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AJNR Am J Neuroradiol 1995, 16 (7) 1393-1398
http://www.ajnr.org/content/16/7/1393

Lumbar Spondylolysis without Spondylolisthesis: Recognition of Isolated Posterior Element Subluxation on Sagittal MR

John L. Ulmer, Vincent P. Mathews, Allen D. Elster, and James C. King

PURPOSE: To document the occurrence of isolated dorsal subluxation of posterior elements in cases of lumbar spondylolysis without spondylolisthesis both quantitatively (using spinal canal measurements) and qualitatively (by visual inspection) on sagittal MR images. **METHODS:** Retrospective analysis identified 63 patients with lumbar spondylolysis (confirmed by CT or conventional radiography) who had undergone MR imaging. From these we identified 12 patients with pars interarticularis defects but no evidence of spondylolisthesis. Measurements of anteroposterior spinal canal diameters were performed in these 12 patients to ascertain whether the sagittal canal diameter at the level of the spondylolysis exceeded the normal range as determined from 100 control subjects. **RESULTS:** In 9 of 12 patients the spinal canal was abnormally widened at the level of the spondylolysis because of dorsal subluxation of posterior elements. In 5 of these patients, the subluxation was readily visible on midline sagittal MR images. In 4 patients, spinal canal measurements were necessary to document this phenomenon. **CONCLUSION:** In the majority of patients with spondylolysis but without spondylolisthesis, sagittal MR images can show isolated dorsal subluxation of posterior spinal elements.

Index terms: Spine, dislocation; Spine, magnetic resonance

AJNR Am J Neuroradiol 16:1393–1398, August 1995

Lumbar spondylolysis is present in more than 14 million people in the United States, 25% of whom will eventually have significant low back pain or sciatica (1, 2). Although magnetic resonance (MR) imaging is widely used to evaluate such patients, it remains inferior to computed tomography (CT) for displaying defects in the pars interarticularis. The sensitivity of MR for detecting pars defects is even further reduced when there is coexisting facet joint degeneration, pedicle sclerosis, or spondylolysis without spondylolisthesis (2–5).

When both spondylolysis and spondylolisthesis are present, the anteroposterior diameter of the spinal canal becomes widened (2, 5–10). This phenomenon may be recognized as a "spinous process step-off sign" on conventional radiographs (10) or as a "wide-canal sign" on sagittal MR images (5). Recently, we noticed that in some patients with spondylolysis but without spondylolisthesis, dorsal subluxation of posterior elements may occur as an isolated sign of the open-arch defect (Fig 1). The goal of this study was to analyze and quantify this phenomenon, thereby determining the use of midsagittal MR images for revealing such a structural change in the posterior spinal column.

Subject and Methods

Reviewing medical records and radiology reports generated over a 4-year period, we identified 63 patients with lumbar spondylolysis who also had undergone MR imaging for lower back or radicular pain at our institution. From this group, 12 patients were found to have spondylolysis but no evidence of spondylolisthesis (ie, vertebral body subluxation) on sagittal MR images (Table). There were 9 male and 3 female patients, ranging from 17 to 63 years old (mean age, 36.3 years). Eight patients had bilateral pars defects at L-5, 2 patients had unilateral defects at L-5, 1 patient had bilateral defects at L-3, and 1 patient had bilateral defects at L-2. Defects in the pars interarticularis

Received September 13, 1994; accepted after revision February 8, 1995.

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AJNR 16:1393–1398, Aug 1995 0195-6108/95/1607–1393

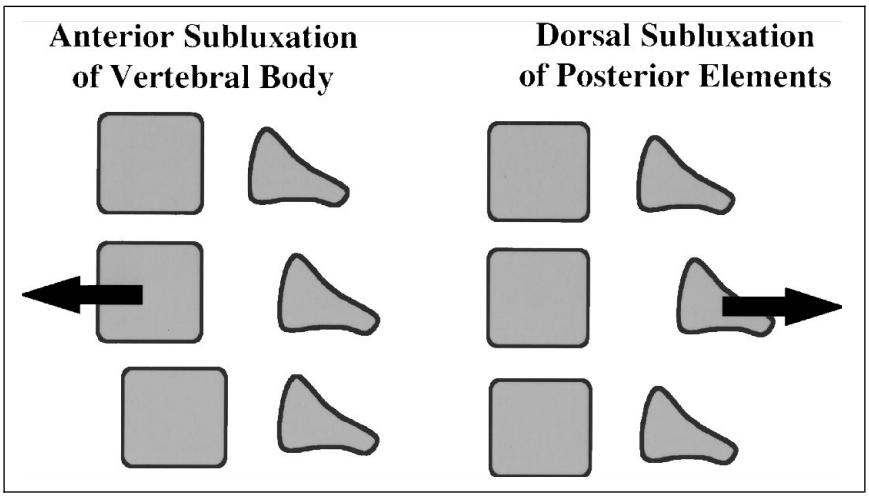

Fig 1. Diagram illustrates two forms of vertebral subluxation that may occur associated with spondylolysis: ventral subluxation of the involved vertebral body and isolated dorsal subluxation of posterior elements.

were confirmed by conventional radiography with oblique views in all patients, supplemented by CT in 7 patients.

All MR studies were performed using surface coils on a high-field (1.5-T) unit. Midline T1-weighted sagittal images (600/15/2 [repetition time/echo time/excitations]) were used exclusively for measurements in this investigation. Other imaging parameters included section thickness, 4 mm; intersection gap, 1 mm; field-of-view, 30 cm; and imaging matrix, 192 × 256.

Sagittal canal diameters at the level of spondylolysis and at L-1 were measured as previously described (5). At each level, a reference line was first constructed tangent to and parallel with the posterior border of the vertebral body at its midportion. A second line was then drawn, parallel to the first, at the most anterior aspect of the lamina of the same vertebra at the spinolaminar junction. The midsagittal canal diameter at this level was defined to be the perpendicular distance between these two lines (Figs 2 and 3).

To normalize these measurements according to patient size, a sagittal canal ratio was defined as the midsagittal canal diameter at the level of spondylolysis divided by that at L-1. Based on analysis of data from 100 control subjects without spondylolysis (5), the normal mean values (±standard deviation) of the sagittal canal ratios as a function of vertebral level have been determined and are as follows: L-2/L-1, 0.95 (±0.05); L-3/L-1, 0.93 (±0.07); L-4/L-1, 0.96 (±0.08); L-5/L-1, 0.99 (±0.10). The range of values at each level is as follows: L-2/L-1, 0.87 to 1.06; L-3/L-1, 0.77 to 1.14; L-4/L-1, 0.83 to 1.24; L-5/L-1, 0.78 to 1.25. The control subjects from this prior study (5) were selected from young adult patients referred for MR imaging to evaluate lower back pain whose MR images were interpreted as unequivocally normal by two experienced neuroradiologists and whose conventional radiographs (with obliques) showed no evidence for lumbar spondylolysis. Using magnified midline sagittal T1-weighted images on an independent console, one observer measured the canals of each patient three times at each level. The mean of the three measurements was taken as the anteroposterior canal diameter that was used to calculate the sagittal canal ratios relative to L-1 in each control subject at the other 4 lumbar levels.

The upper-limit sagittal canal ratio for each level in the 100 control subjects of the prior study (5) was selected as a threshold value to define normal from abnormal in the current study. At each level, the upper-limit sagittal canal ratio value chosen was greater than 2 standard deviations above the mean and, therefore, above the 95% confidence limit established from our control subjects with intact neural arches. When the sagittal canal ratio exceeds the upper limits of normal (L-2, 1.06; L-3, 1.14; L-4, 1.24; L-5, 1.25), an "abnormally widened" anteroposterior diameter of the spinal canal on midsagittal MR images can be diagnosed, suggesting an open-arch defect (5).

Sagittal canal ratios at involved vertebral levels

Patient	Age, y/ Sex	Level of Spondylolysis	Sagittal Canal Ratio
1	17/M	L-5	1.39†
2	18/M	L-2	1.27†
3	20/M	L-3	1.00
4	24/M	L-5	1.27†
5	25/F	L-5	1.17
6	31/M	L-5	1.50†‡
7	37/M	L-5*	1.05
8	41/F	L-5	1.39†‡
9	51/F	L-5	1.75†‡
10	54/M	L-5*	1.29†
11	54/M	L-5	1.71†‡
12	63/M	L-5	1.48†‡

*Unilateral pars defect only.

† Exceeds upper limits of normal by level (L-2 = 1.06, L-3 = 1.14, L-4 = 1.24, L-5 = 1.25).

‡ Canal measurements were not necessary, because posterior element subluxation was visible.

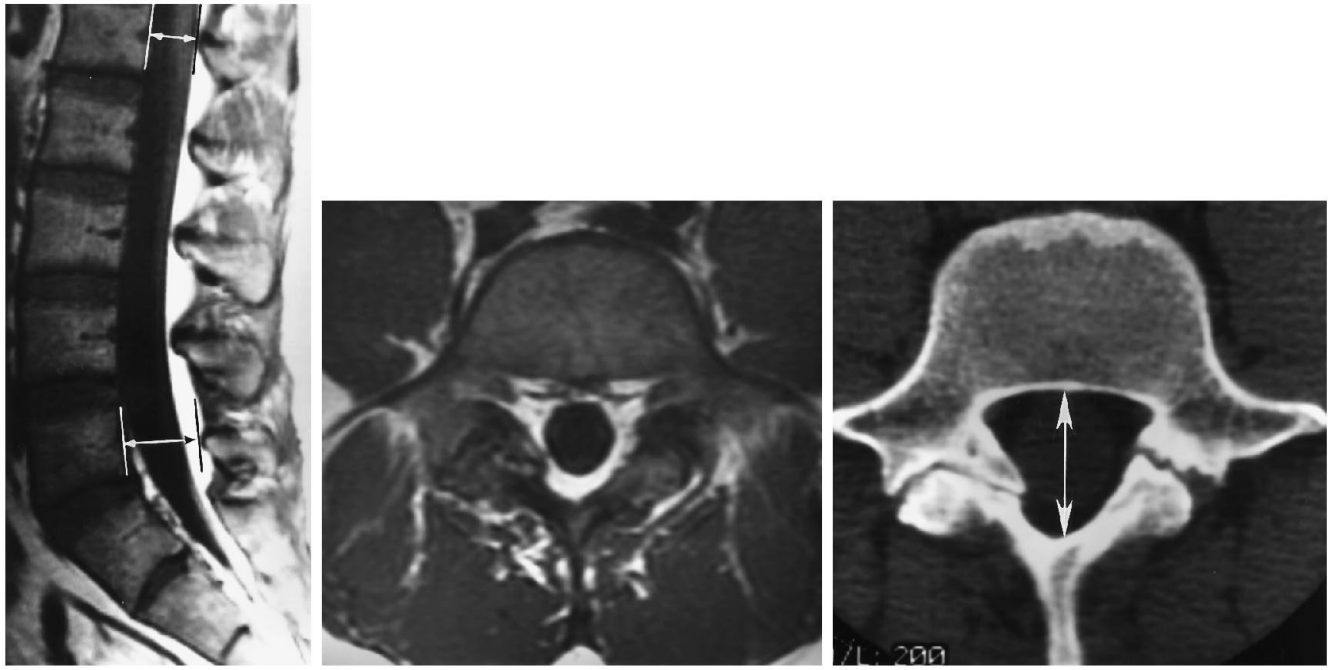

Fig 2. Thirty-one-year-old man with bilateral L-5 spondylolysis (patient 6 in the Table).

A, Midsagittal T1-weighted MR image shows isolated posterior element subluxation, resulting in an increased sagittal canal diameter at the level of spondylolysis (sagittal canal ratio, 1.50).

Axial T1-weighted MR image (*B*) and CT (*C*) confirm the spondylolysis and demonstrate increased canal diameter (*arrow*).

Results

In 9 (75%) of the 12 patients, abnormal widening of the spinal canal at the level of the spondylolysis because of dorsal subluxation of posterior elements was demonstrated (Table). In 5 of these patients, posterior displacement of the spinolaminar line and spinous process at the involved level was visually apparent (Fig 2, patient 6 in the Table). In the other 4 patients, the abnormally widened canal (and dorsal posterior element displacement) was not obvious to visual inspection but could be diagnosed by measurement of the sagittal canal ratios (Fig 3, patient 10 in the Table). (One of these 4 patients had a unilateral L-5 defect and another had bilateral L-2 defects.) In 3 patients, no widening of the spinal canal or posterior element subluxation could be identified (one patient with bilateral L-3 defects, one with a unilateral L-5 defect, and one with bilateral L-5 spondylolysis but a partially sacralized L-5 vertebra). In all cases, the posterior spinal elements were well formed, indicating that hypoplasia did not contribute to the abnormal widening of the spinal canal.

Discussion

Lumbar spondylolysis is characterized by bone defects in the pars interarticularis (11–14). These defects are thought to result from repeated microfractures and elongation of a congenitally weakened pars, usually first becoming radiographically visible in late childhood or adolescence. Typically, the pars defects remain bridged by fibrocartilage but may form a pseudojoint. Occasionally, healing and bone union occurs, a phenomenon likely accounting for many of the 10% to 15% of cases with unilateral defects (2, 11–15). The L-5 level is involved in 90% to 95% of patients. Men are affected two to four times more often than women.

Approximately 25% of patients with lumbar spondylolysis eventually will have significant lower back pain or sciatica (1, 2). The causes of symptoms in these patients include muscular and ligamentous strain, spinal or foraminal stenosis, facet degeneration, and associated disk degeneration or herniation (1, 2, 11–22). Imaging studies, such as CT or MR, may be needed

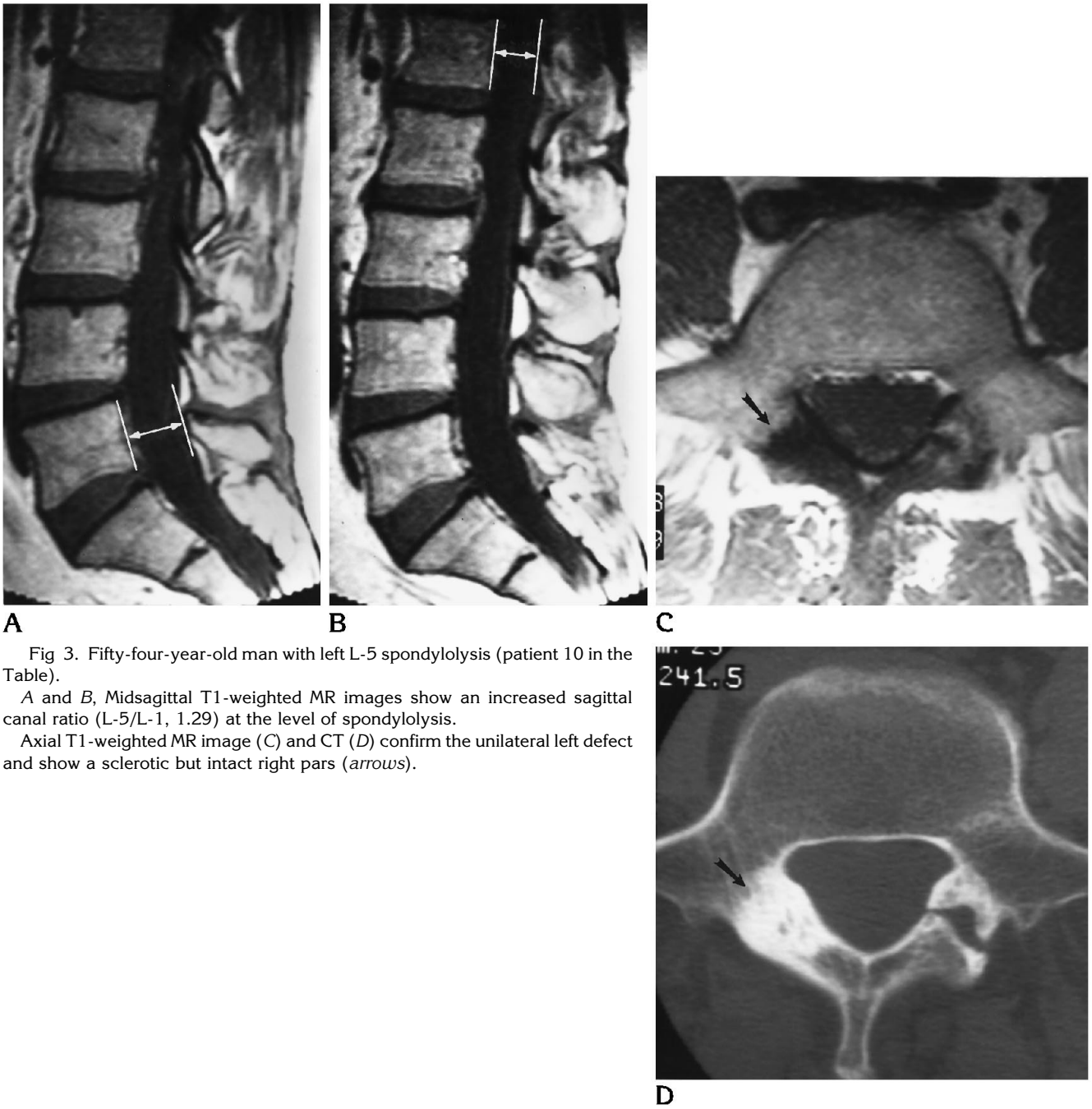

Fig 3. Fifty-four-year-old man with left L-5 spondylolysis (patient 10 in the Table).

A and *B*, Midsagittal T1-weighted MR images show an increased sagittal canal ratio (L-5/L-1, 1.29) at the level of spondylolysis.

Axial T1-weighted MR image (*C*) and CT (*D*) confirm the unilateral left defect and show a sclerotic but intact right pars (*arrows*).

to allow proper diagnosis and selection of therapy for these patients.

The MR characteristics of spondylolysis and spondylolisthesis have been well described (2–6, 23, 24). The pars defect may be recognized on axial or sagittal images as an area of focally decreased signal on T1- and T2-weighted images. If significant anterolisthesis of the vertebral body is present, a fat-filled gap between the pars fragments sometimes can be appreciated. Although these characteristic MR findings, when present, generally allow a confident diagnosis of pars defects to be made, several imaging pitfalls exist (2–4, 6). Specifically, sclerosis of the pars and partial volume averaging of adjacent facet arthropathy can produce a focal signal loss in the pars that is nearly indistinguishable from that seen in spondylolysis. Ancillary imaging findings such as the "spinous process step-off sign" (10) or "wide-canal sign"

(5) occasionally may be useful to support the diagnosis on MR. However, the MR imaging diagnosis of spondylolysis is difficult when spondylolisthesis is not present (2).

Our results show that isolated posterior element subluxation occurs in a significant proportion of spondylolytic patients without spondylolisthesis. In nearly half of our subjects, this dorsal subluxation was visible on midline sagittal MR images. In one third of cases, dorsal displacement of posterior elements occurred but was detectable only by actual canal measurements.

Isolated posterior element subluxation was evident in one of two patients with unilateral pars defects. This suggests that in some cases, unilateral healing of a defect may be associated with lengthening of the pars on that side, allowing dorsal posterior subluxation to occur. This also supports the belief that elongation of the pars related to repeated microfractures may be a precursor to the development of actual bone defects (2, 11–15). We cannot estimate the relative frequency of posterior element subluxation in patients with unilateral pars defects, because only two patients in our series had this condition.

Although none of the patients in our study had hypoplasia or deformity of their posterior elements at the level of the spondylolysis, it is possible that in some cases an increase in the sagittal canal ratio may result from such factors, rather than from posterior element subluxation. For example, spina bifida occulta and segmental defects are associated with lumbar spondylolysis (11–13, 16, 25); either of these could alter the shape of the spinal canal and affect the sagittal canal ratios measurement. Even without spondylolysis, the presence of hypoplastic or dysmorphic posterior elements could produce an apparent increase in spinal canal diameter and mimic the findings we describe here. Additionally, rotation or asymmetric alignment of the posterior elements (16) could conceivably affect measurements of the spinal canal diameter. We also recognize that the relative degree of posterior element subluxation may be affected by positioning; MR imaging in the supine posture may affect the relative alignment of vertebral elements compared with standing, flexion, or extension views.

At present, it is unknown why the spines of patients with pars defects develop spondylolisthesis and/or posterior element subluxation to varying extents. A number of biomechanical factors affect the segmental stability in spines with spondylolysis, including lumbosacral curvature, vertebral body wedging and hypoplasia, sacralization, disk integrity, and the stabilizing forces of paraspinous ligamentous complexes (11–13, 16, 18, 26–29). Under normal physiologic circumstances, anterior shear forces produced by gravity, lumbar curvature, and trunk muscles are opposed by posterior shear forces of the facet joints, disks, and spinal musculature (26–28). When disruption of the pars occurs, these forces may act independently until fibrous union of the defect develops. Our results and one other MR report (30) clearly indicate that segmental vertebral instability resulting from lysis of the pars interarticularis can be expressed not only by anterolisthesis, but also by posterior element subluxation. This suggests that mechanical forces on the lower lumbar spine can be directed to produce anterolisthesis of the vertebral body in some spondylolytic patients, isolated posterior element subluxation in other patients, and a combination of the two in others.

Although MR imaging is not as sensitive or specific as CT in diagnosing lumbar spondylolysis, MR imaging is used at many institutions as the initial method for evaluating patients with significant low back pain. There are at least two scenarios in which recognizing isolated posterior element subluxation on MR imaging may be useful. The first is when visible posterior element subluxation on midsagittal images directs the interpreter to closer inspection of the pars and the diagnosis of spondylolysis. The second is when, in older persons, marrow signal loss seen with lysis of the pars mimics degenerative sclerosis, and the presence of spondylolytic defects then is confirmed by posterior element subluxation. Because failure to recognize spondylolysis on imaging studies in the presence of other spinal abnormalities is a source of failed back surgery (Helms CA, "Body CT: Categorical Course Syllabus," presented at the American Roentgen Ray Society meeting, Reston, Va, 1994), future studies should assess the use of isolated posterior element subluxation on midsagittal images as an ancillary sign for the detection of pars defects, which otherwise may be mistaken for facet arthropathy or pars sclerosis. Because the clinical significance of posterior element subluxation in patients with spondylolysis is unknown, further studies are necessary to determine the potential role of posterior ele-

ment instability, and associated degenerative changes, in the development of lower back pain and radiculopathy in adolescents and adults with lumbar spondylolysis.

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