The evaluation of lumbosacral dysplasia in young patients with lumbosacral spondylolisthesis: comparison with controls and relationship with the severity of slip

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Abstract

Introduction Comparison of lumbosacral dysplasia between normal individuals and patients with low and high grade spondylolisthesis has not been done previously. The objective of this study is to evaluate the relationship between lumbosacral dysplasia and severity of slip in young patients with lumbosacral spondylolisthesis.

Methods Postero-anterior and lateral radiographs of 120 normal individuals and 131 patients with developmental spondylolisthesis (91 low and 40 high grades) were reviewed. Quantitative evaluation of lumbosacral dysplasia was done using 6 criteria involving the degree of laminar dysplasia, degree of facet dysplasia, size of L5 transverse processes, L5/S1 disc height, type of sacral doming and L5 lumbar index. Subjects were categorized as having no/low, moderate or severe dysplasia based on the total dysplasia score. Comparisons in total dysplasia score between normal, low grade and high grade groups were performed and the correlation between degree of dysplasia and percentage of slip was assessed.

Results Most normal individuals (88.3%) had no/low dysplasia; most patients with low grade spondylolisthesis (61.5%) had moderate dysplasia, while most patients with high grade spondylolisthesis (72.5%) had severe dysplasia.

There was a significant difference in dysplasia between normal individuals and patients with spondylolisthesis. Dysplasia also varied significantly between low and high grade spondylolisthesis. There was a strong positive correlation ($r = 0.63$) between severity of dysplasia and percentage of slip.

Conclusion There is a significant relationship between the severity of spondylolisthesis and lumbosacral dysplasia, with mainly no/low dysplasia observed in controls and increasing total dysplasia scores in higher grades of spondylolisthesis. In addition, a variable degree of dysplasia was found within groups with low or high grade spondylolisthesis, suggesting that different subgroups of patients exist with regard to dysplasia. Thus the degree of dysplasia varies in spondylolisthesis and it is possible that different grades of dysplasia could relate to different prognoses or outcomes with treatment.

Keywords Dysplasia · Lumbar · Lumbosacral · Spine · Spondylolisthesis

Introduction

It has been suggested that more severe dysplasia is associated with greater degree of spondylolisthesis [1–3]. Dysplasia affects anterior and posterior column structures, and could potentially change the direction and magnitude of stresses at the lumbosacral junction. In their classification of spondylolisthesis, Marchetti and Bartolozzi [4, 5] described low and high dysplastic subtypes but they did not give any strict criteria to differentiate between the two types.

Curylo et al. [1] assessed the dysplasia in the posterior elements of 53 patients with spondylolisthesis from the degree of laminar dysplasia; pars dysplasia and facet dysplasia were analyzed in their study. However, they did not

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assess anterior dysplasia, and a comparison of dysplastic features between normal individuals and patients with low and high-grade spondylolisthesis was lacking. Vialle et al. [6] focused on the dystrophic changes seen in the upper sacral endplate but did not discuss about dysplastic features of posterior elements. Yue et al. [7] described the abnormal anatomic findings in 27 patients with surgically corrected spondyloptosis. They observed dysplasia in all cases and they proposed proximal sacral endplate damage as a possible cause of spondyloptosis. Mac-Thiong et al. [8] described some features of low and high dysplastic spondylolisthesis but have not provided any quantitative data in their study. As for the treatment of high-grade spondylolisthesis, Molinari et al. [9] have observed that posterior dysplasia manifested by small L5 transverse processes reduces the space available for bone grafting, thereby resulting in an unacceptable high rate of pseudarthrosis with posterior in situ fusion.

Based on the current literature, there is no consensus on the most relevant criteria to use to quantify dysplasia in spondylolisthesis. The potential presence of dysplasia in normal individuals is also poorly documented, although determining the potential amount of dysplasia in the normal population is important before evaluating lumbosacral dysplasia in spondylolisthesis. In addition, the relationship between the degree of dysplasia and the severity of spondylolisthesis has never been investigated thoroughly. As the degree of dysplasia can potentially vary in spondylolisthesis, it is possible that different grades of dysplasia could relate to different prognoses or outcomes with treatment.

Therefore, the purpose of this work is to evaluate and compare the lumbosacral dysplasia between the controls and patients with low and high-grade spondylolisthesis. This study also investigates whether dysplasia varies significantly within each group. The relationship between the severity of dysplasia and the percentage of slip is also characterized.

Methods

Cohorts of 120 controls, 91 patients with low grade and 40 patients with high-grade lumbosacral spondylolisthesis were included in this retrospective study. This study has been approved by the Institutional Review Board. The cohort of 120 controls is composed of asymptomatic adolescents referred by their pediatrician for screening of adolescent idiopathic scoliosis but for whom the clinical evaluation and radiographs did not reveal any spinal pathology. The mean age in controls was 12.1 ± 2.6 years (range 6.8–19.3), and there were 40 males and 80 females. In the group of patients with low-grade spondylolisthesis,

the mean age was 13.5 ± 3.1 years (range 5.0–19.5) and there were 32 males and 59 females. The mean percentage of slip in the group with low-grade spondylolisthesis was $15.1 \pm 8.9\%$. In the group of patients with high-grade spondylolisthesis, the mean age was 14.8 ± 2.7 years (range 7.4–20 years) and there were 11 males and 29 females. The mean percentage of slip in the group with high-grade spondylolisthesis was $85.6 \pm 30.4\%$.

All patients had standing posteroanterior (PA) and lateral (LAT) radiographs of the whole spine. LAT radiograph was obtained for each subject standing in a comfortable position with hips and knees fully extended. For all subjects, the elbows were fully flexed and the fists were resting on the clavicles, as recommended by Faro et al. [10].

Dysplasia was assessed from both PA and LAT radiographs by a single observer. Criteria for assessing dysplasia were defined based on a critical review of the literature and on the clinical experience of two spine surgeons in the management of lumbosacral spondylolisthesis. Six quantitative criteria of lumbosacral dysplasia were selected due to their previous use in the literature, their ease of evaluation from plain radiographs, and their clinical relevance in the management of lumbosacral spondylolisthesis, as determined by the two spine surgeons. The criteria used for evaluating lumbosacral dysplasia were the degree of facet dysplasia, degree of laminar dysplasia, size of L5 transverse processes, type of sacral doming, lumbar index (height of anterior wall divided by height of posterior wall of L5 vertebral body), and the L5–S1 disc height on lateral radiographs (Table 1; Fig. 1). The score associated with

Table 1 Criteria for assessment of lumbosacral dysplasia

Criteria	Finding	Score
Degree of laminar dysplasia	Normal laminae	0
	Spina bifida occulta	1
	Absent laminae	2
Degree of facet dysplasia	Normal facets	0
	Hypoplastic facets	1
	Aplastic facets	2
Size of L5 transverse processes as compared to L4 transverse processes	Equal to L4	0
	Smaller than L4	1
	Almost absent	2
Lumbar index	>0.9	0
	0.8–0.9	1
	<0.8	2
L5/S1 disc height on lateral radiograph compared to L4/L5 disc height	>75%	0
	25–75%	1
	<25%	2
Type of sacral doming	No sacral doming	0
	Moderate anterior doming	1
	High centered doming	2

Fig. 1 Criteria for assessment of lumbosacral dysplasia

each criterion was 0 if there was no abnormality on radiographs and 2 for most severe dysplasia. The maximum total dysplasia score was 12 and the minimum was 0. Subjects with a total score of 0 to 4 were classified as non/low dysplastic, while subjects with a total score of 5 to 8 were classified as moderate dysplastic and those with a score of 9 to 12 were classified as high dysplastic.

The data were analyzed using the SPSS14.0 software (SPSS Inc., Chicago, IL, USA). In addition to descriptive statistics, comparisons between the 3 cohorts

(control, low grade and high grade) were performed using the analysis of variance (ANOVA), followed by Tuckey HSD test for post hoc pair wise comparisons when the ANOVA was significant. The relationship between dysplasia and the percentage of slip was assessed by Pearson's correlation coefficients. The frequency of subjects with no/low, moderate and severe dysplasia within each group was also provided and compared using Chi square tests. The level of significance was set at 0.05.

Results

Typical examples of dysplasia scoring are shown in Figs. 2, 3, 4, 5 for a control subject, a patient with low-grade spondylolisthesis and two patients with high-grade spondylolisthesis, respectively.

Mean total dysplasia score was respectively for 2.2 ± 1.7 , 5.9 ± 2.4 and 9.4 ± 2.0 for the control, low grade and high-grade spondylolisthesis cohorts. ANOVA testing revealed a significant difference between the 3 cohorts with regard to the total dysplasia score ($p < 10^{-4}$). Post hoc Tuckey HSD tests showed significant pair wise differences in total dysplasia scores between all 3 cohorts ($p < 10^{-4}$).

Total dysplasia score was statistically related to slip percentage ($r = 0.63$; $p < 10^{-3}$). Of the 120 controls, 106 (88.3%) had no/low dysplasia, whereas 14 (11.7%) had moderate dysplasia and none had severe dysplasia. Of the 91 patients with low-grade spondylolisthesis, 27 (29.7%) had normal no/low dysplasia, 56 (61.5%) had moderate dysplasia and 8 (8.8%) had severe dysplasia. Of the 40 patients with high-grade spondylolisthesis, 29 (72.5%) had severe dysplasia, while 9 (22.5%) had moderate dysplasia and 2 (5.0%) had no/low dysplasia. The proportion of subjects with no/low, moderate and severe dysplasia was different between all cohorts: controls versus low grade ($p < 10^{-16}$), controls versus high grade ($p < 10^{-26}$) and low grade versus high grade ($p < 10^{-12}$).

Discussion

This study defined specific criteria to quantitatively assess lumbosacral dysplasia from plain radiographs in controls, as well as in patients with low and high-grade lumbosacral spondylolisthesis. This work is important because it sets a solid framework for future studies investigating the influence of dysplasia on the progression or outcome of lumbosacral spondylolisthesis, since dysplasia is recognized by many clinicians as an important aspect to consider in the management of spondylolisthesis. For example, severe dysplasia could lead clinicians to closer follow-up of patients considered at high risk for progression. Also, more severe dysplasia could influence clinicians towards more aggressive surgical treatment when compared to a patient with similar slip severity but a lesser degree of dysplasia, as previously raised by Molinari et al. [9].

As most of the studies in the literature address separately low and high-grade spondylolisthesis, most clinicians tend to dichotomize their management of spondylolisthesis based on the presence of either a low or high-grade slip. However, this study shows that within groups of low and

high-grade spondylolisthesis, there are subgroups with variable degrees of dysplasia. Whereas most patients with low-grade spondylolisthesis had moderate dysplasia (61.5%), some patients had no/low dysplasia (29.7%) or severe dysplasia (8.8%). The finding of a subgroup of low grade patients with severe dysplasia is particularly useful for clinicians. Indeed, clinicians could consider closer follow-up in this subgroup that may be at greater risk for progression to high-grade spondylolisthesis. As for high-grade spondylolisthesis, the great majority of patients have severe dysplasia (72.5%), but some patients also had moderate (22.5%) or no/low dysplasia (5.0%). It is interesting to observe that the proposed scoring system was able to identify a subgroup of high grade patients with no/low dysplasia for whom the outcome of surgical treatment could be more predictable, as previously suggested by Molinari et al. [9]. Conversely, more aggressive surgery (e.g., reduction of spondylolisthesis with anterior column support) could be considered to improve the biomechanical conditions for successful fusion in high-grade spondylolisthesis associated with severe dysplasia.

The proposed 12-point scoring system for dysplasia was easy to use as it only requires observations from plain radiographs. Although it is a recognized limitation of the study, findings from CT scan and MRI were not included as criteria because these imaging modalities are not routinely ordered by clinicians for all patients with spondylolisthesis, especially in low grade slips. However, the relevance of using MRI or CT scan to assess lumbosacral dysplasia should be evaluated in the future.

The scoring system includes 6 criteria previously proposed in the literature [1–3, 6–9, 11] to assess dysplasia of anterior and posterior elements at the lumbosacral junction. Of all dysplastic features proposed in the literature, laminar dysplasia, facet dysplasia, size of L5 transverse processes, lumbar index, L5–S1 disc height, and sacral doming are among the most widely used because they can potentially influence the biomechanical conditions at the lumbosacral junction.

The results support the use of the proposed technique to assess lumbosacral dysplasia and to classify individuals into no/low, moderate or severe dysplasia. As observed clinically, the severity of lumbosacral dysplasia as evaluated from the total dysplasia score tends to increase between the control, low grade and high-grade spondylolisthesis cohorts. Accordingly, most controls have no/low dysplasia, most low-grade slips have moderate dysplasia, and most high-grade slips have severe dysplasia. The tendency for dysplasia to become more severe with increasing severity of spondylolisthesis is further reinforced by the significant correlation between total dysplasia score and slip percentage.

Fig. 2 Radiographs of a control subject with no/low dysplasia (total dysplasia score of 0). He has normal laminae, facets, L5 transverse processes, L5–S1 disc height and upper sacral endplate. The lumbar index is 0.94

Fig. 3 Radiographs of a patient with low-grade spondylolisthesis and moderate dysplasia (total dysplasia score of 5). The patient has spinal bifida occulta, normal L5 transverse processes, hypoplastic facets, a

lumbar index of 0.60, normal L5/S1 disc height and moderate anterior doming of sacrum

Fig. 4 Radiographs of a patient with high-grade spondylolisthesis and severe dysplasia (total dysplasia score of 11). The patient has absent laminae, almost absent L5 transverse processes, aplastic facets,

a lumbar index of 0.57, L5/S1 disc height between 25 and 75% of L4/L5 disc height, and a high centered doming of S1

Fig. 5 Radiographs of a patient with high-grade spondylolisthesis and no/low dysplasia (total dysplasia score of 4). The patient has spina bifida occulta, normal transverse processes of L5, normal L5/S1 disc height, lumbar index of 0.76, normal facets, and moderate anterior sacral doming

Conclusion

The current study proposes a technique for quantifying lumbosacral dysplasia in young patients with spondylolisthesis from plain radiographs. Based on this technique, it was found that the severity of lumbosacral dysplasia tends to increase as the slip percentage progresses. However, a variable degree of lumbosacral dysplasia was also found within groups with low or high-grade spondylolisthesis, suggesting that different subgroups of patients exist with regard to dysplasia of anterior and posterior elements. Future studies should be performed to investigate the influence of dysplasia on the prognosis and outcome of lumbosacral spondylolisthesis.

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Conflict of interest None.

References

1. Curylo LJ, Edwards C, DeWald RW (2002) Radiographic markers in spondylolisthesis: implications for spondylolisthesis progression. *Spine* 27:2021–2025
2. Hammerberg KW (2005) New concepts on the pathogenesis and classification of spondylolisthesis. *Spine* 30:S4–S11
3. Wiltse LL, Newman PH, Macnab I (1976) Classification of spondylolysis and spondylolisthesis. *Clin Orthop Relat Res* 117:23–29
4. Marchetti PG, Bartolozzi P (1997) Classification of spondylolisthesis as a guideline for treatment. In: Bridwell KH, Dewald RL (eds) *The textbook of spinal surgery*, 2nd edn, chap 69. Lippincott-Raven, Philadelphia, pp 1211–1254
5. Lamartina C, Zavatsky JM, Petrucci M et al (2009) Novel concepts in the evaluation and treatment of high-dysplastic spondylolisthesis. *Eur Spine J* 18:S133–S142
6. Vialle R, Schmit P, Dauzac C et al (2005) Radiological assessment of lumbosacral dystrophic changes in high-grade spondylolisthesis. *Skeletal Radiol* 34:528–535
7. Yue WM, Brodner W, Gaines RW (2005) Abnormal spinal anatomy in 27 cases of surgically corrected spondylolisthesis: proximal sacral endplate damage as a possible cause of spondylolisthesis. *Spine* 30:S22–S26
8. Mac-Thiong JM, Labelle H (2006) A proposal for a surgical classification of pediatric lumbosacral spondylolisthesis based on current literature. *Eur Spine J* 15:1425–1435
9. Molinari RW, Bridwell KH, Lenke L et al (1999) Complications in the surgical treatment of pediatric high-grade, isthmic dysplastic spondylolisthesis. A comparison of three surgical approaches. *Spine* 24:1701–1711
10. Faro FD, Marks MC, Pawelek J et al (2004) Evaluation of a functional position for lateral radiograph acquisition in adolescent idiopathic scoliosis. *Spine* 29:2284–2289
11. Saraste H, Brostrom LA, Aparisi T (1984) Prognostic radiographic aspects of spondylolisthesis. *Acta Radiol Diagn* 25:427–432