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Clinical Study

Clinical and radiographic degenerative spondylolisthesis (CARDS) classification

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Abstract

BACKGROUND CONTEXT: Lumbar degenerative spondylolisthesis (DS) is a common, acquired condition leading to disabling back and/or leg pain. Although surgery is common used to treat patients with severe symptoms, there are no universally accepted treatment guidelines. Wide variation in vertebral translation, disc collapse, sagittal alignment, and vertebral mobility suggests this is a heterogeneous disease. A classification scheme would be useful to differentiate homogenous subgroups that may benefit from different treatment strategies.

PURPOSE: To develop and test the reliability of a simple, clinically useful classification scheme for lumbar DS.

STUDY DESIGN: Retrospective case series.

PATIENT SAMPLE: One hundred twenty-six patients.

OUTCOME MEASURES: Proposed radiographic classification system.

METHODS: A classification system is proposed that considers disc space height, sagittal alignment and translation, and the absence or presence of unilateral or bilateral leg pain. Test cases were graded by six observers to establish interobserver reliability and regraded in a different order 1 month later to establish intraobserver reliability using Kappa analysis. To establish the relative prevalence of each subtype, a series of 100 consecutive patients presenting with L4–L5 DS were classified.

RESULTS: Four radiographic subtypes were identified: Type A: advanced Disc space collapse without kyphosis; Type B: disc partially preserved with translation of 5 mm or less; Type C: disc partially preserved with translation of more than 5 mm; and Type D: kyphotic alignment. The leg pain modifier 0 denotes no leg pain, 1 denotes unilateral leg pain, and 2 represents bilateral leg pain. The Kappa value describing interobserver reliability was 0.82, representing near-perfect agreement. Intraobserver reliability analysis demonstrated Kappa=0.83, representing near-perfect agreement.

FDA device/drug status: Approved (Pedicle Screws), (Interbody Cages).

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Grading of the consecutive series of 100 patients revealed the following distribution: 16% Type A, 37% Type B, 33% Type C, and 14% Type D.
CONCLUSIONS: A new radiographic and clinical classification scheme for lumbar DS with high inter- and intraobserver reliabilites is proposed. Use of this classification scheme should facilitate communication to enhance the quality of outcomes research on DS.

Keywords: Lumbar degenerative spondylolisthesis; Degenerative spondylolisthesis; Classification system; Lumbar spinal fusion; Spondylolisthesis; Iatrogenic destabilization

Introduction

Lumbar degenerative spondylolisthesis (DS) is a common, acquired, pathologic condition that can lead to disabling back or leg pain. Although surgery is commonly required for patients with severe symptoms secondary to DS, there are no universally accepted treatment guidelines. Many surgeons routinely perform spinal fusion when decompressing the neural structures for symptoms of neurogenic claudication or radiculopathy. This approach is based, in part, on the work by Herkowitz and Kurz [1], who demonstrated superior clinical outcomes for patients undergoing noninstrumented fusion for DS compared with those who underwent laminectomy alone. In recent years, fusion for DS has commonly been supplemented with instrumentation, which has been shown to enhance the rate of successful arthrodesis [2]. Recently, it has become increasingly common to encounter patients undergoing interbody fusion for DS [3–5]. At the other end of the spectrum, some surgeons perform a decompression without fusion, especially when using a minimally invasive approach that preserves the midline structures [6–9]. Another subset of surgeons advocate the use of dynamic instrumentation without fusion to address the potential instability after decompression [10]. Clearly, more clarity is needed to define the optimal treatment strategies for this common clinical condition.

A major difficulty with studying or discussing treatment approaches to DS is the heterogeneous nature of the condition. Radiographically, a wide range is seen in the magnitude of vertebral translation, intervertebral disc collapse, sagittal alignment, and mobility with flexion and extension, parameters that have been previously demonstrated to change the biomechanical loading environment of spinal elements [11] and also affect loads placed on spinal instrumentation. Based on these differences, optimal treatment strategies may vary to address the biomechanical goals of the specific case but no classification scheme has ever been developed to encourage discussion and investigation of anatomic variations in DS. Such a scheme should be simple and reproducible so that clinicians and researchers can easily define the subgroup of a given patient and then apply a research or treatment approach designed for a more homogeneous subgroup instead of the entire disease spectrum.

The present study was undertaken to develop and test the reliability among spine surgeons of a simple, four-part classification scheme for patients with DS. The purpose of this classification scheme is to subdivide the wide spectrum of DS into reproducible subgroups to facilitate communication between clinicians and promote high quality outcomes research to be performed.

Materials and methods

Radiographic measurement survey

A prior radiographic survey was conducted [12] involving 304 patients with L4–L5 DS. In this survey, measurements were taken of anterior and posterior disc heights, vertebral translation, and vertebral movement with flexion and extension. This survey demonstrated a wide range of values for each of the measured parameters. The data from each measured parameter were continuous, without any natural ‘‘breaks’’ in data that could be used to subcategorize DS patients.

Selection of clinical and morphologic characteristics for the classification scheme

Given the absence of any useful data patterns that could be used to develop a classification scheme, a literature-based review was conducted to define a list of clinical and morphologic characteristics that were attributable to DS. Using the Delphi process [13], radiographic features felt to be important for identifying morphologically and biomechanically distinct groups of patients with DS were suggested and refined through circulation between three senior spine surgeons using a spine fellow as the Delphi process mediator. Through repeated circulation of the selected radiographic criteria, a proposed radiographic classification scheme for DS was determined by consensus. Although this study only analyzes the reproducibility of radiographic features of the classification system, the presence or absence of lower extremity pain (including buttocks) was added as a modifier to further stratify the groups.

The proposed classification scheme was based on three radiographic variables and one clinical variable. The radiographic variables for the slip level were: the presence of bony apposition of vertebral end plates; the presence of kyphosis on any radiographic view; and the magnitude of translation on lateral radiographic views. The clinical variable used was the presence and nature of lower extremity pain reported by the patient (graded as absent, unilateral, or bilateral).

Bony apposition

Loss of disc space leading to bony apposition is easily recognized on lateral radiographs. In the current classification scheme, bony apposition defined as ''bone on bone'' contact seen on any lateral radiographic view constitutes a distinct subgroup.

Kyphosis

Kyphotic alignment between the upper end plate of the caudal vertebra and the lower end plate of the cranial vertebra is also easily recognized. In the current classification scheme, kyphosis on any lateral view constitutes a distinct subgroup.

Translation

The magnitude of translation at the slip level is simple to measure as shown in Fig. 1. In the current classification scheme, translation on any lateral view was considered to divide patients into two groups—those in whom the magnitude of translation was less than 5 mm and those in whom translation exceeded 5 mm.

Lower extremity pain symptoms

Lower extremity pain is determined from the patient's history. In the current classification scheme, lower extremity pain is defined as being either absent, unilateral, or bilateral in nature.

Intra- and interrater reliability study

After institutional investigational review board approval, the proposed classification scheme was subjected to a reproducibility study. For this, the radiographic images of a retrospective cohort of 26 consecutive patients seen in the office of the senior author for lumbar symptoms and found to have DS at the L4–L5 level were assembled by a member of the research team who had no knowledge of the radiographic criteria included in the classification and did not participate in grading the cases. All patients had undergone plain radiography using a digital radiography system (Philips 9806 206 70102, version 1.5; Digital diagnostic, Hamburg, Germany), with standardized imaging techniques at a single institution. Radiographs were performed standing and included posteroanterior, neutral lateral, flexion lateral, and extension lateral images. All images were stored on picture archiving and communications system (IDS5 workstation, version 11.1; Sectro, Linköping, Sweden). A 5-mm line was placed on each lateral radiographic image adjacent to the L5 end plate using the picture archiving and communications system integrated software. The digital files of each patient's images were completely deidentified and assembled into a single document for distribution to the graders (Adobe, Orem, Utah).

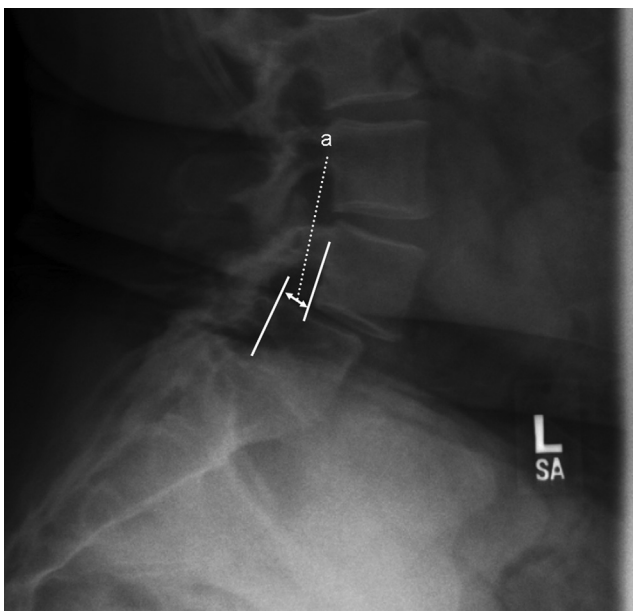

Fig. 1. Neutral lateral radiograph demonstrating technique used for determining the amount of vertebral translation (a).

The radiographic images were independently graded using the proposed classification scheme by five fellowship trained spinal surgeons and a spine fellow, including the three fellowship trained spinal surgeons who developed the grading system. Before being given the case series, each grader received an approximately 5 to 10 minutes tutorial on the classification scheme. The tutorial included a description of the different radiographic features included in the classification system and radiographs of a single archetypal case example representing each subgroup. One month later, the same 26 DS cases were independently regraded by each of the six graders after the order of the cases was changed to prevent recall bias.

Inter- and intraobserver reliabilities were analyzed through the calculation of the Kappa statistic for nominal data. Interobserver reliability was calculated by comparing results from all observers on the first grading round to minimize the benefit of experience with the system and prevent against observers discussing the system with one another. The Kappa statistic for interobserver reliability is presented with 95% confidence interval. Intraobserver reliability was calculated by calculating a Kappa statistic for each grader between the first and second grading rounds and then averaging Kappa statistics across all six observers. Similarly, this was done separately for those attending surgeons who did and did not participate in formulation of the classification scheme. Kappa values were analyzed according to a previously described semiquantitative scale [14]: no agreement for values less than 0, slight for 0 to 0.20, fair for 0.21 to 0.40, moderate for 0.41 to 0.60, substantial for 0.61 to 0.80, and near-perfect for 0.81 to 1.0.

General distribution of subcategories

To provide insight into the general distribution of classification subgroups within a spinal practice population, a series of 100 consecutive patients seen between January 2007 and December 2009 presenting to the senior author's

practice with evidence of L4–L5 DS were retrospectively classified by a single grader. The purpose of this series is primarily to show the distribution of patients by morphology with the secondary purpose of describing whether morphologic features were associated with differential surgical treatments or whether these patients were treated similarly despite differing morphologic DS characteristics.

Results

Morphology subgroups

Type A: advanced disc space collapse without kyphosis

This subgroup is characterized by complete collapse of the disc space with bony apposition of adjacent vertebral end plates that would prevent further axial settling. For Type A designation, the disc space collapse may be symmetric with nearly parallel end plates (Fig. 2) or asymmetric with bony apposition along only the posterior margin of the end plate (Fig. 3). In the Type A subgroup, no kyphosis between the end plates on any lateral radiographic view should be seen.

Type B: disc partially preserved with translation of 5 mm or less

This subgroup is characterized by at least partial preservation of the disc space and an absence of kyphosis between the end plates. For the Type B subgroup, the magnitude of vertebral translation observed on all lateral radiographic images (neutral, flexion lateral, or extension lateral) must be 5 mm or less (Fig. 4).

Type C: disc partially preserved with translation of more than 5mm

This subgroup is characterized by at least partial preservation of the disc space and an absence of kyphosis between the end plates. For the Type C subgroup, the magnitude of translation observed on at least one lateral radiographic view (neutral, flexion lateral, or extension lateral) must be more than 5 mm (Fig. 5).

Type D: kyphotic alignment

This subgroup is characterized by a kyphotic angle subtended by lines drawn parallel to the end plates at the slip level on at least one lateral radiographic view (neutral, flexion lateral, or extension lateral) (Fig. 6). Type D subgroup patients may have preservation of disc height or bony apposition at the anterior margin of the end plates. Additionally, kyphotic alignment may be fixed or may move with flexion and extension radiographs.

Leg pain modifier

The leg pain modifier is based on the presence and location of leg pain reported by the patient during the medical history. Those without leg pain (absent) are designated with the modifier 0. Those with unilateral leg pain are designated with the modifier 1 and those with bilateral leg pain are designated with the modifier 2.

Overall classification scheme

Overall, the clinical and radiographic degenerative spondylolisthesis (CARDS) classification scheme has four morphologic types (A, B, C, and D) and three leg pain modifiers (0, 1, and 2), resulting in 12 subgroups based on the combination of radiographic morphology and leg pain symptoms: Types A0, A1, A2, B0, B1, B2, C0, C1, C2, D0, D1, and D2.

Reliability analysis

The Kappa value for the interobserver analysis (six observers) of the four morphologic subgroups was 0.82

Fig. 2. Type A: (Left) neutral, (Middle) flexion, and (Right) extension lateral radiographs demonstrating collapse of disc space with preserved lumbar lordosis on all views.

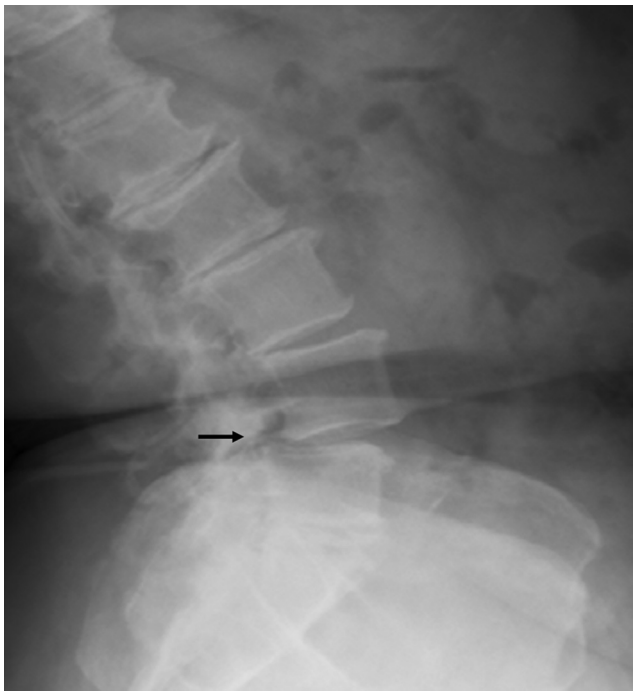

Fig. 3. Type A: asymmetric disc space collapse variant. Although this lateral radiograph shows that the disc space is asymmetrically collapsed, the presence of bony apposition (arrow) places this case in the Type A subgroup.

(95% confidence interval, 0.74–0.90), representing near-perfect agreement. Intraobserver reliability analysis demonstrated an average Kappa value of 0.83 (range, 0.77–0.89) based on repeated grading 1 month later, also representing near-perfect agreement. Average Kappa score for the three attending surgeons who participated in the formulation of the classification (0.80) was similar to the average score for the two attending surgeons who did not participate (0.83).

Distribution of cases

Of the 100 consecutive patients, 96 were female and the average age was 61.5 years. Grading of the consecutive series of 100 DS patients revealed the following distribution of morphologic subtypes: 16% Type A, 37% Type B, 33% Type C, and 14% Type D. Of the 92 patients for whom clinical information was available, 76% were treated surgically compared with 24% nonoperatively. There was no difference in the likelihood of surgical treatment based on morphologic subtype ($p=.92$). Similarly, there was no difference in the likelihood of anterior column reconstruction via either transforaminal interbody fusion ($p=.26$) or anterior lumbar interbody fusion ($p=.64$) based on morphologic subtype.

Discussion

The wide range of radiographic parameters seen with DS is indicative of a heterogeneous disease for which a ''one size fits all'' treatment approach may overtreat or undertreat a significant percentage of the patient population. Given how frequently DS is encountered in clinical practice, it may seem surprising that no classification scheme for this condition entered common usage. A wide range of surgical approaches have been advocated in the scientific literature including simple decompression [9], decompression with noninstrumented posterolateral fusion [1], decompression with instrumented posterolateral fusion [2], decompression with interbody fusion [15], and decompression with dynamic stabilization [16]. The reported results after surgical treatment of DS patients have been widely variable [8,17,18].

One factor that hampers research in the field of DS is the lack of a method to subdivide this patient population into

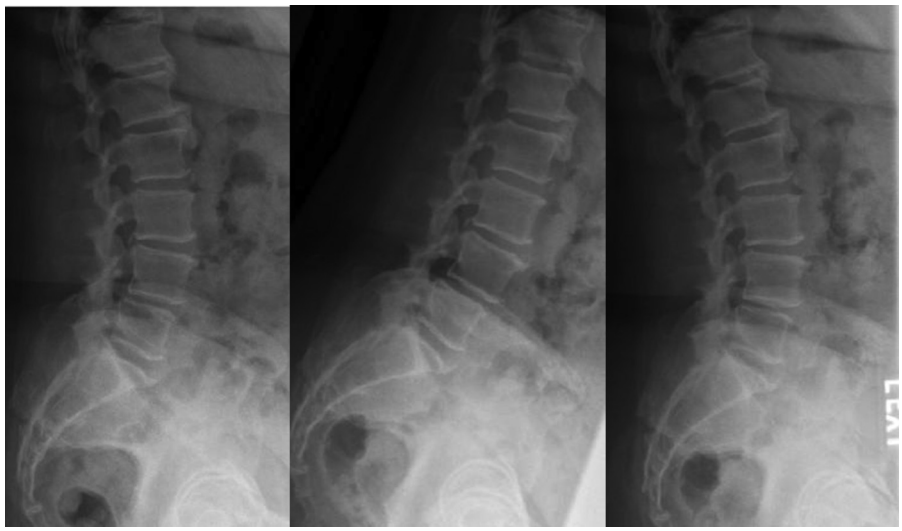

Fig. 4. Type B: (Left) neutral, (Middle) flexion, and (Right) extension lateral radiographs demonstrating partial preservation of disc space with 5 mm or less translation.

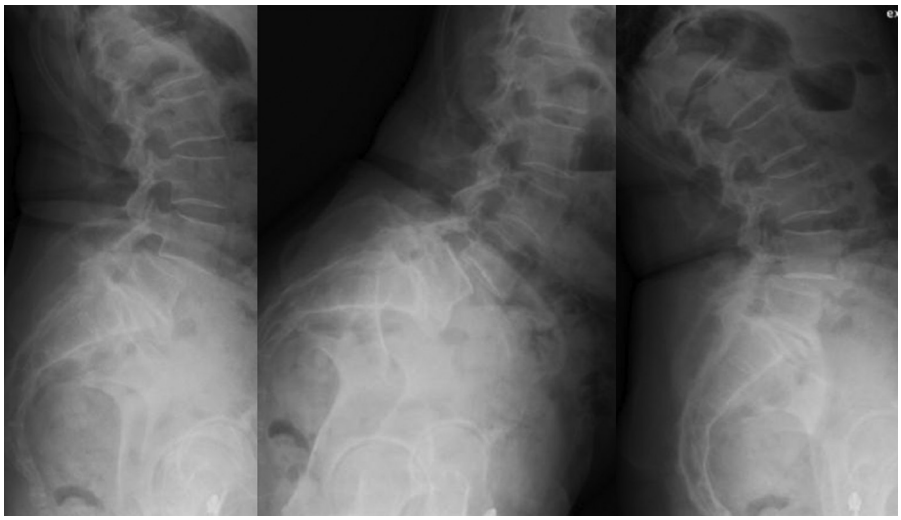

Fig. 5. Type C: (Left) neutral, (Middle) flexion, and (Right) extension lateral radiographs demonstrating partial preservation of disc space with more than 5 mm of translation.

reproducible subgroups. The current literature on DS treatments, almost exclusively, lumps all patients together, making it impossible to understand the makeup of a particular study population and compare patients between studies. This ''one size fits all'' approach is shown by the lack of treatment variation when patients are separated based on DS morphology in our series of 100 consecutive patients. To improve this situation, a reproducible method of subcategorizing DS is needed. Such a classification scheme should improve the definition of study populations in the future and allow research to be conducted in a more systematic manner. In addition, a classification scheme would foster accurate communication between clinicians.

In the present study, we set out to define subgroups of DS patients that could be reproducibly categorized based on radiographic and clinical features. Our goal was to produce a simple scheme that could be used by clinicians and researchers. We based our scheme on plain radiographs because of the wide availability and relatively low cost of these imaging studies. Importantly, we have shown that the current scheme has high intra- and interrater reliabilities, suggesting that it should be useful in defining radiographic subgroups of DS patients when conducting clinical research.

Previously described spondylolisthesis classification systems have generally not attempted to subclassify DS based on morphology. The etiology-based classification system described by Wiltse et al. [19] includes DS as a subtype of spondylolisthesis, but made no further attempts at subdivision, which prevents characterization of outcomes for DS subgroups. The widely used Meyerding classification divides spondylolisthesis into four grades (I–IV) depending on the magnitude of translation and includes spondyloptosis as Grade V, but does not consider other radiographic parameters such as disc height or sagittal alignment. Although the Meyerding classification likely provides some insight into segmental instability as greater translation is probably associated with greater instability,

Fig. 6. Type D: (Left) neutral, (Middle) flexion, and (Right) extension lateral radiographs demonstrating kyphotic alignment of L4–L5 on flexion view based on the kyphotic Cobb angle lines.

this system does not consider other factors that likely influence stability, such as sagittal alignment. Additionally, almost all patients with DS would be graded as Grade I or II slips on the Meyerding scale [20], leaving little room for differentiation between DS patients.

The concept of disc space collapse having prognostic implications on patients with DS is not new. Matsunaga et al. [20,21] found in a natural history study that DS patients with collapsed disc spaces tended to demonstrate no slip progression at 10- to 18-year follow-up. Other authors have suggested that disc space collapse may influence the need for supplemental instrumentation when performing a spinal fusion for DS [22,23]. Still others have concluded that the stability conferred by a collapsed disc space may allow this subgroup to be treated with decompression alone [6–9].

The largest group of DS patients in the present study had partial preservation of disc height and no evidence of segmental kyphosis. In our scheme, we subdivided these into two subgroups: those with lower magnitude slips (5mm or less [Type B]) and those with larger magnitude slips (greater than 5 mm [Type C]). Our rationale for subdividing this category was that the lower magnitude slips likely represented a more stable cohort compared with the higher magnitude slips. The 5-mm cutoff for dividing the groups was chosen arbitrarily because it represented the approximate median slip magnitude observed in the radiographic survey of 304 consecutive patients presenting with L4–L5 spondylolisthesis [12]; we admit there is no evidence that this distance represents a biomechanical breakpoint and was empirically chosen. The continuous nature of the sagittal translation values in this survey did not allow us to identify a ''natural break'' or other type of ''groupings'' that could be used in the current classification scheme. Others have suggested that larger slips should be treated with instrumentation or supplemental interbody fusion to achieve an optimal rate of arthrodesis [22,24]. Using a classification scheme, investigators will be able to test these hypotheses in the future and potentially identify optimal treatment strategies based on spondylolisthesis morphology.

Sagittal alignment has increasingly been suggested to be an important factor in improving outcomes after lumbar fusion [25–29] and in the avoidance of adjacent segment disease [30–33]. A recent investigation found a positive association between lumbar lordosis and improved outcome after surgery for DS [34]. The subset of patients who assume a kyphotic alignment of the slip level on lateral radiographic views presumably have either a deficiency of anterior column support and/or increased facet complex instability compared with other subgroups of DS. Sengupta and Herkowitz [22] recommended the use of interbody support in similar cases to reduce the excessive stresses imparted to the posterior instrumentation. Further study with careful stratification of patients will be necessary to validate this approach.

The presence of leg pain is believed to be an important issue when making clinical decisions regarding the treatment of DS patients. Multiple studies have suggested that leg pain (as opposed to low back pain) is more responsive to surgical intervention [18,35]. The distinction of unilateral versus bilateral leg pain symptoms may be a factor to consider when making treatment decisions. For instance, some have suggested that only the symptomatic side of the spinal canal requires decompression when performing a minimally invasive decompression [6–9] or dynamic stabilization [10]. The current classification scheme uses the leg pain modifier to stratify patients in a way that will allow investigators to test the validity of this approach. Although we did not include the lower extremity component in our study of the reproducibility of this classification system, our goal was first to investigate the radiographic scheme we have proposed retrospectively and there would be little variation in retrospective application of the leg modifier because the history would have to be provided to observers.

Certain additional limitations of the present study should be acknowledged. The present classification scheme was based on the selection of reproducible criteria that could be gleamed from history and plain radiographs rather than biomechanical studies. Therefore, there is presently no proof that the classification subgroups are biomechanically distinct although biomechanical studies have demonstrated biomechanical consequences of the features our classification considers, such as loss of disc height and vertebral translation [11]. It is also unknown at the current time, whether the optimal treatment approaches to the various subgroups of DS will differ. Further clinical studies will be necessary to determine the validity of the classification scheme with regard to patient outcome. Specifically, prospective study backed by validated clinical outcome measures will be used to compare outcomes among groups of patients with similar DS morphology treated using different surgical techniques and to compare patients with different DS morphology treated with the same technique as a first step. The series of 100 consecutive patients was reviewed only to give insight into the general distribution of the morphologic subtypes; a classification system with a heavily skewed patient distribution between various categories would not be clinically practical. We do not have outcome data on these patients nor were they followed for uniform periods to compare surgical outcomes, but we have begun to gather such data prospectively. Our classification system does not consider global lumbar sagittal or coronal plane imbalance that may be important in more complex degenerative deformity. Despite these limitations, we believe that the CARDS classification scheme will facilitate a more detailed and systematic approach to clinical research, which will address outstanding questions regarding optimal treatment for most patients with DS.

Conclusion

A new classification scheme for lumbar DS is proposed based on radiographic and clinical criteria. This scheme is shown to have high inter- and intraobserver reliabilities. Use of the CARDS classification scheme should facilitate communication between clinicians and enhance the quality of outcomes research in the field of DS.

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