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Research Article

Adult scoliosis: classification based on the L3-L5 segment

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• Spine; Deformity; Scoliosis; Adult Scoliosis; Idiopathic Scoliosis; Degenerative Scoliosis; Balance; Classification

Abstract

1.1. Study Design: Retrospective review of a case series.

1.2. Objective: Define objective parameters to differentiate between Adults Degenerative Scoliosis (ADS), and Adult Idiopathic Scoliosis (AdIS). These are at the L3-L5 segment.

1.3. Methods: A series of 53 adult scoliosis (mean age 55 y.o., median 57 y.o. range: 20-84 y.o.), was studied. Variables: age, curve parameters (Cobb, end vertebra), coronal and sagittal balance, spinopelvic parameters, and L3-L5 parameters (distance from the center of the disc to CSVL, and endplate coronal tilt). Statistical study: R package software, some variables not normal distribution, non-parametric tests. Approved by the IRB.

1.4. Results: Distance of L3-L4 disc (18 mm; 2-52) showed a bimodal distribution that also correlated to spinopelvic parameters: if 15mm or less, then PT 22°±8°; if > 15 mm, then PT 32°±17° (p=0.04 U Mann-Whitney). L4 endplate tilt inversely correlates to SS (Pearson -0.3; p<0.01), and positively to PT (Pearson 0.4;p=0.002) L3-L5 segment helps differentiate ADS from AdIS.

1.5. Conclusions: Distance of the center of the disc L3-L4 to the central sacral line is an objective parameter to differentiate ADS from AdIS.

It also correlates with compensatory mechanisms (PT), with statistical differences in PT between types of adult scoliosis.

ABBREVIATIONS

ADS: Adult Degenerative Scoliosis; **AdIS**: Adult Idiopathic Scoliosis; **CSVL**: Central Sacral Vertical Line; **SVA**: Sacral Vertical Axis; **PI**: Pelvic Incidence; **PT**: Pelvic Tilt; **SS**: Sacral Slope

INTRODUCTION

The pathogenesis of adult scoliosis is a deformity from the collapse of the spine that bends due to asymmetrical changes at the vertebral functional units, especially at the facet joints; this type being de novo adult degenerative scoliosis (ADS); or else, the evolution of an adolescent idiopathic curve (AdIS), in which, usually the symptomatic decompensation arises from distal junctional problems. Aebi called the first situation adult scoliosis type I and the second adult scoliosis type II [1]. This differentiation probably has implications on surgical planning, but the quest for criteria to differentiate between both types has not been successful.

It is for granted, on differentiating ADS from AdIS, that ADS has low Cobb angles, involves few vertebral bodies that are not wedge-shaped, and then develops no thoracic compensatory curve [2]. But, in real life, differentiation between both types is not easy. Even more, the intra-observer agreement is moderate to substantial, but the inter-observer one is just fair [3].

So, those theoretical items set to differentiate are of some (not high), value when the same radiographies are evaluated twice by the same observer, but they have hardly any value when different observers classify. This fact makes the problem even bigger as individual observers do not perceive this low reliability unless challenged by the judgment of others.

When you need to evaluate the radiographies of an adult patient with scoliosis with a lumbar curve, the question arises: how did we get to this point? That is, we try to look back at the pathogenesis.

Why the L3-L5 segment?

Once having said that, degenerative changes responsible for ADS usually happen at L3-L4 or else L4-L5 levels, as the L5-S1 (also degenerated), is deep in the pelvis, with L5 tied by iliolumbar ligaments and thus making vertebral rotation not possible; also, from the other pathogenic pathway, the end vertebra in AdIS curves is either L3 or L4, so that junctional issues happen at L3-L4 or else L4-L5 levels. Hence, at the L3-L5 segment in ADS, we will see the apical disc, which is horizontal and away from the central sacral line. On the other hand, in patients of AdIS, we will see the junction, with an end vertebra close to the midline (central sacral vertical line, CSVL), and a slanted disc between the

Figure 1 Adult Idiopathic Scoliosis.

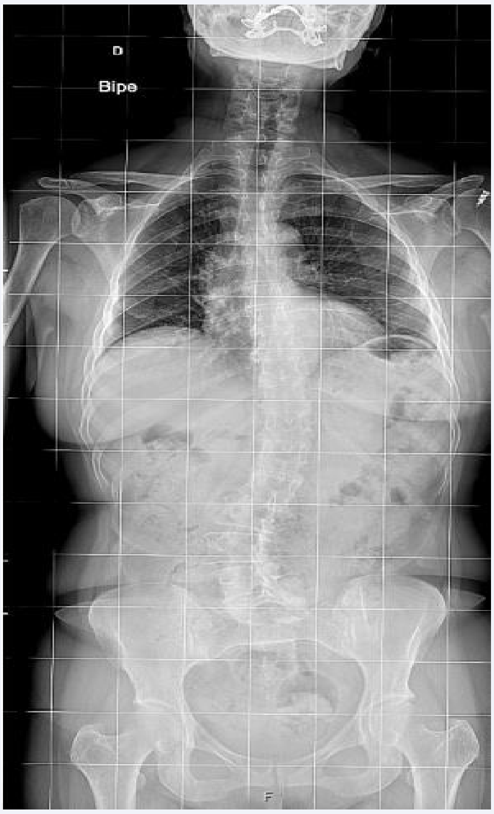

Figure 2 Adult Degenerative Scoliosis.

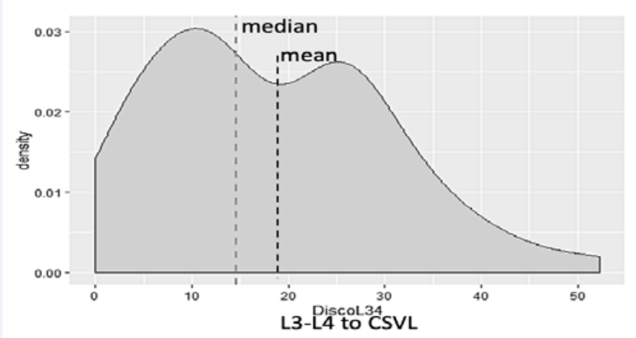

Figure 3 Distance L3-L4 to CSVL.

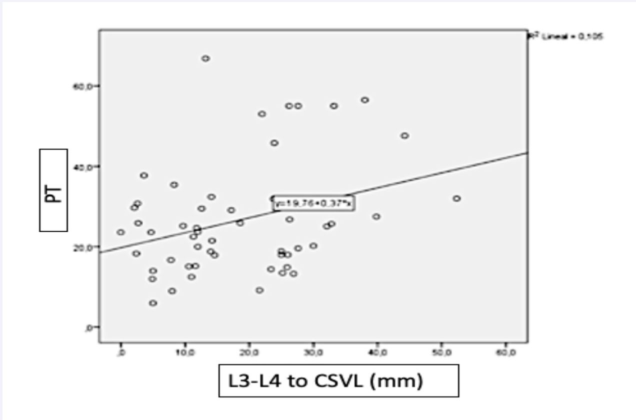

Figure 4 Distance L3-L4 to CSVL versus Pelvic Tilt.

end vertebra and the neutral (sometimes the same as the stable one, see Figures 1 and 2).

Hypothesis

At the L3-L5 segment, there are objective data to differentiate between ADS and AdIS.

Secondary hypothesis

These different pathogenetic pathways result in a different balance, the ADS being imbalanced due to that degenerative collapse at the lower lumbar spine.

MATERIALS AND METHODS

A series of 60 patients had surgery for scoliosis affecting the lumbar spine, all by the same surgeon. Seven patients had poor imaging (not possible to see the center of rotation of the hips in lateral radiographies), and had to be left out. So 53 remained and were considered for the study. Seven had had surgery before 45 years of age, all seven with a thoracic curve; besides, another 14 patients had thoracic scoliosis (curve > 10º), and surgery older than 45 years of age. Variables: age, thoracic curve (Cobb, upper and lower limits, and apex), lumbar curve (Cobb, upper and lower limits, and apex), lumbosacral curve (Cobb, upper and lower limits, and apex), T1 and L1 balance both coronal and sagittal (millimeters from CSVL and sacral vertical axis -SVA-

, respectively), spinopelvic parameters (pelvic incidence -PI-, pelvic tilt -PT- and sacral slope -SS-), and L3-L5 parameters (distance of the center of L3-L4 and L4-L5 discs to CSL in AP view; the tilt of each endplate of these discs: inferior endplate L3, superior & inferior endplates L4 and superior endplate L5). Statistics: R package software, non-parametrical tests as non all variables had a normal distribution. This research has got the approval of the Institutional Review Board (Ethical Committee for Clinical Research of the Hospital).

RESULTS

Data from 53 valid patients: age 55y.o. (20-84 y., median 57 y.), thoracic curve (present in 21 out of the 53), 34º (0-91º), lumbar curve (in 48 out of the 53), 32º (0-73º), lumbosacral curve 17º (0-31º). Spinopelvic parameters: PI 60º (21-90º), SS 34º (7-61º), PT 26º (6-67º). L3- L5 variables: distance L3-L4 disc to CSL 18 mm (2-52 mm) showing a bimodal distribution, distance L4-L5 disc to CSL 8 mm (0-43 mm), tilt L3 inferior endplate 13º (1-32º), tilt L4 superior endplate 13º (0-31º), tilt L4 inferior endplate 13º (0-32º), tilt L5 superior endplate 8º (0-30º). The results showed a correlation between the endplate tilt at the L3-L5 segment versus the spinopelvic parameters (see **Table 1**). No differentiation could be made based on the stratification of data. The analysis of results showed: a) disc distance from CSL at the L3-L5 segment vs. spinopelvic parameters showed a bimodal distribution at the L3L4 disc with a mean of 17.86 mm and a median of 14.15 mm. If a cut-point of 15 mm is selected, we can differentiate two groups regarding PT, if < 15 mm then PT 22º+8º, but if >15mm then PT 32º+17º (p=0.042; U Mann-Whitney). In the overall analysis of the results, distance L3-L4 to CSL vs. PT had a positive correlation (Pearson 0.32; R-square=0.105, p=0.018) (see **Figures 1** and **2**).

DISCUSSION

The first question is why classify adult scoliosis. That is not simply an academic action; it has been a must for surgeons, the goals being: systematic categorization, prognostic information based on natural history, correlation with health status, and guiding optimal care [4]. Aside from the descriptive, purely nominal classifications, the rationale is a basis for the management. Sometimes, like the one described by Kuntz [5], many items are considered (up to 17 in the coronal plane and 21 in the sagittal), to focus on the NUSA (neutral upright spinal alignment), which means balance. And balance is the guiding thread in the paper by Nakashima [6], again striving for an energy-sparing environment to avoid unnecessary fatigue. All this becomes especially important in adults, and thus another methodology is evolving from adolescent classification by adding relevant modifiers for the adult deformities setting: the fractional lumbosacral curve and, again, balance, but in the form of a global alignment, a step beyond spinopelvic parameters [7].

Table 1: L3-L5 endplate tilt vs. spinopelvic parameters: Pearson correlation and p values in brackets.

Endplate tilt (º)	SS	PT
Inferior L3	-0.228 (<0.05)	NS
Superior L4	-0.364 (0.007)	0.421 (0.002)
Inferior L4	-0.31 (0.002)	0.41 (0.002)

Abbreviations: PT: Pelvic Tilt; SS: Sacral Slope; NS: not significant.

Due to its aggressiveness, surgery in adult scoliosis might be fraught with perioperative complications. Then, another classification comes out by Silva and Lenke to design the most overall profitable stepwise approach in surgical planning [8]. And finally, but probably not the last to come, AO Spine proposes a "comprehensive patient evaluation" (quote) instead of a classification [9]. This evaluation comprises general health (both comorbidities and demographics, including social support), spine-specific status (both health, including pain, quality of life, expectations, and previous surgery; and neurologic status), imaging (both radiographies and MRI), and type of deformity.

Type of deformity comes into play as a feature for understanding the patient spine deformity, and the distinction between types (ADS, AdIS), has shown to be an unclear field, mainly because although an acceptable intra-rater agreement exists, that was not the case with inter-rater one [3].

That situation, from our perspective, is a deceptive problem as it is not perceived as such until confronted by peers. And there is a need to define some clear-cut criteria to differentiate among curve types.

When looking for a rationale for this differentiation, we focused on the pathogeny. Then, addressing the problem: on one side, we have a "crack" in the spine at a junction, with rotatory subluxation, canal encroachment, and one mechanically vulnerable point, whereas, on the other, we have spondylosis with huge syndesmophytes, causing neurogenic claudication to the lower limbs sometimes not relieved by sitting [10], and perhaps, a balance problem of the trunk, but not with one unstable vertebral functional unit.

Our results clearly show two different types of lumbar adult scoliotic curves regarding distance to CSVL from the L3-L4 disc, as this variable shows a bimodal distribution with statistically significant differences between them. Besides, this same variable correlates to PT, which is known to be an important compensatory mechanism for sagittal imbalance, with a different mean for PT in any of the two types of the bimodal distribution of the distance L3-L4 disc to CSVL. And, going a step further, the PT value in one of them is below the consensual level for deformity in itself (PT=25, after Schwab)[11] while in the other is quite above; that is, one is pathological versus the other, which is not. Thence, we describe a variable with little margin for error that can give information about the kind (not just type), of deformity we are managing.

And the distinction happens in the L3-L5 segment, where the natural history differs in ADS versus AdIS. Whether these types match may be a question for further debate, but it seems an at least acceptable assumption. It seems clear also that there are different pathogenic pathways to get to a twisted spine in an adult patient, the two main groups being: a) those already scoliotic patients since adolescence in which, due to the degeneration of discs and then the spine, an asymptomatic situation becomes symptomatic; b) another one would be those patients in which without any previous curve, a whole degenerative collapse brings about the deformity [1]. As we said before, research to distinguish ADS patients from AdIS patients with standard variables obtained no positive outcome [3].

Of note is that, probably due to the rib cage and, besides, the biomechanical environment with higher loads and demands in the lumbar spine, adult scoliosis is a problem of the lumbar spine, the thoracic spine especially being concomitantly affected by aging and kyphosis, which adds to the lumbar issues sometimes. Symptoms in patients with adult scoliosis arise in the lumbar spine, whether directly (root compression), or indirectly (trunk imbalance). And this trunk imbalance has two main components: spine deformity and sarcopenia, which makes the body unable to maintain proper balance. Once having said that, now the second question is whether surgical planning is affected by this different pathogenesis. And we think it should: on the one hand, given there is a definite unstable short area, it is possible to address only this segment in some patients, with aggressive work in the disc space and facets; on the other, a multilevel degeneration problem is more prone to cause a disbalance of the trunk, or else, canal stenosis in a more stable biomechanical environment in which localized decompressions without fusion or short fusions (one or two levels), could be the best planning for one specific patient. Besides, be a need for a global realignment, the L4-L5 disc usually has to be addressed as part of the restoration of lordosis, but the L3-L4 disc might also need it if there is a junctional subluxation; otherwise, a weak point in the anterior column could act as a stress riser and facilitate pseudoarthrosis. In the same line of reasoning, it seems not advisable to plan a pure decompressive procedure on an unstable level, but it could be wise to do an instrumented fusion of that single level.

All this reasoning goes in the same line as the paper of Li [12], which addresses the anterior column in a more aggressive way LLIF), may change the planning. Thus, as a result of our research, sometimes the L3-L4 disc needs stable anterior support, not necessary for lordosis, which usually lies in L4-S1, but just for further stabilization of the segment. We could spare the L5-S1 segment fusion after a thorough anterior reconstruction by LLIF L3-L4.

We propose some such parameters, the distance to CSVL and endplate tilt, both at the L3-L5 segment, which are not usually measured when planning for these patients, are capable of differentiating two kinds of adult scoliosis. And, for sure, a classification after them, due to their simplicity (a distance and a tilt), will have high intra-observer reliability and a much better interobserver than in other series [3].

Although we did not formally address intra-observer and interobserver reliabilities in our series, there was a group of radiographies (the 20 patients that were the first to be measured), in which we repeated the measurements (disregarding the 20 initial values). That served both as training and a way to diminish this intra-observer variability.

Nevertheless, the initial values showed almost identical results compared to the repeated ones. Besides, most measurements were done collectively and by on-site consensus, so there was no role for interobserver variability. The objective was not a classification to be validated but to find objective parameters to foster interobserver reliability in the existing ones [1,9].

CONCLUSIONS

1) We have found a criterion to differentiate two groups in adult scoliosis patients regarding PT: distance from the center of the L3-L4 disc to CSL.

2) L4 endplates tilt correlates with compensation mechanisms (SS vs. PT).

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CONFLICT OF INTEREST

The authors declare no conflict of interest related to the topic of the manuscript or any conflict of interest exists.

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