

ORIGINAL  
RESEARCH

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# Adult Lumbar Scoliosis: Underreported on Lumbar MR Scans

**BACKGROUND AND PURPOSE:** Adult lumbar scoliosis is an increasingly recognized entity that may contribute to back pain. We investigated the epidemiology of lumbar scoliosis and the rate at which it is unreported on lumbar MR images.

**MATERIALS AND METHODS:** The coronal and sagittal sequences of lumbar spine MR imaging scans of 1299 adult patients, seeking care for low back pain, were reviewed to assess for and measure the degree of scoliosis and spondylolisthesis. Findings were compared with previously transcribed reports by subspecialty trained neuroradiologists. Inter- and intraobserver reliability was calculated.

**RESULTS:** The prevalence of adult lumbar scoliosis on MR imaging was 19.9%, with higher rates in ages >60 years (38.9%,  $P < .001$ ) and in females (22.6%,  $P = .002$ ). Of scoliotic cases, 66.9% went unreported, particularly when the scoliotic angle was  $<20^\circ$  (73.9%,  $P < .001$ ); 10.5% of moderate to severe cases were not reported. Spondylolisthesis was present in 15.3% (199/1299) of cases, demonstrating increased rates in scoliotic patients (32.4%,  $P < .001$ ), and it was reported in 99.5% of cases.

**CONCLUSIONS:** Adult lumbar scoliosis is a prevalent condition with particularly higher rates among older individuals and females but is underreported on spine MR images. This can possibly result in delayed 1) identification of a potential cause of low back pain, 2) referral to specialized professionals for targeted evaluation and management, and 3) provision of health care. The coronal "scout images" should be reviewed as part of the complete lumbar spine evaluation if dedicated coronal sequences are not already part of the spine protocol.

**ABBREVIATIONS:** CI = confidence interval; OR = odds ratio

Adult scoliosis is defined as a curvature deformity of the spine with a Cobb angle of  $>10^\circ$  in the coronal plane in skeletally mature individuals.<sup>1,2</sup> Generally speaking, scoliosis is a broad entity encompassing 4 distinct clinical categories, namely 1) primary degenerative/de novo scoliosis, 2) progressive idiopathic scoliosis in adult life, 3) secondary degenerative scoliosis following idiopathic or other forms of scoliosis, and 4) secondary degenerative scoliosis secondary to metabolic bone disease (mostly osteoporosis), asymmetric arthritic disease, and/or vertebral fractures. All of these categories may affect the lumbar spine.<sup>3-12</sup>

Studies dealing exclusively with lumbar scoliosis are few and not recent. The reported prevalence rates vary from 2.5% to 15% in a control population versus 7.5% to 9.1% in those individuals with low back pain.<sup>4,8,12-14</sup> Back pain is the most frequent complaint in adult scoliosis and is reported in 40–90% of cases. Lumbar scoliosis is particularly associated with higher degrees of low back pain.<sup>3,4,8,10,15-20</sup>

The prevalence of scoliosis is reported to be higher in the older age group, with estimates as high as 60%.<sup>12,21</sup> Life expectancy in the United States has increased to unprecedented levels as medical advances have proliferated, causing a profound demographic shift toward the "gray society".<sup>22,23</sup> This, with increased desire for high quality of life and consequent eagerness to seek care for problems that the patients would

traditionally learn to live with, has made adult scoliosis a much more frequent clinical problem.<sup>22,24,25</sup>

We hypothesized that the prevalence of adult lumbar scoliosis has increased in the last decade or so. Furthermore, it has been our clinical observation that adult lumbar scoliosis is underreported on lumbar MR images that could potentially have a bearing on health care provision. Our study sought to examine the epidemiologic aspects of adult lumbar scoliosis in patients seeking care for low back pain being evaluated with MR images of the lumbar spine. We also evaluated the rate at which adult lumbar scoliosis and spondylolisthesis are reported in lumbar spine MR imaging reports and addressed its implications vis-à-vis health care provision. The secondary objectives were to 1) determine prevalence, level, and grade of concomitant spondylolisthesis and scoliosis and 2) document inter- and intraobserver reliability for both scoliotic degrees and severity category.

## Materials and Methods

### Research Design and Patients

Under an institutional review board–approved and US Health Insurance Portability and Accountability Act–compliant protocol, all consecutive lumbar MR imaging scans performed in skeletally mature patients (called "adults" hereafter), females  $\geq 17$  and males  $\geq 19$ –26 years old<sup>26</sup> presenting with low back pain during the period of November 1, 2008 through March 14, 2009, were prospectively reviewed.

### Investigators

Investigators included 2 board subspecialty-certified neuroradiologists (S.K.G. and D.M.Y. with 7 and 19 years' experience) and a med-

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ical student trained in digital measurement of scoliotic angles and evaluation of spondylolisthesis.

### Investigations

Each study of the lumbar spine included a coronal 3–5 section gradient-echo, 5-mm-thick scout view through the vertebral bodies, followed by standard sagittal T1-weighted, T2-weighted, short TR inversion-recovery sequences with axial T1-weighted and T2-weighted images. Because multiple vendors and field strengths of MR scanners were employed, the TRs, TIs, and TEs varied. Section thicknesses were 3–5 mm. Coronal scout images were reviewed to evaluate lumbar scoliosis in accordance with the Scoliosis Research Society criterion (ie, single scoliosis with the apical vertebra between L1 and L2 disk to L4 vertebral body).<sup>27</sup> Curve angulations were measured digitally with reference to the summit vertebrae (Fig 1). Those measuring  $>10^\circ$  were termed scoliotic and the rest were labeled nonscoliotic. The direction of the curves (levo, dextro, or double) was documented. Sagittal sequences were looked at to assess spondylolisthesis and document its level and Meyerding grade (1 =  $<0.25$  vertebral body width, 2 =  $>0.25$  but  $<0.50$  vertebral body width, 3 =  $>0.50$  but  $<0.75$  vertebral body width, 4 =  $>0.75$  vertebral body width). The differences based on sex and age groups were documented for prevalence, scoliotic degrees, and direction of the curve.

Findings of the research team were compared with those reported in the official reports of board-certified subspecialty-trained neuro-radiologists who had independently reported these scans and were unaware of the ongoing study. The rate of reporting thus obtained was analyzed further to observe any patterns based on sex and age groups.

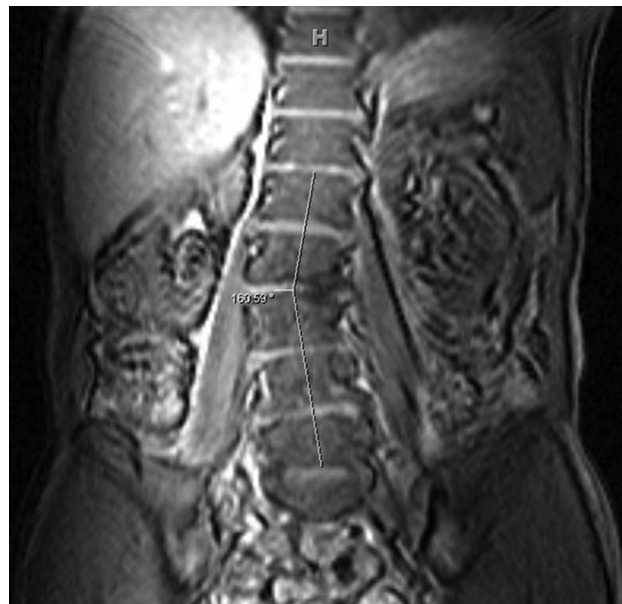
After a washout period of  $>6$  weeks, 50 random scans were evaluated by all 3 investigators to measure interobserver reliability. Additionally, a subset of 50 random cases each was dually evaluated by all 3 investigators to establish intraobserver reliability.

The 2 neuroradiology coinvestigators had also officially reported some of the scans evaluated in the research project after the conception of the project, introducing a confounding bias. On these scans, 87 instances of scoliosis were reported (33.6% of the scoliotic cases in our study). Because of this bias, only the interpretations of the scans evaluated by other members of the neuroradiology team (not coauthors) were utilized to measure the rate of reporting scoliosis.

### Statistical Analyses

Data were analyzed by using SPSS 17.0 (SPSS, Chicago, Illinois). The sample was stratified into 3 groups on the basis of age, namely 1) young adults (up to 45 years of age), 2) middle-aged (46–60 years of age), and 3) older-age group ( $>60$  years of age). Severity of scoliosis was categorized as mild ( $11\text{--}20^\circ$ ) and moderate and severe ( $\geq 21^\circ$ ). Moderate ( $21\text{--}40^\circ$ ) and severe ( $\geq 41^\circ$ ) scolioses were combined into 1 category for the purpose of analysis on account of only 3 cases of severe scoliosis.

Frequencies and cross-tabulations were used for descriptive statistics. Any significant associations were deduced with  $\chi^2$  test or Fisher exact test in the case of qualitative variables and a  $t$  test in the case of quantitative variables. An intraclass correlation coefficient was employed to assess inter- and intraobserver reliability for scoliotic angle measurement, and generalized Cohen kappa and Cohen kappa statistics were used to compute inter- and intraobserver agreement in severity assessment category, respectively. Multivariate statistics were



**Fig 1.** Coronal MR lumbar image of a 75-year-old man with dextroscoliotic angle measuring  $19.41^\circ$  that went unreported.

also used to adjust for confounding variables. A level of significance of  $P < .05$  was used in all cases.

### Results

#### Prevalence of Scoliosis by Demographic Variables

There were 1299 patients in our study population. The prevalence of adult lumbar scoliosis was 19.9% (259/1299), with a significantly ( $P = .002$ ) higher rate of 22.6% (182/804) in females versus 15.6% (77/495) in males. The prevalence also increased significantly ( $P < .001$ ) by age groups, ranging from 9.1% (37/406) in young adults ( $<45$  years old) to 13.3% (65/489) in middle-aged (46–60 years old) and 38.9% (157/404) in older-age groups ( $>60$  years old).

#### Risk Assessment among Demographic Variables

The confounding effect of sex and age groups on scoliosis was evaluated through single-model logistic regression analysis and it showed statistically significant effects of both. Females were 1.5 times more likely to have scoliosis than males (OR 1.54,  $P = .006$ , 95% CI, 1.130–2.097). Older-age patients were 6.2 times (OR 6.25,  $P < .001$ , 95% CI, 4.217–9.268) and middle-aged adults were 1.5 times (OR 1.51,  $P = .059$ , 95% CI, 0.984–2.315) more likely to have scoliosis than were young adults. Effect modification analysis was performed through interaction of age groups and sex in a logistic regression model and it showed a greater impact of advanced age for females than for males. Middle-aged females were 1.0 time (OR 1.03,  $P = .859$ , 95% CI, 0.707–1.516) and older-age females were 4.6 times (OR 4.57,  $P < .001$ , 95% CI, 3.312–6.298) more likely to have scoliosis than were young females. On the other hand, middle-aged males were 1.9 (1/0.517) times less likely (OR 0.52,  $P = .007$ , 95% CI, 0.320–0.836) and older-age males were 1.9 times more likely (OR 1.87,  $P = .001$ , 95% CI, 1.272–2.757) to have scoliosis than were young males.

Multiple linear regression modeling was used to see if sco-

**Table 1: Baseline features of the study population (n = 1299)**

	Overall (n = 1299)	Scoliotics (n = 259)	Nonscoliotics (n = 1040)	P
Mean age (years)	53.14 ± 15.441	63.25 ± 15.356	50.62 ± 14.404	.000
Age groups				
Young adults	31.3% (406)	14.3% (37)	35.5% (369)	.000
Middle-aged	37.6% (489)	25.1% (65)	40.8% (424)	
Older-age group	31.1% (404)	60.6% (157)	23.8% (247)	
Gender				
Male	38.1% (495)	29.7% (77)	40.2% (418)	.002
Female	61.9% (804)	70.3% (182)	59.8% (622)	
Spondylolisthesis				
Yes	15.3% (199)	32.4% (84)	11.1% (115)	.000
No	84.7% (1100)	67.6% (175)	88.9% (925)	
Spondylolisthesis levels				
L3/L4	7.5% (15)	8.3% (7)	7% (8)	.025
L4/L5	43.7% (87)	56% (47)	34.8% (40)	
L5/S1	35.2% (70)	22.6% (19)	44.3% (51)	
Multiple-level	10.1% (20)	9.5% (8)	10.4% (12)	

liotic angle depended on age and sex. Age was weakly related to scoliotic angle as every unit (1 year) change in age predicted a meager increase of 0.19° in scoliotic angle ( $\beta$  unstandardized coefficient = 0.077,  $\beta$  standardized coefficient = 0.194,  $P = .002$ , 95% CI, 0.030–0.125). Likewise, being of female sex was positively but weakly (0.16°) related to scoliotic angle ( $\beta$  unstandardized coefficient = 2.116,  $\beta$  standardized coefficient = 0.158,  $P = .010$ , 95% CI, 0.520–3.711).

### Prevalence of Spondylolisthesis

The prevalence of spondylolisthesis was 15.3% (199/1299), demonstrating a statistically significant ( $P = .003$ ) difference between genders with 11.5% (57/495) in males versus 17.7% (142/804) in females. Prevalence, too, increased significantly ( $P < .001$ ) between age groups from 5.9% (24/406) in young adults to 11.2% (55/489) in middle-aged adults to 29.7% (120/404) in the older-age group. Prevalence of spondylolisthesis also differed significantly between scoliotic (32.4%, 84/259) and nonscoliotic (11.1%, 115/1040) groups ( $P < .001$ ) (Table 1). Within the spondylolisthetic cases ( $n = 199$ ), L4/L5 listhesis turned out to be the most frequent (43.7%, 87), followed by L5/S1 (35.2%, 70), multiple-level (10.1%, 20), L3/L4 (7.5%, 15), L2/L3 (1.5%, 3), and L1/L2 listhesis (2%, 4). As for the Meyerding grade, 88.9% (177) of cases demonstrated grade 1, 10.6% (21) grade 2, and only 0.5% (1) grade 4 listhesis.

### Impact of Spondylolisthesis on Prevalence of Scoliosis

The prevalence of scoliosis was observed to be significantly higher ( $P < .001$ ) in patients with spondylolisthesis (42.2%, 84/199) than in those patients without it (15.9%, 175/1100). Within the spondylolisthesis group, a significantly increased ( $P = .025$ ) prevalence of scoliosis was documented with L4/L5-level listheses (54%, 47/87) as compared with L3/L4-level listheses (46.7%, 7/15), multiple-level listheses (40%, 8/20), and L5/S1-level listheses (27.1%, 19/70). The effect could not be assessed due to small sample sizes with the L2/L3-level listheses (66.7%, 2/3) and L1/L2-level listheses (25%, 1/4).

**Table 2: Features in those with scoliosis (n = 259)**

	Mild (n = 218)	Moderate and Severe (n = 41)	P
Mean age	62.05 ± 15.267	69.63 ± 14.380	.004
Gender			
Male	32.1% (70)	17.1% (7)	.053
Female	67.9% (148)	82.9% (34)	
Spondylolisthesis			
Yes	31.2% (68)	39% (16)	.326
No	68.8% (150)	61% (25)	
Spondylolisthesis levels			
L3/L4	8.8% (6)	6.3% (1)	.512
L4/L5	58.8% (40)	43.8% (7)	
L5/S1	19.1% (13)	37.5% (6)	
Multiple-level	10.3% (7)	6.3% (1)	
Direction of curvature			
Levo-	65.1% (142)	58.5% (24)	.489
Dextro-	33.5% (73)	41.5% (17)	
Double	1.4% (3)	0% (0)	

### Severity of Scoliosis

Among scoliotic cases, 84.2% (218/259) were of the mild category (11–20°) and 15.8% (38/259 moderate and 3/259 severe) were of moderate and severe ( $\geq 21^\circ$ ) categories. Mean scoliotic angle was  $15.8 \pm 6.1^\circ$  (range, 11–53°) and differed significantly ( $P = .009$ ) between genders ( $14.3 \pm 4.9^\circ$  in males and  $16.5 \pm 6.5^\circ$  in females). The difference in severity between age groups was also significant ( $P = .041$ ), with the proportion of moderate and severe cases increasing from 10.8% (4/37) in young adults to 7.7% (5/65) in middle-aged adults and 20.4% (32/157) in the older-age group. Levoscoliosis constituted 64.1% (166/259) of the cases, followed by dextroscoliosis with 34.7% (90/259) and double curves with 1.2% (3/259) of cases (Table 2). No difference in direction of curvature between genders ( $P = .205$ ) and age groups ( $P = .585$ ) was found.

### Reporting of Scoliosis and Spondylolisthesis in Lumbar Spine MR Imaging Interpretations

Of 259 scoliotic cases, 87 (33.6%) were interpreted and reported by the 2 coinvestigators and thus were excluded during appraisal of the rate of reporting. Most (66.9%, 115/172) of the scoliotic cases went unreported per the official radiology evaluation. Reporting differed significantly based on both severity ( $P < .001$ ) and sex ( $P = .007$ ). Single-model logistic regression analysis showed that both predictors acted independently. Females, as compared with males, were 2.3 times (OR 2.30,  $P = .039$ , 95% CI, 1.042–5.100) more likely to be reported and moderate and severe cases were 21.7 times (OR 21.74,  $P < .001$ , 95% CI, 4.757–99.330) more likely to be reported than were mild cases. There were 153 instances of mild scoliosis present in the scans interpreted by the neuroradiologists other than the coinvestigators. Of these, just 40 (26.1%) were documented. However, of the 19 moderate to severe cases, 17 (89.5%) were noted (Table 3).

Nearly all (99.5%, 198/199) instances of spondylolisthesis were officially reported.

### Inter- and Intraobserver Reliability

For intraobserver and interobserver reliability in scoliotic angle measurement category, intraclass correlation coefficients were computed to be between 0.92 to 0.99, indicating an out-

**Table 3: Scoliosis reporting**

	Reported (n = 57)	Unreported (n = 115)	P
Mean age	67.16 ± 14.575	62.65 ± 15.668	.071
Mean scoliotic angle	18.11 ± 6.776°	13.01 ± 2.511°	.000
Gender			
Male	21.1% (12)	41.7% (48)	.007
Female	78.9% (45)	58.3% (67)	
Severity			
Mild	70.2% (40)	98.3% (113)	.000 <sup>a</sup>
Moderate and severe	29.8% (17)	1.7% (2)	

<sup>a</sup> Fisher exact test; 87 cases originally interpreted by coinvestigators were excluded to avoid bias in conclusions.

standing rate of agreement between the student and the neuroradiologists and on repeated measures. Intraobserver and interobserver reliability in severity assessment category (ie, mild, moderate, and severe) was graded with kappa values between 0.96 and 1.0, indicating near perfect agreement ( $P < .001$ ).

### Discussion

In this study, MR imaging scans of 1299 patients were reviewed for the presence of scoliosis. Although upright weight-bearing plain films are considered the criterion standard by which spinal deformity is classically measured, most patients who undergo such evaluation have been referred to a spine surgeon specializing in deformity correction. In the present study, the patients who were enrolled merely received a lumbar spine MR imaging, a study that is more routinely ordered by a broad range of health care specialists, not those focused on spine deformity. In this way, the prevalence and characteristics of a “less biased” population may be more relevant to the actual prevalence in the population at large. Additionally, this study sought to determine the level at which radiologists detect and report such findings. Given that many practitioners use the evaluation of the radiologist as the official statement of spine pathology, regardless of whether the images are personally reviewed by the ordering practitioner, it is imperative to understand the current standard of spinal deformity screening on MR imaging. In this way, because patients with scoliosis and symptoms of radiculopathy, claudication, and low back pain may require referral to deformity specialists to improve their condition, improved diagnostic assessment may be paramount in providing improved care.

The mean age of  $53.1 \pm 15.4$  years in our population is in keeping with  $50.6 \pm 13.4$  years reported in a comparable study by Perennou et al.<sup>13</sup> The significant ( $P < .001$ ) difference in mean ages of the scoliosis ( $63.25 \pm 15.36$ ) versus nonscoliosis ( $50.62 \pm 14.40$ ) group noticed in our study is tantamount to what has been reported by Perennou et al. No other studies with similar demographics were found for comparison. Overall distribution of genders in our study (38.1% males versus 61.9% females) was considerably different from the proportion (50.2% males versus 49.8% females) observed by Perennou et al. Within the scoliosis group in our study, 70.3% (182/259) were females, a proportion comparable to 63% and 72% observed by Robin et al and by Perennou et al, respectively.<sup>12,13</sup>

### Prevalence of Scoliosis

Our study revealed a prevalence rate of 19.9% (259/1299) for adult lumbar scoliosis, which, as contended, is considerably higher than what has been reported in a number of studies on adult scoliosis, including a study on 5000 intravenous pyelograms imaged in the 1970s by Kostuik et al<sup>8</sup> that suggested a prevalence of 2.5% for lumbar scoliosis, and an x-ray study by Robin et al,<sup>12</sup> also from patients imaged in the late 1970s, which reported a frequency of 15%. In 2 other comparable studies, Perennou et al<sup>13</sup> demonstrated a rate of 7.5% for adult lumbar scoliosis in patients with low back pain, and Witt et al<sup>14</sup> documented a figure of 9.1% in such a population as opposed to 4.6% in a control population. The increased prevalence of scoliosis demonstrated by our study could be explained by an increase in life expectancy in the United States on account of advanced medical care resulting in a shift toward the “gray society”<sup>22,23</sup> and an increased number of patients seeking medical care in pursuit of a higher quality of life rather than simply learning to live with their low back pain.<sup>22,24,25</sup>

A significant increase seen in the prevalence of adult lumbar scoliosis among older age groups is a reiterated pattern that has previously been documented by 2 studies.<sup>12,13</sup> However, an increase from 2% to 6% to 15% in young, middle-aged, and older age groups reported by Perennou et al<sup>13</sup> is noticeably less than 9.1% to 13.3% to 38.9% observed in our data. Robin et al<sup>12</sup> reported an increased prevalence rate of 32% among 50- to 84-year-old patients during a follow-up period of 4 years.

The difference in the prevalence of scoliosis between genders in our study (15.6% in all males versus 22.6% in all females) was no different from what has been reported by Robin et al,<sup>12</sup> who reported rates of 27.6% and 35.9% for older males and females, respectively. On a similar note, we observed a prevalence of 31.7% (45/142) and 42.7% (112/262) between older-age group males and females, respectively, again suggestive of an ever-increasing incidence.

An increased prevalence of scoliosis (42.2%) in patients with spondylolisthesis confirms previously documented association between the two.<sup>28-32</sup> Scoliosis occurring concomitantly with spondylolisthesis has been divided into 3 main categories.<sup>30</sup> First, it can simply be idiopathic scoliosis of the upper spine, likely unrelated to the olisthetic defect. Second, it can be of the sciatic type, in which irritation associated with the olisthetic defect induces scoliosis via muscle spasm. Third, it can be the result of an asymmetric olisthetic defect as first explained by Tojner.<sup>32</sup> Highest prevalence of scoliosis (54%) with L4/L5-level listheses is also in conformity with what has been documented before.<sup>29,33</sup> This has been attributed to the absence of stabilizing ligaments, such as the ilio-lumbar ligament, at the L4–L5 level. The indications for a surgical approach to coexistent scoliosis and spondylolisthesis parallel the indications for either of the problems arising independently.<sup>28</sup>

### Severity of Scoliosis

In total, 84.2% (218/259) of scoliotic patients were mild in severity and 15.8% (41/259) were of the moderate and severe categories, which is in sharp contrast to figures recorded by Perennou et al,<sup>13</sup> who reported 56% mild and 44% moderate

and severe curves. This disparity could be a result of underestimation of scoliotic degrees on standard MR images<sup>34-36</sup> used in our study as opposed to standing radiographs used by Perennou et al. As a corollary to this distribution, the mean scoliotic angle recorded by Perennou et al was  $21.2 \pm 11.4^\circ$  as compared with  $15.8 \pm 6.1^\circ$  noticed by us. They, however, did not notice any difference in mean scoliotic angle between genders, while we observed such a difference ( $14.3^\circ$  in males and  $16.5^\circ$  in females), which was statistically significant ( $P = .009$ ). As for direction of curvature, our study recorded 63.8% (166) levoscoliotic, 35% (91) dextroscoliotic, and 1.2% (3) double curves, which contrasts with 56% levoscoliotic and 44% dextroscoliotic curves observed by Perennou et al.<sup>13</sup> The difference would be explained by an increased proportion of rotatory listhesis (34%) and its significant ( $P < .01$ ) association with dextroscoliosis, recorded by Perennou et al, or by the differences in the demographics of the study subjects. Statistically insignificant ( $P = .205$ ) differences between genders in the direction of curvature is in line with findings documented by Perennou et al.

### Reporting

We have demonstrated that lumbar scoliosis in adults with low back pain is underreported on MR imaging reports. This deficiency was especially observed for cases of mild severity, where 113 of 153 (73.9%) cases were not reported, whereas just 2 of 19 (10.5%) of moderate to severe cases were not reported. The finding that spondylolisthesis was noted in  $>99.5\%$  (198/199) of cases suggests that the underreporting was not a matter of insufficient training or skill, but was more a reflection of not being attentive to the value of the coronal scout images. Neuroradiologists as a group have not considered the reporting of scoliosis, particularly mild scoliosis, as important to their reporting efforts or to their spine surgery colleagues.

Standard MR images are done in supine position and are known to have a diminutive effect on the extent of scoliotic curvature<sup>34-36</sup> unless they are axially loaded.<sup>36</sup> Our study used standard MR images for scoliotic angle measurements, leading to possible underestimation of the true extent of the curves. Furthermore, exclusive review of sagittal scans may lead to underreporting, hence the critical importance of either including clinical quality coronal sequences to supplement axial and sagittal scans or careful scrutiny of the multiplanar scout images, which include coronal sequences that better depict the scoliosis.

### Implications for Care

Adult spinal deformity is an increasingly recognized entity that may significantly contribute to back pain, disability, and neurologic dysfunction. In particular, adult degenerative or de novo scoliosis patients typically present with symptoms of low back pain, often reporting extensive time periods before coming to the attention of a spine surgeon. In those patients with unrecognized spinal deformity/scoliosis, some surgeons perform minimal decompressions or short fusion procedures that do not adequately address the regional and global spine alignment. In doing so, such surgeries may, at the very least, inadequately address the cause of the patient's initial complaint and, at the very most, lead to iatrogenic worsening

of the spine malalignment, neurologic decline, or severe pain. Such outcomes may also require additional surgeries, which by nature are often associated with greater procedure-related morbidity.<sup>37</sup> Ploumis et al have noted that though patients with minor scoliosis of  $<15^\circ$  may be treated with decompression only, those with  $>15^\circ$  and/or lateral subluxation and/or dynamic instability should have both decompression and fusion.<sup>38</sup> Extension of the fusion to the sacrum may also be recommended with coronal plane decompensation. Additionally, pseudoarthrosis in patients with degenerative scoliosis treated with posterior fusions occurs in 40% of cases, whereas those who have anteroposterior fusions have a  $<5\%$  pseudoarthrosis rate.<sup>39</sup> Treatment of concomitant scoliosis with spondylosis therefore makes a difference in outcomes.

Additionally, given that radiologists may underreport the presence of such deformities on MR imaging, even when they are radiographically apparent, there may be inadequate preoperative evaluation of these patients with the criterion standard of upright plain films. With an improvement in the detection and reporting of scoliotic spinal deformity present on MR imaging, there may be a higher rate of referral to spine surgeons specializing in spine deformity. Such referrals would lead to the performance of appropriate work-up (that of standing, weight-bearing plain films) to determine the true extent of the scoliosis and how that would affect the surgical planning on the case. Furthermore, as discussed earlier, standard MR images (supine and nonloaded) have a diminutive effect on the true extent of scoliotic curves. Wessberg et al<sup>36</sup> have demonstrated a mean difference of  $8^\circ$  between nonloaded MR images and axially loaded ones or standing radiographs. Of the 218 cases of mild scoliosis in our study, 50.9% (111/218) fall between  $13^\circ$  and  $20^\circ$ . This, then, logically leads us to think that most of the borderline mild cases detected on standard MR images might convert to moderate severity if Wessberg's analysis were applied to our subjects. This is where it becomes imperative to meticulously detect and report mild cases.

The use of standing, weight-bearing views of the spine, a requirement for scoliosis evaluation, is not typically performed before lumbar spine disk surgery. The reporting by the radiologist of the presence of scoliosis on an MR imaging, even if mild in severity on a supine MR imaging study, may lead to such definitive studies being ordered. Because, in many cases, the lumbar spine MR imaging is requested by a primary care physician before referral to a spine surgeon, the reporting of scoliosis may expedite the work-up of the patient. By referring the patient for weight-bearing radiographs before the consultation by the spine surgeon, the surgeon will have adequate data to make a treatment decision at the initial consultation rather than having to return after those studies are performed. Scoliosis is a consideration that the spine surgeon must address when contemplating what surgery is appropriate.

### Conclusions

We conclude, in keeping with our contention, that adult lumbar scoliosis is a prevalent condition (19.9% of adults presenting with low back pain) and is underreported on lumbar MR images (67% overall, 73.9% mild, and 10.5% moderate and severe cases) with potential bearing on health care decisions. We therefore recommend a high index of suspicion and scru-

tiny on the part of diagnostic imaging professionals and contemplation of the routine use of coronal imaging if scout images are not satisfactory.

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