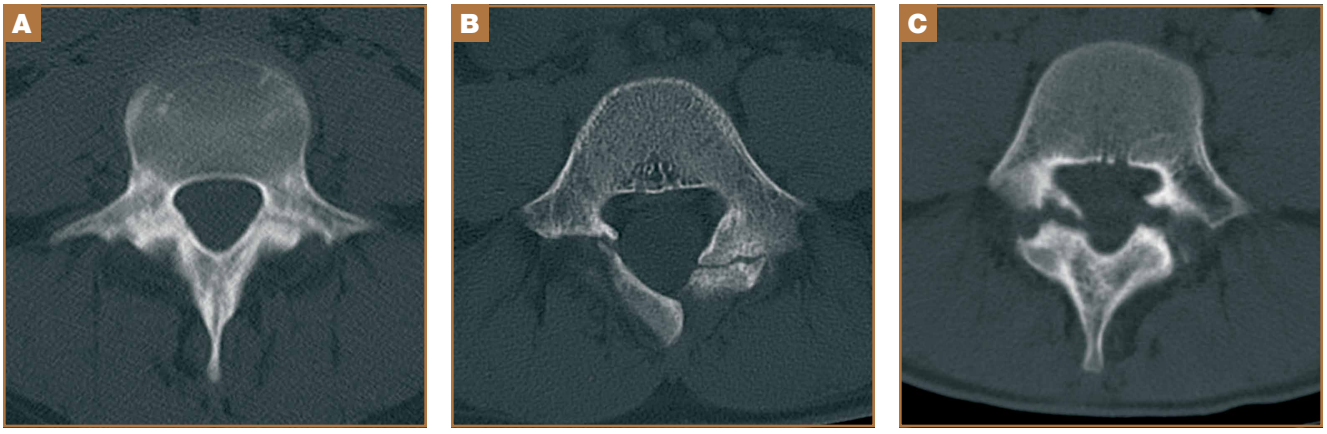

Figure 2. Representative axial computed tomography shows pars defects in (A) early stage, (B) progressive stage, and (C) terminal stage.

2011 billing data from a single specialty spine practice. Baseline data—including height, weight, sex, age, symptom duration, sporting activities, defect location, pain score, and previous treatments—were collected from a standardized patient intake questionnaire and office medical records. We also determined radiographic data, including level, laterality (right vs left, unilateral vs bilateral), presence of listhesis, and slip grade and percentage. CT scans were reviewed to confirm the spondylolysis diagnosis and to measure parameters described by Fujii and colleagues.[15] These parameters include spondylolysis chronicity (early, progressive, terminal) (**Figure 2**), distance from defect to posterior margin of vertebral body, and defect angle relative to posterior margin of vertebral body. We also measured sagittal radiographic parameters, including pelvic incidence and lumbar lordosis.

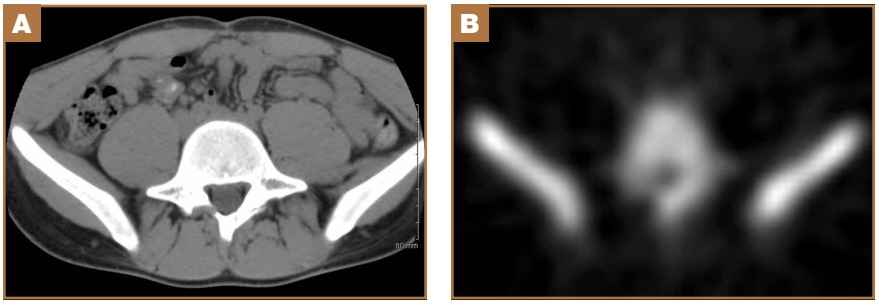

Figure 3. Example of single-photon emission computed tomography (SPECT) showing active defect on bony window of (A) computed tomography scan and (B) SPECT scan.

Pars lesions were divided into active and inactive defects[16] based on signal characteristics on either MRI or SPECT (**Figure 3**). Defects with a positive SPECT or HSC on T2 MRI were classified as active; all other defects were classified as inactive. All MRIs were reviewed by a radiologist, and any mention of HSC in the pedicle or pars of the corresponding level was considered positive. For the sake of accuracy, all MRIs were also reviewed by a spine surgeon. All CT measurements were done by 1 of 2 authors. Demographic, clinical, and radiographic characteristics were compared between patients with active defects and patients with inactive defects. Independent t tests and Fisher exact tests were used to compare continuous and categorical variables, respectively. Threshold P was set at .01 to account for the small sample size and multiple concurrent comparisons.

Results

Fifty-seven patients (29 males, 28 females) with a total of 108 pars defects (6 unilateral, 102 bilateral) were identified. Mean age was 14.64 years. Of the 108 defects, 49 were classified as active and 59 as inactive. SPECT results were available for 52 defects, MRI results for 85, and CT results for 76 (**Table 1**). There was no difference between the active and inactive groups in age (14.7 vs 14.6 years; P = .083), body mass index (24.2 vs 21.7 kg/m^2; P = .034), symptom duration

Table 1. **Distribution of Imaging Modalities**

	Defects	
Modality	**Inactive**	**Active**
Single-photon emission computed tomography		
Negative	18	3
Positive	0	31
Not available	40	15
Magnetic resonance imaging		
Negative	50	9
Positive	0	26
Not available	9	14
Computed tomography		
Available	37	39
Not available	22	10

(236.3 vs 397.4 days; P = .016), lumbar lordosis (27.4° vs 32.1°; P = .097), pelvic incidence (59.0° vs 61.2°; P = .488), slip percentage (9.5% vs 14.2%; P = .034), and laterality (right vs left, P = .847; unilateral vs bilateral, P = .281) (**Table 2**). There was a significant difference between the active and inactive groups in sex (35 vs 19 males; P < .0001) and presence of listhesis (16 vs 35; P = .006) (Table 2).

Of the 49 active defects, 3 were graded as early, 10 as progressive, and 11 as terminal (**Table 3**). There was a statistically significant (P < .0001) difference between active and inactive lesions for each stage. Mean distance from posterior margin of the vertebral body was 0.57 mm and 0.68 mm for inactive and active lesions, respectively (P = .007). There was no significant difference (P = .294) in the posterior angle of the vertebral body and the defect between inactive (20.54°) and active (24.73°) lesions (**Table 3**).

Subanalysis by sex showed no difference in age (males, 16.4 years vs females, 18.7 years; P = .073), slip percentage (10.4% vs 13.4%; P = .168), or presence or absence of slip (25 vs 26; P > .99) (**Table 4**).

Table 2. Summary Statistics Comparing Groups With Inactive and Active Defects

	Defect Group		
Variable	Inactive	Active	*P*
N	59	49	—
Males	19	35	<.0001
Slip			.006
0	24	33	
1	35	16	
Laterality			.407
Bilateral	57	45	
Unilateral	2	4	
Age, y	14.62	14.67	.083
Body mass index, kg/m^2	21.74	24.18	.034
Lumbar lordosis, °	32.08	27.38	.097
Preoperative slip, %	14.22	9.52	.034
Pelvic incidence, °	61.25	59	.488
Symptom duration, d	397.43	236.33	.016

Table 3. Distribution of Fujii Chronicity Score, Defect Distance, and Angle Among Groups With Inactive and Active Defects

	Defect Group		
	Inactive	Active	*P*
Fujii Chronicity Score			<.0001
1	0	3	
2	0	10	
3	25	11	
Defect distance, mm	0.57	0.68	.007
Angle, °	20.54	24.73	.294

Table 4. Subanalysis Comparing Male and Female Patients

	Patients		
Variable	Male	Female	*P*
Age, y	16.4	18.7	.073
Preoperative slip, %	10.4	13.4	.168
Slip present	25	26	>.99

Discussion

Increasing MRI resolution combined with increasing concern about unnecessary radiation exposure has added to the attractiveness of MRI in the diagnosis of spondylolysis. Spondylolysis progresses on a continuum, starting with a stress reaction (early or active defect) and ending with either healing or nonunion of the pars defect (terminal defect) (**Figure 4**). Although risk factors for progression are not clearly defined, Fujii and colleagues[15] showed that the reaction around the defect is the most important factor for osseous union. It would then make sense that the earlier the spondylolytic defect is identified, the higher the likelihood for union, especially with nonoperative treatment such as rest, activity restriction, and bracing.[12,17]

There is a lack of consensus regarding MRI use in the diagnosis of spondylolysis. Masci and colleagues[18] prospectively evaluated 50 defects in 39 patients using a 1.5-Tesla MRI scanner, concluded MRI is inferior to SPECT/CT, and recommended that SPECT remain the first-line advanced imaging modality. Conversely, Campbell and colleagues[4] prospectively evaluated 40 defects in 22 patients using a 1.0-Tesla magnet and concluded that MRI can be used as an effective and reliable first-line advanced imaging modality. These are the only 2 prospective studies conducted within the past decade. Both were underpowered and used outdated technology (newer MRI scanners use 3.0-Tesla magnets). In addition, specific imaging characteristics (eg, edema in pars or pedicle on fluid-specific sequences) that suggest a positive finding—versus overt fracture on T1 MRI—have been recently emphasized. Neither Masci and colleagues[18] nor Campbell and colleagues[4] detailed what constituted a positive MRI finding. Although an adequately powered prospective study will provide a better analysis of the utility of MRI versus SPECT, such a study is costly and time-consuming. It is important to identify patient and lesion characteristics to help optimize the usefulness of MRI. It is also important to identify the subset of patients most likely to experience osseous healing of active defects,[16] as this is the same subset of patients most likely to respond to nonoperative treatment.

We conducted the present study to identify any clinical or radiographic characteristics associated with the diagnosis of

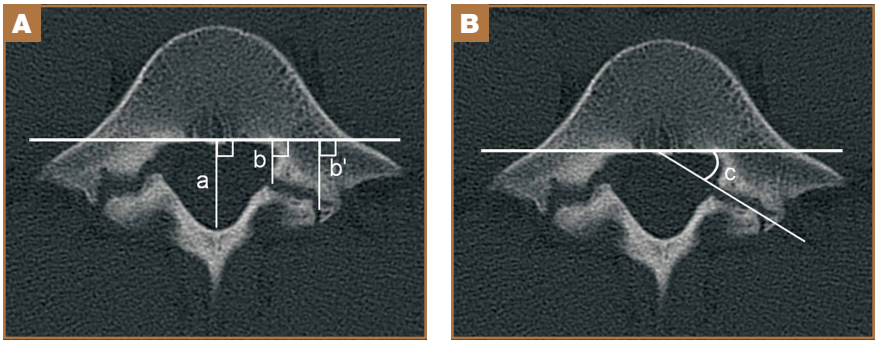

Figure 4. Measurement of pars defects on axial computed tomography. (A) Distance of defect from posterior margin of vertebral body calculated using formula: distance = (b + b′)/2a. (B) Angle of defect to posterior margin of vertebral body, c.

early or active spondylolysis. Almost equal numbers of active and inactive defects (49, 59) were identified. There were no differences in patient characteristics, including age, body mass index, and symptom duration. However, there was a significant sex difference—a relatively high proportion of males with active spondylolysis. This finding, which had been reported before,[16,19,20] is probably the result of several factors, including males' lower lumbar spine bone mineral density[21]; their relatively less spinal flexibility, which affects the distribution of torsional loads on the spine[22]; and their relatively greater participation in sports, especially sports involving high-velocity, torsional loading of the lumbar spine.[23] Studies are needed to delineate the extent to which sex influences the development and persistence of active spondylolytic lesions. Alternatively, a subanalysis revealed an age difference, between our female and male cohorts (18.7 vs 16.4 years), that may have contributed to the high proportion of males with active spondylolysis.

Although the groups' difference in symptom duration was not significant, it was trending toward significance. As discussed, it could be explained that, along the continuum of disease, earlier defects are more active and either achieve fibrous or osseous union or become chronic and "burn out" to inactive lesions, potentially leading to a listhesis.[24] The listhesis association was higher in the inactive group than in the active group ($P = .006$). The difference in numbers of active and inactive defects at each stage (early, progressive, late) confirms this finding, with no inactive lesions in the early and progressive stages and many fewer active lesions in the terminal stage. Overall, presence of a spondylolisthesis on plain radiographs may obviate the need for SPECT or MRI, as it indicates an inactive chronic lesion—unless new symptoms are suspicious for reactivation or development of previously described adjacent-level pars defects.

No other radiographic parameters were found to be significant—consistent with findings of other studies.[2,5,16] Pelvic incidence has been shown to predict progression of spondylisthesis, but under our study parameters it appears not to be associated with development of a slip.

This study had several weaknesses. First, it was retrospective, and imaging parameters were inconsistent, as we included patients who underwent imaging at other facilities. Second, the timing of imaging was inconsistent. Ideally, the same sequence protocol would be used, and all imaging studies (MRI, SPECT, CT) would be performed within a specific period after the initial concern for a spondylolysis was raised. Last, not all patients underwent all 3 advanced imaging modalities; having all 3 would have allowed for a retrospective comparison of MRI and SPECT sensitivity in detecting spondylolysis. Such a comparison would have been interesting, though it was not the goal of this study.

With its technological improvements and lack of radiation exposure, MRI is becoming more attractive as a first-line advanced imaging modality. Although the superiority of MRI over SPECT is yet to be confirmed, clinical use of MRI in the evaluation of spondylolysis seems to be increasing. It is therefore important to characterize the spondylolytic defects that are readily detected with MRI.

Active or early juvenile spondylolysis appears to be associated with males and absence of an associated listhesis. These clinical and radiographic characteristics may be important in the identification of patients with higher potential for osseous healing after nonoperative treatment.

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