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Correlation of Radiographic and Clinical Findings in Spinal Deformities

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Spinal deformity refers to an abnormal coronal or sagittal plane curvature or displacement of the spine. Patients with a spinal deformity present to a spine surgeon for a variety of reasons. Adult patients typically present with pain: axial back pain in the area of their curvature, leg pain that can present with a typical radicular distribution, or neurogenic claudication. Many patients with adolescent idiopathic scoliosis present with no subjective symptoms at all and seek treatment only on the advice of a pediatrician or school nurse who noticed signs of a deformity on routine examination. For the physician to treat a patient with a spinal deformity optimally, he or she must first decide if the recommended treatment is designed to address the deformity only and prevent progression or whether treatment is designed to address subjective clinical symptoms. To treat clinical complaints, one must first understand how clinical symptoms correlate with specific radiographic findings that are encountered in evaluation of the patient. How specific radiographic parameters correlate with clinical symptoms in patients with spinal deformity has been studied surprisingly little in the past but has received increasing attention in the literature in recent years.

Some prior studies have attempted to correlate radiographic appearance and clinical symptoms, but the effect of a spinal deformity on the patient's overall health status has been difficult to predict based on degree of deformity alone [1–4]. Many past studies have focused on improving the radiographic appearance of the deformity, with less attention paid to the effects of treatment on the patient's symptoms and overall health status. More recent studies have focused on patient-directed health outcomes instruments, such as the 36-Item Short-Form Health Survey (SF-36), Short-Form-12 (SF-12), Scoliosis Research Society-29 (SRS-29), and Oswestry Disability Index (ODI). These studies focus on the patient's experience of pain and impaired function, and they have yielded important information with respect to which radiographic parameters are truly associated with symptoms. These more recent studies are the focus of this review.

Adolescent idiopathic scoliosis

Many patients with adolescent idiopathic scoliosis present to the surgeon with little or no clinical complaints. School screening programs and increased awareness in the general public have led to scoliosis being detected at a much earlier stage. In general, adolescent idiopathic scoliosis does not cause pain; however, one recent study reported that up to 32% of patients with adolescent idiopathic scoliosis present with pain, although this pain is rarely disabling [5]. In up to 9% of these cases, an underlying pathologic condition may be contributing to the pain and the spinal deformity, such as syringomyelia, a tethered cord, a herniated disc, or a tumor. Thus, complaints of significant pain associated with adolescent idiopathic scoliosis should be taken seriously and worked up with a careful neurologic examination and advanced imaging studies (CT or MRI) when indicated.

The indications for MRI in the setting of adolescent idiopathic scoliosis remain somewhat

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controversial. Commonly quoted indications for MRI in the setting of idiopathic scoliosis include all cases of infantile or juvenile scoliosis (presentation before the age of 10 years), rapid curve progression, left thoracic curves, painful curves, and curves associated with any abnormal findings on neurologic examination. These factors have been associated with an increased incidence of intraspinal pathologic findings that could lead to a neurologic injury during surgical curve correction. A recent large prospective study was performed on 327 consecutive patients presenting with adolescent idiopathic scoliosis [6]. All patients underwent a complete physical and neurologic examination, followed by MRI of the brain and spinal cord. Seven patients (2.1%) were found to have an abnormality, including 2 patients with a syrinx, and 4 patients with an Arnold-Chiari malformation. No patient required neurosurgical intervention before deformity surgery, and there were no neurologic complications associated with the deformity correction. The authors concluded that routine preoperative MRI is not necessary for adolescent idiopathic scoliosis in the setting of normal findings on neurologic examination. Another recent prospective study of 250 patients from Japan [7] found that 44 patients (18%) had neural axis abnormalities on routine MRI but that only 12 of the 44 required neurosurgical treatment before deformity surgery.

Other recent studies have sought to determine if the clinical results of surgery for adolescent idiopathic scoliosis correlate with postoperative radiographic parameters, particularly the degree of correction. Goetze and colleagues [8] examined health-related quality of life in 82 patients at an average of 17 years after Harrington rod instrumentation and fusion for adolescent scoliosis using the SF-36 and Roland-Morris questionnaire. They found no difference compared with age-matched controls in the incidence of low-back pain or physical quality-of-life measures but did find diminished mental health measures in the surgically treated patients compared with controls. Helenius and colleagues [9] performed a retrospective follow-up study of 78 patients at an average of 20 years after Harrington instrumentation. They assessed health-related quality of life using the SRS-29. They found no correlation between the ultimate Cobb angle and clinical outcome or back pain score. They did demonstrate an inverse relation between SRS scores with regard to cosmesis and the magnitude of the thoracic curve at follow-up assessment, however.

D'Andrea and colleagues [1] performed a multicenter study specifically to examine whether clinical results of adolescent idiopathic scoliosis surgery correlate with radiographic parameters. Seventy-eight patients were questioned 3 years after their deformity surgery. Patient-based outcomes were assessed with the SRS-29, and radiographs were examined for several factors, including final Cobb angle, location of the C7 plumb line in the coronal and sagittal planes, apical translation and rotation, and others. An overall radiographic deformity score derived from the Harms Study Group was calculated using these measures. The authors found no correlation between patient clinical outcome and overall radiographic score, final curve measurements, or age at surgery. They concluded that clinical outcomes with surgery for adolescent idiopathic scoliosis did not correlate with radiographic improvement.

Adult scoliosis

Adult scoliosis differs from adolescent scoliosis in that subjective patient complaints are generally quite significant. Adult scoliosis generally falls into one of two broad categories. Adult idiopathic onset scoliosis represents a scoliosis that evolved during adolescence and has persisted or progressed into adulthood. The second category is degenerative or de novo scoliosis, which generally first develops in late adulthood because of the development of degenerative instability, subluxation, and rotational deformity. The latter represents a convergence of degeneration and deformity and is particularly prone to symptoms. Symptoms can include axial low back pain, radicular pain, neurogenic claudication, or any combination of symptoms [10–12]. These symptoms can range from mild complaints to severe disabling pain. Recent work has sought to determine which particular radiographic changes of adult scoliosis correspond with subjective clinical complaints.

One of the difficulties in determining which radiographic parameters are most predictive of symptoms has been the lack of a comprehensive classification system for adult scoliosis. An interesting study by Schwab and colleagues [13] has tried to address this point. They performed a prospective study of 98 patients who presented to their clinic with adult scoliosis. Inclusion criteria into the study included age greater than 20 years, a coronal plane curvature of greater than 10°, degenerative or adolescent idiopathic onset scoliosis, and a minimum of 2 years of follow-up. All patients

were questioned with regard to pain level (visual analog scale [VAS] score, pain diagrams) and completed an SF-36 questionnaire at the outset of the study. All patients had their initial 36" anteroposterior and lateral radiographs digitized and underwent computer analysis of more than 300 radiographic parameters. They found that 3 parameters most consistently correlated with VAS scores: L3 end plate obliquity, frontal (or coronal) plane intervertebral olisthesis, and L1-S1 lordosis. Based on this finding they formed a classification system for lumbar curves that was based on L3 end plate obliquity and total lumbar lordosis. Type I curves were defined by lordosis greater than 55° and obliquity less than 15°, type II curves had lordosis of 35° to 55° and obliquity of 15° to 25°, and type III curves had lordosis less than 35° and L3 obliquity greater than 25°. VAS scores (100-point scale) were 27.7 for type I curves, 43.3 for type II curves, and 47.1 for type III curves. Surgical rates (after failure of at least 3 months of conservative treatment) were 0% for type I, 9% for type II, and 22.7% for type III. The SF-36 showed statistically significant differences in bodily pain and physical function between type I and type III curves. Thus, they concluded that based on their classification system, clinical pain and disability did correlate with specific radiographic parameters. Interestingly, there was no relation between VAS and SF-36 scores and frontal plane Cobb measurements.

Glassman and coworkers [14] performed a multicenter study specifically to examine which radiographic parameters most closely correlated with clinical symptoms in adult scoliosis. Patients had been prospectively enrolled into an adult spinal deformity database and were asked to complete the SRS-22, SF-12, and ODI questionnaires. The study group consisted of 298 patients, including 172 patients who had not undergone prior surgery and 126 patients who had undergone prior deformity surgery. They examined multiple radiographic parameters, including location of major and minor curves, Cobb measurements, coronal balance, apical rotation, lateral listhesis, and sagittal Cobb measures and balance. In the patients who had not undergone prior surgery, clinical outcomes did not correlate with curve magnitude, apical rotation, or the presence of single versus double major curves. Isolated thoracic curves had better scores than thoracolumbar and lumbar curves. The most significant compromise in health-related quality-of-life measures was seen in patients with positive sagittal balance compared with patients with neutral or negative sagittal balance. This included subcategories of pain, physical function, self-image, and social function. This finding was similarly seen in patients who had undergone prior surgery. This study emphasized that a loss of sagittal balance (C7 plumb line falling anterior to the L5-S1 disc on 36" lateral radiographs) was the single most important predictor of health-related quality-of-life measures in patients who had and had not undergone surgery for spinal deformity. The authors concluded that the maintenance or restoration of sagittal balance should be a primary goal of spinal deformity surgery (Fig. 1).

In a follow-up study, Glassman and coworkers [15] examined whether outcomes measures correlated with the degree of positive sagittal balance and the region of the spine involved. They again reviewed a multicenter spinal deformity database of 752 patients and identified 352 patients with positive sagittal balance. Patients were subdivided based on the number of millimeters of positive sagittal balance. All patients had completed the SRS-29, SF-12, and ODI questionnaires on enrollment. They found that pain and other measures of health status correlated with the degree of sagittal imbalance. They also found that relative kyphosis (or hypolordosis) was more poorly tolerated in the lumbar spine than in the thoracic or thoracolumbar spine.

With respect to operative treatment of adult scoliosis, curve flexibility is an important factor in planning surgical reconstruction because it can allow the surgeon to obtain better deformity correction while maintaining more mobile segments and performing a more limited fusion. Determinants of curve flexibility and pain patterns were examined by Deviren and coworkers [2] in a recent study that looked at 75 patients with thoracolumbar or lumbar scoliosis who underwent operative treatment of adult scoliosis. These investigators measured curve magnitude and flexibility and then examined how these correlated with patient age, presence of lateral listhesis, and axial and radicular pain patterns, using the Pearson correlation and linear regression modeling. Curve flexibility showed a strong inverse correlation with curve magnitude ($r = -0.7$) and age ($r = -0.6$). Using linear regression, they found that for curves greater than 40°, every 10° increase in curve magnitude led to a 10% decrease in structural curve flexibility. Similarly, with every 10-year increase in age, flexibility decreased 5%. Axial pain had a moderate correlation with

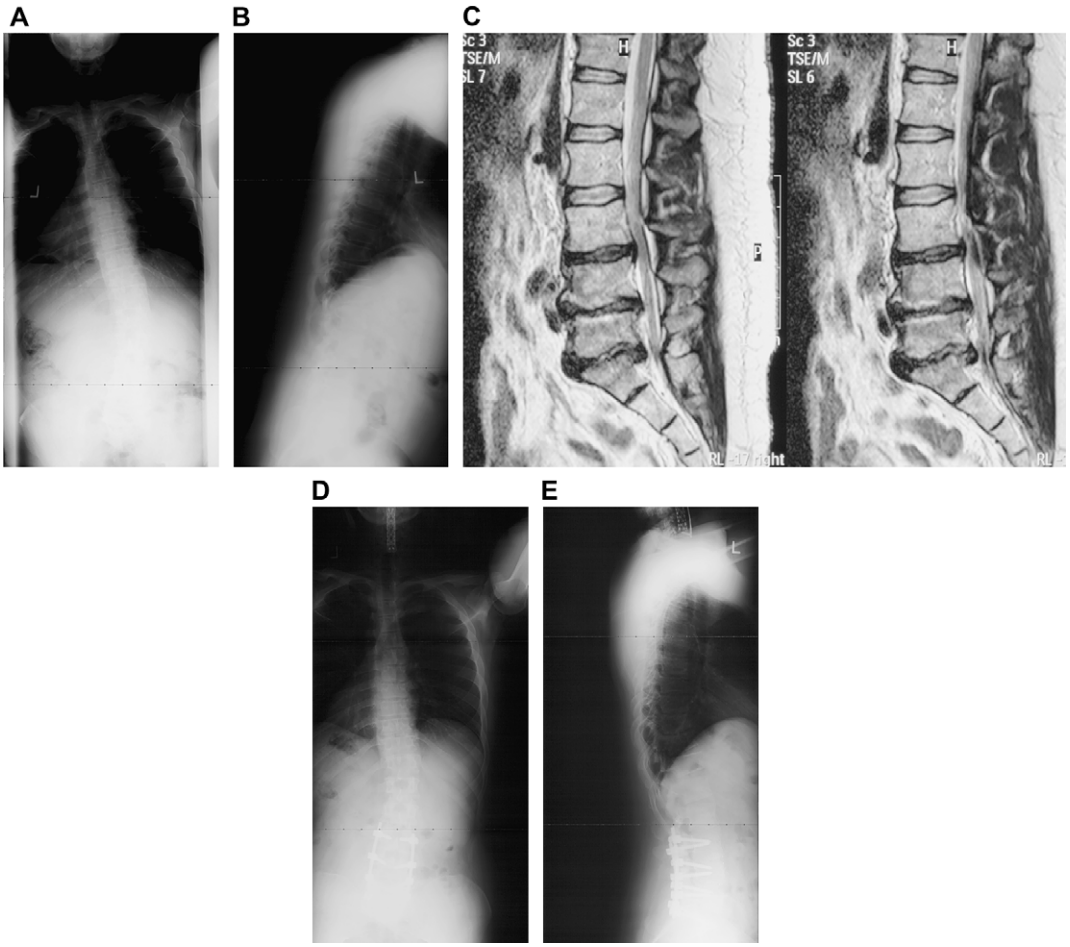

Fig. 1. Standing 36'' posteroanterior (*A*) and lateral (*B*) radiographs demonstrate significant loss of lumbar lordosis and positive sagittal balance in a patient with severe degenerative disease of the lumbar spine (*C*). (*D, E*) Surgical treatment included anterior releases and lordotic interbody grafts as well as posterior osteotomies and correction with instrumentation.

flexibility and a strong correlation with age, whereas radicular pain had only mild correlations with flexibility, lateral listhesis, and percent slip. The authors concluded that with aging and further degeneration of adult scoliosis, curve flexibility decreases and axial pain complaints increase.

In summary, when reviewing the available literature for adult scoliosis, it seems that curve magnitude is not a strong determinant of clinical complaints. With age and degeneration of thoracolumbar and lumbar curves, curve stiffness increases and the likelihood of axial pain complaints increases. Positive sagittal balance is a strong determinant of subjective patient complaints and is associated with diminished health-related outcomes measurements.

Summary

Surgical indications for spinal deformities can be straightforward in cases of clear deformity progression but are less clear-cut when surgery is performed to address clinical symptoms. Standardized validated outcomes questionnaires provide an important tool to examine which aspects of spinal deformity are most closely associated with these clinical complaints. This may allow further refinement of surgical procedures in the future to address and ameliorate these clinical complaints better.

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