Adult Scoliosis
A Quantitative Radiographic and Clinical Analysis

Frank J. Schwab, MD,*† Vinson A. Smith, MD,* Michele Bisemi, MD,‡ Lorenzo Gamez,§ Jean-Pierre C. Farcy, MD,*† and Murali Pagala, PhD||

Study Design. Prospective analysis of a consecutive series of adult patients with adolescent idiopathic scoliosis of the adult and de novo degenerative scoliosis.

Objectives. To clinically and radiographically study two populations of adult patients with either adolescent idiopathic scoliosis of the adult or de novo degenerative scoliosis in a quantitative manner to identify reliable radiographic parameters that correlate with clinical symptoms.

Summary and Background. Although there are many causes of spinal deformity in the adult, there are two main categories of adult scoliosis: adolescent idiopathic scoliosis of the adult and de novo degenerative scoliosis. Unlike pediatric scoliosis, in adults there are no established radiographic parameters or classification systems that reliably provide a clinical correlation or offer a useful language for communication among specialists. This study gathered complete clinical and radiographic information on 95 patients with adult scoliosis and established several radiographic parameters that correlated with clinical symptoms.

Methods. Each of the 95 patients completed a clinical questionnaire that included a self-reported visual analog scale and underwent full-length standing anteroposterior and lateral radiography. Radiographic analysis was performed by use of digital analysis and included measurement of the Cobb angle, the number of vertebrae in each curve, plumbline offset from T1 to the midsacral line, the upper endplate obliquities of L3 and L4, and maximal lateral olisthys between two adjacent lumbar vertebrae. Sagittal plane measurements included lumbar lordosis, thoracolumbar kyphosis, and the Sagittal Pelvic Tilt Index. Statistical analysis of both radiographic and clinical parameters of pain was performed to determine any significant correlations between the two.

Results. This study showed that lateral vertebral olisthys, L3 and L4 endplate obliquity angles, lumbar lordosis, and thoracolumbar kyphosis were significantly correlated with pain.

Conclusion. This quantitative analysis identified several clinically relevant radiographic parameters in adult scoliosis patients. Additionally, excellent predictive for-

mals for self-reported pain levels were obtained. [Key words: adult scoliosis, pain, radiographic analysis, lateral olisthys] Spine 2002;27:387–392

Significant work has been dedicated to the diagnosis, classification, and treatment of scoliosis in the pediatric population. Based on radiographic parameters and natural history studies, classification systems and clinical treatment guidelines have been established for idiopathic, congenital, neuromuscular, and metabolic scoliotic spinal deformities. By contrast, for adult scoliotic deformities there are no clear diagnostic criteria, useful classification systems, or accepted treatment guidelines. A significant limitation in developing useful classifications and treatment guidelines for adult scoliosis has been the limited understanding of relevant radiographic parameters in these deformities.

The prevalence of adult scoliosis in the general population has been reported as ranging from 1.4% to 12%.1,11,14 Aside from the esthetic considerations of this physical deformity, significant pain and disability can develop.1,3,4,12 With the demographic shift involving an aging population in the United States and increased attention to quality of life issues, adult scoliosis is becoming a significant health care concern. The progression of spinal deformities in the adult population, treatment approaches for adult scoliosis, and surgical techniques have been reported in the literature.5,7,13,15–18

Adult scoliosis can be defined as a spinal deformity in a skeletally mature patient with a Cobb angle greater than 10°. Although there are many known causes of spinal deformity in the adult, two categories include the largest number of scolioses. The first category includes patients with scoliosis during childhood and adolescence that may progress or become symptomatic as the patient ages. This type of scoliosis is often idiopathic and can be termed adolescent scoliosis of the adult (ASA). The second category includes patients in whom a the spinal deformity developed after skeletal maturity.6 This type of scoliosis most commonly involves some form of degenerative disease and can be termed de novo degenerative scoliosis (DDS). Although the causes of ASA and DDS appear quite different, they may share a common pathway in symptomatic patients: gradual loss of intersegmental stability with aging and consequent progressive deformity and pain. Certainly, many adult deformities may not fit clearly into the categories of ASA or DDS, such as traumatic, metabolic, osteoporotic,16 or iatrogenic deformities.
The purpose of this study was to clinically and radiographically study a population of adult patients with ASA or DDS in a quantitative manner. The hypothesis was that reliable radiographic parameters could be identified that would correlate with clinical symptoms in a population of patients with adult scoliosis.

Materials and Methods

The study included a consecutive series of adult patients with ASA or DDS in the practice of the two lead authors. The inclusion criteria were as follows: patient age over 18 years, scoliosis (thoracic, thoracolumbar, or lumbar) exceeding 15° by Cobb angle, complete radiographic and clinical data. The exclusion criteria were as follows: recent trauma, history of spinal surgery, evidence of compression fracture or severe osteoporosis, metabolic bone disease, or underlying pathologic state of the bone such as metastatic disease.

A series of 95 patients met the above criteria. Each patient completed a detailed questionnaire, which reviewed demographic data, medical history, and type, location, and duration of pain. The self-reported Visual Analog Scale (VAS) was applied to evaluate the severity of pain. In addition to the clinical questionnaire, each patient underwent a complete radiographic series, including full-length standing anteroposterior and lateral radiographs (scoliosis series).

Radiographic Analysis. The full-length spine radiographs were evaluated for several parameters. All measurements were made by digital analysis, using the Xcalliper (Eisenlohr Corp., Davis, CA). From the frontal plane (anteroposterior radiographs), the following were recorded: Cobb angle of all scoliotic curvatures (thoracic, thoracolumbar, lumbar), number of vertebrae in each curve, plumbline offset from T1 to midsacral line, endplate obliquities (from the horizontal) of L3 and L4 vertebrae, and maximal lateral olisthesis (offset) between any two adjacent lumbar vertebrae (Figure 1). From the sagittal plane (lateral radiographs) the following were recorded: lumbar lordosis (upper endplate L1 vertebra to upper endplate S1 vertebra, Cobb angle), thoracolumbar kyphosis (upper endplate T11 vertebra to lower endplate L1 vertebra, Cobb angle), sagittal pelvic tilt index (Figure 2).

Table 1. Correlation Between Radiographic Parameters and Self-Reported Pain in Adult Scoliosis

<table>
<thead>
<tr>
<th>Relevant</th>
<th>Nonrelevant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Olisthesis</td>
<td>Cobb angle</td>
</tr>
<tr>
<td>L3 Endplate angle</td>
<td>Age</td>
</tr>
<tr>
<td>L4 Endplate angle</td>
<td>Level of olisthesis</td>
</tr>
<tr>
<td>Lumbar lordosis</td>
<td>SPTI</td>
</tr>
<tr>
<td>Thoracolumbar kyphosis</td>
<td>Plumbline offset</td>
</tr>
</tbody>
</table>

SPTI = Sagittal Pelvic Tilt Index.
Statistical Analysis. The clinical parameters of pain (leg or back), intensity of pain by self-reported VAS, and radiographic parameters were entered into a SigmaStat (SPSS Corp., Chicago, IL) worksheet. A statistician not involved with data acquisition and blinded to patient identity evaluated the correlations between pain and radiographic parameters. Linear regression analysis was applied to assess the relation between the VAS score of pain and each of the relevant radiographic parameters to obtain predictive formulas.

Results

The study population included 95 patients, 33 men and 62 women. The average age was 59 years (range, 18-88 years). Some degree of pain was reported in 78 patients (74%). The mean VAS score for the symptomatic patients in the study group was 58 (range, 20-100). The type of scoliotic deformity was DDS in 57 patients (54%) and ADA in 38 patients (46%). Scoliotic curvatures of the lumbar or thoracolumbar spine averaged 36° (SD, 18°; range, 15-72°), and curvatures of the thoracic spine averaged 28° (SD, 22°; range, 10-120°).

After statistical analysis of both radiographic and clinical data, significant correlations between radio-
graphic and clinical parameters (pain) were identified. From standing anteroposterior radiographs it was determined that lateral vertebral olisthys, and L3 and L4 endplate obliquity angles, were correlated with VAS pain score. From standing lateral radiographs it was determined that lumbar lordosis and thoracolumbar kyphosis were statistically significantly correlated with self-reported pain (Table 1).

In terms of frontal plane radiographic analysis, the correlation between VAS and lateral olisthys was statistically significant \( (r = 0.473, \ P < 0.001) \). The predictive formula was \( VAS = 41.52 + (3.152 \times \text{olisthys}) \) (Figure 3). The level of lateral vertebral olisthys from L1 to L5 did not bear a statistically significant correlation with the VAS. In other words, although the amount of olisthys was highly significant, the level of the olisthys had no impact on patient pain scores. The correlation between VAS and L3 endplate obliquity angle was significant \( (r = 0.433, \ P < 0.002) \). The predictive formula was \( VAS = 45.96 + (0.833 \times \text{L3 angle}) \) (Figure 4). The VAS and L4 endplate angle showed a significant correlation \( (r = 0.375, \ P < 0.006) \). The predictive formula was \( VAS = 42.95 + (0.934 \times \text{L4 angle}) \) (Figure 5). In terms of sagittal plane radiographic analysis, the correlation between VAS and lumbar lordosis was significant \( (r = 0.465, \ P < 0.001) \). The predictive formula was \( VAS = 86.353 - (0.695 \times \text{lordosis}) \) (Figure 6). The correlation between VAS and thoracolumbar kyphosis was significant \( (r = 0.508, \ P < 0.001) \). The predictive formula was \( VAS = 39.612 + (1.720 \times \text{kyphosis}) \) (Figure 7).

There was no statistically significant correlation between the VAS and the number of vertebrae involved in the scoliotic Cobb angle. Even more convincing was that the Cobb angle of the scoliotic deformity had no statistically significant correlation to the VAS. The sagittal pelvic tilt index and plumbline offset showed no statistically significant correlation with self-reported pain by VAS (Table 2).

**Table 2. Predictive Formulas for Self-Reported Pain in Study Group of Adult Scoliosis Patients: Visual Analog Pain Score and Radiographic Parameters**

<table>
<thead>
<tr>
<th>Formula</th>
<th>Level of Significance of ( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( VAS = 42.947 + (0.934 \times \text{L4 angle}) )</td>
<td>&lt;0.006</td>
</tr>
<tr>
<td>( VAS = 45.96 + (0.833 + \text{L3 angle}) )</td>
<td>&lt;0.002</td>
</tr>
<tr>
<td>( VAS = 41.52 + (3.152 \times \text{olisthys}) )</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>( VAS = 86.353 - (0.695 \times \text{lordosis}) )</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>( VAS = 39.612 + (1.720 \times \text{kyphosis}) )</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

VAS = Visual Analog Scale.

**Discussion**

Adult scoliotic deformities have received little attention. In part this may result from the impression of limited scoliotic progression in this group and the focus of treatment on regional degenerative pathologic conditions (stenosis, spondylolisthesis, disc degeneration) rather than the deformity itself. An additional reason may lie in

![Figure 8. A, Standing anteroposterior radiograph of the spine in a subject with minimal back discomfort, showing a marked scoliotic deformity. The patient received a diagnosis of idiopathic scoliosis as an adolescent. B, Standing lateral radiograph of the spine in the same patient. A well-preserved lumbar lordosis is evident.](image-url)
the limited surgical treatment in the elderly who have deformities frequently associated with other medical conditions. For several reasons the perceptions of scoliosis in the adult may be changing. Notable demographic shifts in Western societies and an increased life expectancy are evident, and quality of life concerns are focusing attention on the degenerative pathologic conditions in aging persons who wish not only to age but to do so with independence in daily living.

Although the common degenerative conditions of the spine are frequently treated as focal pathologic states, it appears intuitive that deformity of the spinal column, by altering the mechanical loading conditions, can accelerate the degenerative cascade. The question that arises, therefore, is whether radiographic parameters can be identified in an adult with scoliosis that will serve a predictive purpose on a clinical level. Furthermore, it appears that radiographic criteria should be developed for the adult scolioses to serve as a basis of analysis in longitudinal studies and perhaps eventually for treatment guidelines.

The findings in this study clearly illustrate that traditional parameters such as Cobb angle and age are not useful in the assessment of adult scoliosis (Figures 8 and 9). The Cobb angles of patients in this study covered a wide range, but this parameter itself was not a significant criterion in this group of adult scoliosis patients, although its role in pediatric deformity is paramount. Patients with ASA had larger major scoliosis curvatures than patients with DDS (ASA mean, 40°; DDS mean, 25°; although the radiographic parameters correlating with pain were identical for these groups). This appears to substantiate the belief that a common end pathway (degenerative instability and unfavorable lumbar vertebral alignment) among both groups of patients is related to symptoms rather than the degree of curvature or the cause of the original scoliosis.

In this quantitative analysis, several clinically relevant radiographic criteria in two adult scoliosis populations were identified. Excellent predictive formulas for self-reported pain levels on the VAS were obtained. The most significant radiographic parameters in the adult scoliotic group were upper endplate obliquities of L3 and L4, lateral olisthy between adjacent lumbar vertebrae on the frontal plane, lumbar lordosis, and thoracolumbar kyphosis.

The highly significant radiographic parameters identified in this study population of adult scoliosis patients appear to reflect the level of regional balance, instability, and pathologic mechanical loads of the spinal elements. It is not clear to what degree the individual parameters are interrelated and whether progression beyond a certain level of intervertebral alignment of one factor will inevitably lead to changes in other measured parameters.
That is, we cannot yet conclude that a certain degree of endplate obliquity in the frontal plane will lead to inevitable vertebral olisthesis over time and thence to changes in sagittal plane contour and to pain. Such a theory would be appealing, and clearly longitudinal studies are important in this area. Once such a link can be confirmed, treatment guidelines may be strongly affected, and early intervention in a middle-aged adult with scoliosis may, in some cases, be preferable to treating advanced deformity in that same person once he or she has become elderly.

Statistically highly significant radiographic parameters in the setting of clinical symptoms and adult scoliosis have been identified. These data are encouraging, and the establishment of a multicenter database is anticipated. Further investigation will permit increased statistical power of these findings and may lay the groundwork for a classification system of the adult scolioses.

Key Points
- There is a correlation between radiographic parameters and pain in adult scoliosis.
- Highly significant radiographic parameters include endplate obliquities of L3 and L4, lateral olisthesis between the lumbar vertebrae, lumbar lordosis, and thoracolumbar kyphosis.

Acknowledgments

The authors thank Sobhan Pagala for statistical support.

References