Research Square

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Analysis of coronal and sagittal parameters in young Han Chinese patients with lumbar disc herniation

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Research Article

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Abstract

Lumbar disc herniation (LDH) in adolescents and young adults is increasingly recognised as a distinct clinical entity, yet the interplay between coronal and sagittal spinal alignment in this population remains incompletely characterised. In this retrospective cohort study, 256 young Han Chinese patients aged 14–25 years who underwent surgical treatment for LDH were enrolled and allocated to a non-scoliosis group (Cobb angle < 10°, n = 116) or a scoliosis group (Cobb angle ≥ 10°, n = 140); the latter was further subclassified into coronally balanced (Type A, n = 91) and imbalanced subtypes (Type B, C7 plumb line on the concave side, n = 28; Type C, C7 plumb line on the convex side, n = 21) according to the Gulou classification. Whole-spine standing radiographs were used to measure spinopelvic sagittal parameters (TPA, SVA, PI, PT, SS, TK, LL) and coronal parameters (Cobb angle, CBD). Compared with the non-scoliosis group, the scoliosis group had a significantly higher prevalence of sagittal imbalance (42.14% versus 27.59%, p = 0.015) and multi-level disc herniation, together with a more pathological sagittal profile: higher TPA and SVA, increased pelvic retroversion (higher PT, lower SS) and a flatter spine (reduced TK and LL), whereas pelvic incidence did not differ. Among the three Gulou subtypes, Type B patients displayed the most compromised sagittal alignment (highest TPA and SVA, lowest LL). These findings indicate that young LDH patients with concomitant coronal scoliosis constitute a distinct subgroup with more severe three-dimensional malalignment, and that their sagittal alignment is associated with coronal-plane morphology.

Introduction

Lumbar disc herniation (LDH) is a common degenerative spinal disorder characterised by protrusion of nucleus pulposus material into the spinal canal, causing low back pain and radiculopathy [1–3]. Although LDH predominantly affects adults, adolescent lumbar disc herniation (ALDH) has distinct epidemiological and pathophysiological features; its reported incidence is approximately 0.2–0.6%, with trauma, developmental abnormalities and biomechanical factors regarded as key aetiological contributors [1, 4, 5].

Young patients with LDH frequently present with abnormal spinal morphology, including scoliosis and trunk tilt in the coronal plane and sagittal imbalance [6, 7]. Sagittal and coronal alignment parameters are important determinants of spinal biomechanics and are increasingly recognised as relevant to spinal pathogenesis [8–10]. Scoliotic posture may even be the initial presenting feature in adolescents with LDH, and its curve pattern and natural history after discectomy have been described previously [6, 11].

Nevertheless, a comprehensive account of coronal and sagittal alignment parameters specifically in young patients with LDH remains lacking. The present study was therefore designed to investigate the coronal and sagittal spinal profiles of young Han Chinese patients with LDH, comparing those with and without concomitant scoliosis and examining how different coronal-plane morphologies correlate with sagittal alignment. We hypothesised that young LDH patients with scoliosis would demonstrate distinct

sagittal alignment characteristics compared with those without scoliosis. The findings are intended to inform the biomechanical understanding of ALDH and to provide a reference for future studies.

Materials and Methods

Study design and participants

All methods were carried out in accordance with relevant guidelines and regulations. This retrospective cohort study consecutively enrolled 256 young Han Chinese patients who underwent surgical treatment for LDH at Nanjing Drum Tower Hospital between January 2016 and December 2023. Patients sought medical attention because of low back pain and/or radicular symptoms, and symptomatic LDH was confirmed by lumbar magnetic resonance imaging (MRI). Inclusion criteria were age 14–25 years and availability of complete clinical and imaging data. Exclusion criteria were spinal infection, tumour, fracture and poor-quality whole-spine radiographs. The study was conducted in accordance with the ethical principles of the Declaration of Helsinki and received approval from the Medical Ethics Committee of Nanjing Drum Tower Hospital (approval number 2021-LCYJ-DBZ05).

Radiographic data collection and parameter definitions

All patients underwent standard standing whole-spine posteroanterior and lateral radiography. On lateral radiographs, the following sagittal parameters were measured independently by two senior spine surgeons: thoracic kyphosis (TK), the angle between the superior endplate of T5 and the inferior endplate of T12; lumbar lordosis (LL), the angle between the superior endplate of L1 and the superior endplate of S1; pelvic incidence (PI), the angle between the line perpendicular to the sacral plate at its midpoint and the line connecting this point to the bicommon femoral axis; pelvic tilt (PT), the angle between the vertical reference line and the line connecting the midpoint of the sacral plate to the bicommon femoral axis; sacral slope (SS), the angle between the superior endplate of S1 and the horizontal reference line; thoracic-pelvic angle (TPA), the sum of the thoracic inlet angle and PT; and SVA, the horizontal distance between the C7 plumb line and the posterosuperior corner of S1, with a positive value indicating anterior displacement. On posteroanterior radiographs, the following coronal parameters were measured: Cobb angle, the angle between the superior endplate of the most tilted upper-end vertebra and the inferior endplate of the most tilted lower-end vertebra, with a Cobb angle of ≥ 10° defining the presence of coronal scoliosis; and coronal balance distance (CBD), the horizontal distance between the C7 plumb line and the central sacral vertical line. Sagittal imbalance was defined as an absolute SVA exceeding 50 mm; an absolute value of 50 mm or less defined sagittal balance.

Grouping and classification criteria

On the basis of a whole-spine posteroanterior Cobb angle of ≥ 10°, patients were divided into a non-scoliosis group (n = 116) and a scoliosis group (n = 140). Patients in the scoliosis group were further subclassified according to the Gulou classification, based on CBD and the position of the C7 plumb line relative to the major curve: Type A (coronally balanced), CBD below 30 mm; Type B (coronally

imbalanced, C7 plumb line on the concave side), CBD of 30 mm or more with the C7 plumb line on the concave side of the major curve; and Type C (coronally imbalanced, C7 plumb line on the convex side), CBD of 30 mm or more with the C7 plumb line on the convex side of the major curve. Accordingly, the 140 scoliosis patients comprised 91 Type A, 28 Type B and 21 Type C cases.

Statistical analysis

Data analysis was performed using SPSS software (version 26.0; IBM, Armonk, NY, USA). The normality of continuous variables was assessed using the Shapiro-Wilk test. Normally distributed continuous data are presented as mean ± SD and were compared between two groups using the independent-samples t-test; comparisons among three or more groups used one-way analysis of variance (ANOVA) with post-hoc testing. Categorical data are presented as numbers and percentages and were compared using the χ^2 test, or Fisher's exact test where appropriate. Inter-observer reliability for radiographic measurements was assessed using intraclass correlation coefficients. All statistical tests were two-sided, and a P value of less than 0.05 was considered statistically significant. Effect sizes (mean differences with 95% confidence intervals) are reported in the text.

Results

The scoliosis group had a significantly higher prevalence of sagittal imbalance (42.14% versus 27.59%, p = 0.015) and of multi-level disc herniation than the non-scoliosis group. Its sagittal profile was more pathological, with significantly higher TPA and SVA, increased pelvic retroversion (higher PT, lower SS) and a flatter spine (reduced TK and LL); pelvic incidence did not differ between groups. Within the scoliosis cohort, sagittal alignment varied significantly among Gulou subtypes, with Type B patients showing the most compromised parameters (highest TPA and SVA, lowest LL).

Demographic characteristics

As detailed in Table 1, no significant differences were observed between the non-scoliosis and scoliosis groups in age (20.3 ± 3.4 versus 19.9 ± 3.5 years, p = 0.401), sex distribution (p = 0.725), prevalence of lumbosacral transitional vertebrae (p = 0.504), lumbar spinal stenosis (p = 0.263) or spondylolisthesis (p = 0.088). A significant difference was present in the pattern of disc herniation (p = 0.036): the scoliosis group contained a higher proportion of double-level (20.71% versus 12.07%) and multi-level (4.29% versus 0.86%) herniations, whereas the non-scoliosis group was predominantly single-level (87.07% versus 75.00%).

Table 1
Demographic and baseline clinical characteristics

Variable	Total (n = 256)	Non-scoliosis (n = 116)	Scoliosis (n = 140)	Statistic	P
Age (years)	20.1 ± 3.4	20.3 ± 3.4	19.9 ± 3.5	t = 0.84	0.401
Sex, n (%)				χ2 = 0.12	0.725
Female	60 (23.44)	26 (22.41)	34 (24.29)		
Male	196 (76.56)	90 (77.59)	106 (75.71)		
Lumbosacral transitional vertebrae, n (%)				χ2 = 0.45	0.504
No	246 (96.09)	113 (97.41)	133 (95.00)		
Yes	10 (3.91)	3 (2.59)	7 (5.00)		
Number of herniations, n (%)				–	0.036
Single-level	206 (80.47)	101 (87.07)	105 (75.00)		
Double-level	43 (16.80)	14 (12.07)	29 (20.71)		
Multi-level	7 (2.73)	1 (0.86)	6 (4.29)		
Lumbar spinal stenosis, n (%)				χ2 = 1.25	0.263
No	211 (82.42)	99 (85.34)	112 (80.00)		
Yes	45 (17.58)	17 (14.66)	28 (20.00)		
Spondylolisthesis, n (%)				χ2 = 2.92	0.088
No	252 (98.44)	112 (96.55)	140 (100.00)		
Yes	4 (1.56)	4 (3.45)	0 (0.00)		

Table 1. *Demographic and baseline clinical characteristics. Data are mean ± SD or n (%). t, independent-samples t-test; χ2, χ² test; –, Fisher's exact test. SD, standard deviation.*

Sagittal parameters and balance status

Comparison of spinopelvic sagittal parameters between the two groups (Table 2) revealed a markedly more pathological profile in the scoliosis group. Specifically, the scoliosis group had significantly higher

thoracic-pelvic angle (TPA) (24.3 ± 11.3° versus 18.5 ± 9.7°, p < 0.001) and SVA (−50.1 ± 61.6 versus −19.6 ± 47.3 mm, p < 0.001), together with increased pelvic retroversion (higher PT, 23.3 ± 10.1° versus 20.1 ± 9.8°, p = 0.010; lower SS, 20.7 ± 10.0° versus 24.6 ± 10.0°, p = 0.002) and a flatter spinal profile (reduced TK, 13.7 ± 14.9° versus 19.0 ± 13.3°, p = 0.003; reduced LL, 21.3 ± 18.9° versus 30.8 ± 16.6°, p < 0.001). No significant difference was found in pelvic incidence (PI) (44.1 ± 10.5° versus 44.6 ± 11.4°, p = 0.679). Consistent with these parameter differences, sagittal imbalance was significantly more prevalent in the scoliosis group (42.14% versus 27.59%, p = 0.015; Table 3).

Table 2
Comparison of sagittal parameters between the scoliosis and non-scoliosis groups

Variable	Total (n = 256)	Non-scoliosis (n = 116)	Scoliosis (n = 140)	Statistic	P
TPA (°)	21.6 ± 10.9	18.5 ± 9.7	24.3 ± 11.3	t=−4.36	< 0.001
SVA (mm)	−36.3 ± 57.5	−19.6 ± 47.3	−50.1 ± 61.6	t = 4.47	< 0.001
PI (°)	44.3 ± 10.9	44.6 ± 11.4	44.1 ± 10.5	t = 0.41	0.679
PT (°)	21.9 ± 10.1	20.1 ± 9.8	23.3 ± 10.1	t=−2.61	0.010
SS (°)	22.5 ± 10.2	24.6 ± 10.0	20.7 ± 10.0	t = 3.06	0.002
TK (°)	16.1 ± 14.4	19.0 ± 13.3	13.7 ± 14.9	t = 2.96	0.003
LL (°)	25.6 ± 18.5	30.8 ± 16.6	21.3 ± 18.9	t = 4.24	< 0.001

Table 2. *Comparison of sagittal parameters between the scoliosis and non-scoliosis groups. Data are mean ± SD. TPA, thoracic-pelvic angle; SVA, sagittal vertical axis; PI, pelvic incidence; PT, pelvic tilt; SS, sacral slope; TK, thoracic kyphosis; LL, lumbar lordosis.*

Table 3
Prevalence of sagittal imbalance between the scoliosis and non-scoliosis groups

Sagittal balance	Total (n = 256)	Non-scoliosis (n = 116)	Scoliosis (n = 140)	Statistic	P
Balanced, n (%)	165 (64.45)	84 (72.41)	81 (57.86)	$\chi 2$ = 5.87	0.015
Imbalanced, n (%)	91 (35.55)	32 (27.59)	59 (42.14)		

Table 3. *Prevalence of sagittal imbalance between the scoliosis and non-scoliosis groups. Sagittal imbalance was defined as an absolute SVA exceeding 50 mm; a value below 50 mm indicated sagittal balance.*

Sub-analysis by coronal-plane (Gulou) classification

Within the scoliosis cohort (n = 140), patients were subclassified according to the Gulou classification: coronally balanced Type A (n = 91), imbalanced with the C7 plumb line on the concave side (Type B, n = 28) and imbalanced with the C7 plumb line on the convex side (Type C, n = 21). Comparisons of sagittal parameters and balance status among the three subtypes are shown in Tables 4 and 5. Cobb angle differed significantly among subtypes ($p < 0.001$), with Type C largest (26.4 ± 8.2°), followed by Type B (19.4 ± 5.8°) and Type A (18.1 ± 6.7°). Sagittal alignment also varied across subtypes (Table 4): significant differences were observed for TPA ($p = 0.008$), SVA ($p = 0.002$) and LL ($p = 0.016$), with post-hoc analysis indicating that Type B patients had the most compromised sagittal alignment (highest TPA, 29.2 ± 10.7°; highest SVA, − 84.5 ± 58.3 mm; lowest LL, 14.2 ± 14.1°), whereas Type A had the most favourable profile. Although the comparison of sagittal balance status across the three Gulou types did not reach formal statistical significance ($p = 0.072$, Table 5), a clear trend was present: Type B had the highest proportion of sagittal imbalance (60.71%) and Type A the lowest (36.26%).

Table 4
Cobb angle and sagittal parameters across the three coronal-plane subtypes

Variable	Total (n = 140)	Type A (n = 91)	Type B (n = 28)	Type C (n = 21)	Statistic	P
Cobb angle (°)	19.6 ± 7.3	18.1 ± 6.7	19.4 ± 5.8	26.4 ± 8.2	F = 12.48	< 0.001
TPA (°)	24.3 ± 11.3	22.2 ± 10.6	29.2 ± 10.7	26.7 ± 12.8	F = 4.95	0.008
SVA (mm)	−50.1 ± 61.6	−38.0 ± 60.7	−84.5 ± 58.3	−56.6 ± 52.7	F = 6.79	0.002
PI (°)	44.1 ± 10.5	43.9 ± 10.9	46.0 ± 9.2	42.1 ± 10.4	F = 0.82	0.442
PT (°)	23.3 ± 10.1	22.0 ± 9.4	26.8 ± 11.4	24.5 ± 10.8	F = 2.56	0.081
SS (°)	20.7 ± 10.0	21.9 ± 10.3	19.2 ± 9.3	17.6 ± 8.9	F = 2.03	0.136
TK (°)	13.7 ± 14.9	15.9 ± 15.3	8.5 ± 13.2	11.3 ± 13.7	F = 3.05	0.050
LL (°)	21.3 ± 18.9	24.6 ± 19.9	14.2 ± 14.1	16.3 ± 17.1	F = 4.26	0.016

Table 4. *Cobb angle and sagittal parameters across the three coronal-plane subtypes. Data are mean ± SD. Type A, coronally balanced; Type B, coronally imbalanced with the C7 plumb line on the concave side; Type C, coronally imbalanced with the C7 plumb line on the convex side.*

Table 5
Sagittal imbalance across the three coronal-plane subtypes.

Sagittal balance	Total (n = 140)	Type A (n = 91)	Type B (n = 28)	Type C (n = 21)	Statistic	P
Balanced, n (%)	81 (57.86)	58 (63.74)	11 (39.29)	12 (57.14)	$\chi 2$ = 5.26	0.072
Imbalanced, n (%)	59 (42.14)	33 (36.26)	17 (60.71)	9 (42.86)		

Table 5. *Sagittal imbalance across the three coronal-plane subtypes. Sagittal imbalance was defined as an absolute SVA exceeding 50 mm.*

Representative Cases

Figure 1 shows a 17-year-old female patient with no coronal imbalance or scoliosis, and with well-maintained sagittal alignment. Figure 2, in contrast, demonstrates a young patient with concomitant scoliosis; however, this patient does not exhibit coronal imbalance and is classified as Type A, also presenting with favorable sagittal alignment.

Figure 3 and 4 demonstrate patients with coronal Type B and Type C, respectively. These patients exhibit significant coronal imbalance, concomitant with marked sagittal imbalance, as well as a loss of lumbar lordosis (LL) and thoracic kyphosis (TK).

Discussion

This study examined coronal and sagittal spinal alignment in 256 young Han Chinese patients with LDH aged 14–25 years, with particular attention to differences between those with and without concomitant coronal scoliosis. The principal findings were threefold: (1) young LDH patients with scoliosis (Cobb angle ≥ 10°) had a significantly higher prevalence of sagittal imbalance and multi-level disc herniation than those without scoliosis; (2) the scoliosis group displayed a more pathological sagittal profile, characterised by increased pelvic retroversion (higher PT and TPA, lower SS) and a flatter spine (reduced TK, LL and, in places, a more negative SVA); and (3) the underlying pelvic morphology, as represented by PI, did not differ between groups.

The present observation of sagittal imbalance in young LDH patients is consistent with a growing body of evidence. The findings of reduced LL and SS alongside increased PT agree with previous work in adolescent and young-adult LDH populations [12], reinforcing the view that loss of lumbar lordosis and compensatory pelvic retroversion are key biomechanical features associated with LDH in younger patients. Reports of the spinopelvic parameters of patients with lumbar disc lesions likewise describe a relatively straight sagittal spine and a more vertical sacrum in affected individuals. The present results extend these observations by linking them directly to the presence and severity of coronal-plane deformity.

The role of pelvic incidence, however, remains a point of divergence in the literature. Some studies have reported a lower PI in young LDH patients, supporting a “flat back” as a risk factor [13, 14]. In the present cohort, by contrast, PI was similar between the scoliosis and non-scoliosis groups. This suggests that the observed malalignment may be acquired or compensatory rather than predetermined by native pelvic morphology. Existing studies have largely focused on preoperative sagittal spinopelvic parameters; the present data indicate that these patients commonly exhibit a reduction in LL and TK, plausibly as a compensatory mechanism to alleviate pain. In clinical practice this manifests as an inability to maintain

an upright stance unaided for prolonged periods or to sit comfortably. Classification of spinopelvic alignment based solely on preoperative imaging may therefore be inaccurate.

Reported prevalences of scoliosis in patients with LDH vary. Kim et al. [15] observed an incidence of trunk list of approximately 18% in 164 adult patients, whereas Ozgen et al. [16] reported a notably higher prevalence of approximately 47% in an adolescent population. The present study found that 54.68% (140/256) of the young Han Chinese cohort had a Cobb angle of ≥ 10°. This discrepancy is likely to reflect differences in study population: the present series focused specifically on a younger Chinese Han surgical cohort. The high prevalence of sagittal imbalance in the scoliosis group (42.14%) suggests that three-dimensional spinal imbalance may identify a distinct and more severe phenotype of young LDH. Kim et al. [15] identified correlations between SS, PT, LL and trunk inclination but found that trunk inclination was not associated with sagittal imbalance. In contrast, the present study demonstrates that the scoliosis group had a significantly higher likelihood of sagittal imbalance, and that among coronal Type B and C patients larger TPA and SVA and smaller LL were observed, although no significant differences in PT or SS emerged between coronal subtypes.

Endo et al. [17] described the relationship between changes in SVA, LL and pain in patients with LDH. On this basis, a plausible clinical inference is that LDH-related pain prompts patients to adopt two compensatory postures: scoliosis in the coronal plane and a tilted, flattened back in the sagittal plane. Because the spine functions as a dynamic chain, decreased SS contributes to diminished lower lumbar lordosis, while pain-induced active straightening of the back further reduces upper lumbar lordosis; through this chain mechanism, TK is subsequently lessened, producing a flattened profile in which the SS curve remains distinct while LL and TK are attenuated [18].

The study has several limitations. Its retrospective, single-centre design may have introduced selection bias, and all patients were surgical candidates, limiting generalisability to non-operative populations. The cohort consisted entirely of Han Chinese patients, so the findings may not generalise to other ethnicities. Furthermore, the cross-sectional nature of the study establishes associations but cannot determine causal relationships between pain, LDH and three-dimensional spinal imbalance. Longitudinal studies are needed to trace the evolution of spinal alignment in these young patients, and future work incorporating pain and functional outcome measures would help to clarify the compensatory mechanisms proposed above.

In conclusion, young patients with LDH and concomitant coronal scoliosis represent a distinct subgroup with more severe three-dimensional spinal malalignment, characterised by a higher prevalence of sagittal imbalance, a flatter spinal profile and a greater likelihood of multi-level disc herniation. Their sagittal alignment is associated with their coronal-plane Gulou classification, with Type B patients showing the least favourable sagittal parameters. Recognition of this phenotype may be relevant to assessment and management, although prospective validation is required.

Declarations

Clinical trial number

Not applicable.

Consent for publication

Not Applicable.

Competing interests

The authors declare no competing interests.

Ethics approval and consent to participate

This study was conducted in accordance with the ethical principles of the Declaration of Helsinki and was approved by the Medical Ethics Committee of Nanjing Drum Tower Hospital on 2026-05-10 (approval number 2021-LCYJ-DBZ05). Because of the retrospective design and the use of fully anonymised data, the ethics committee waived the requirement for informed consent for the use of anonymised data in this study.

Author Contribution

Kun Feng: Conceptualization, study design and manuscript drafting; Jiaan Li: Statistical analysis, patient data collection and clinical follow-up;Wanshuang Zhang: Clinical data sorting; Zezhang Zhu: Funding acquisition and project administration;Haibo Li: Research supervision, critical review.

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Data Availability

The datasets generated and analysed during the current study are available from the corresponding author on reasonable request. Because of the sensitive nature of the data, which contain potentially identifying patient information, they are not publicly available.

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Figures

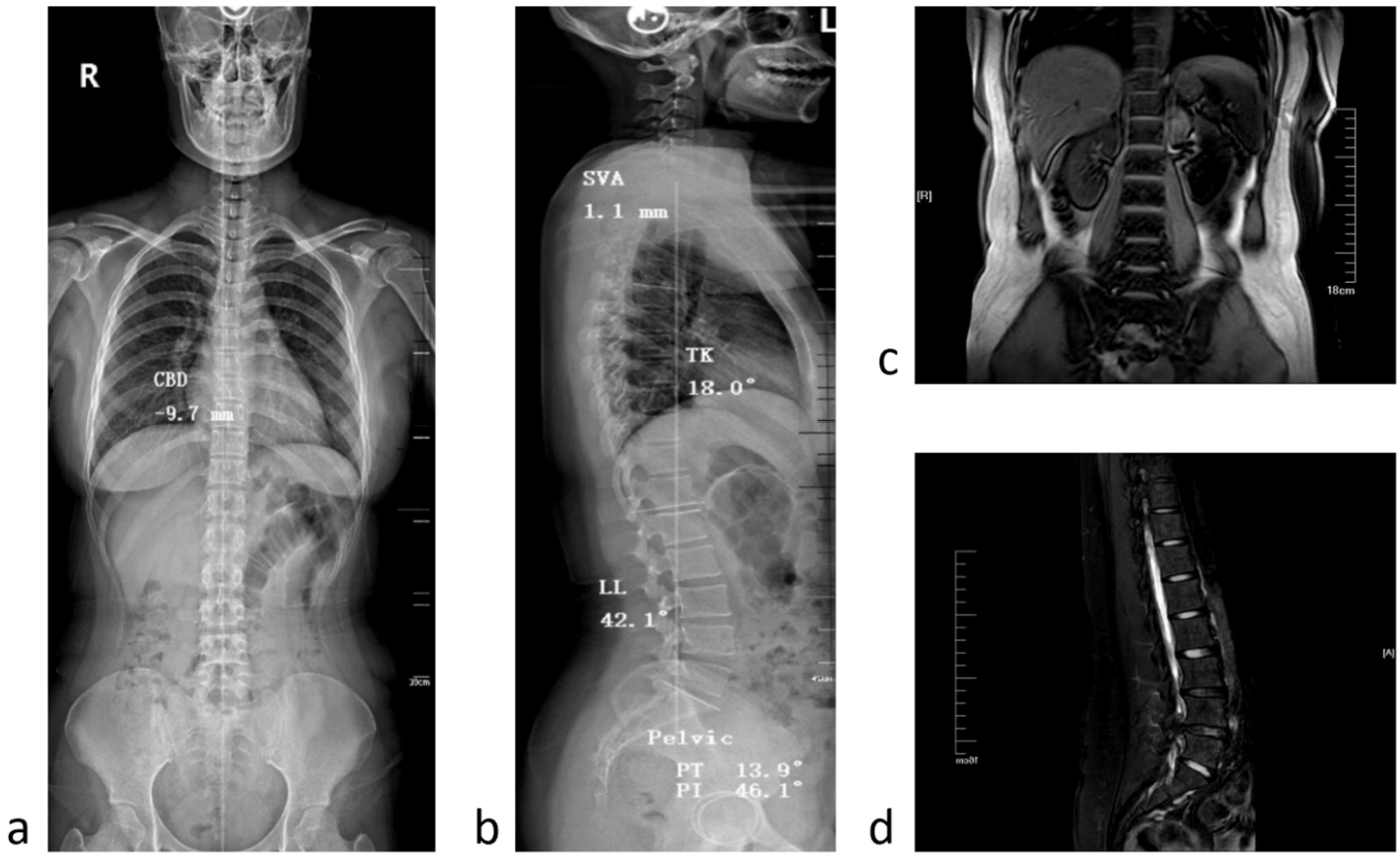


Figure 1

Patient with L4/5 disc herniation without scoliosis.

(a) Preoperative AP radiograph showed the CBD was 9.7 mm.

(b) Preoperative lateral radiograph showed theSVA=9.7 mm, SS=32.2°,LL=42.1°，TK=18°.

(c,d) MRI revealed L4/5 disc protrusion.

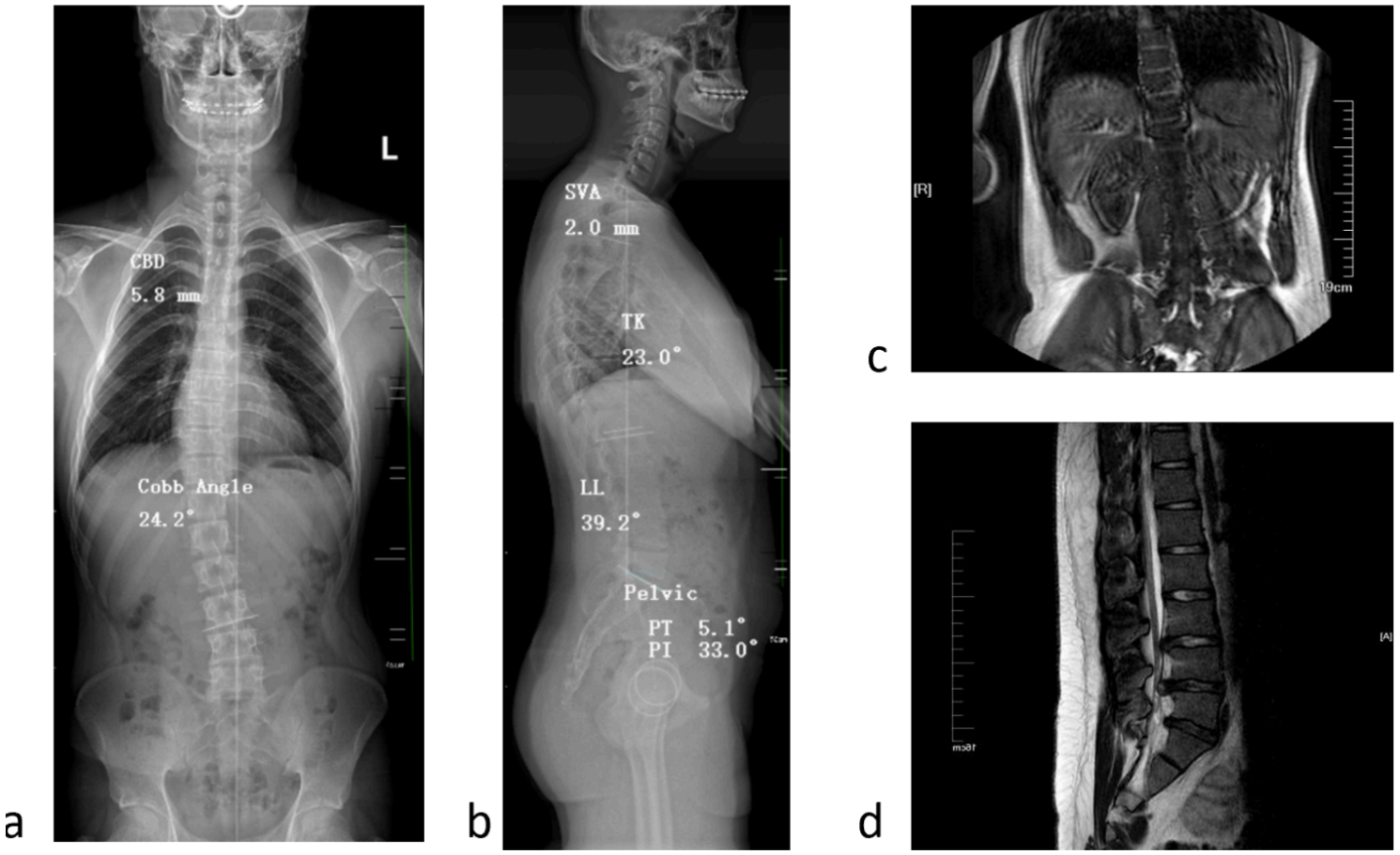


Figure 2

Patient with L3-S1 disc herniation and scoliosis.

(a) Preoperative AP radiograph showed the Cobb Angle=24.2°，and the CBD was 5.8 mm, belongs to Type A in coronal morphology.

(b) Preoperative lateral radiograph showed theSVA=2.0 mm, SS=27.9°，LL=39.2°，TK=23°. (c, d) MRI revealed L3-S1 disc protrusion.

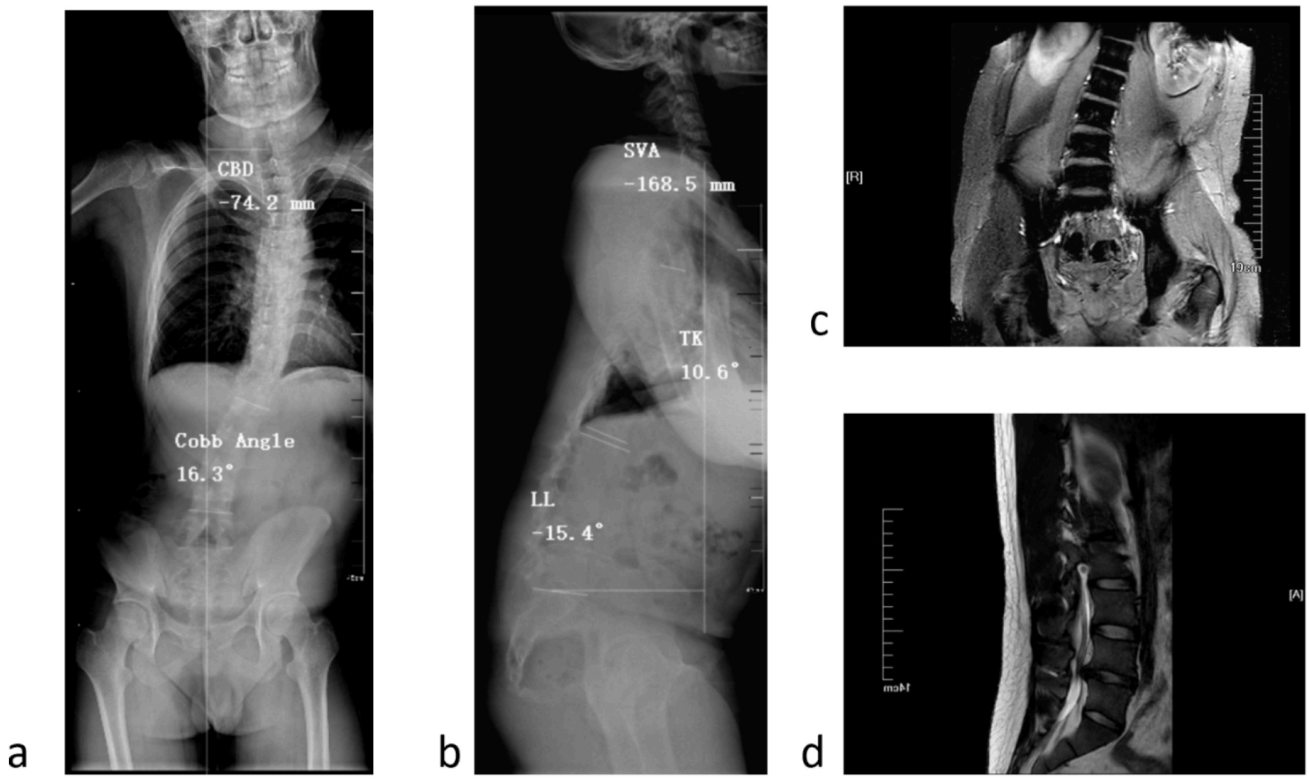


Figure 3

Patient with L4/5 disc herniation and trunk shift.

(a) Preoperative AP radiograph showed the Cobb Angle=16.3°, and the CBD was 74.2 mm, C7PL located on the concave side of the lumbosacral curve. It belongs to Type B in Gulou classification.

(b) Preoperative lateral radiograph showed theSVA=-168.5 mm,SS=13°，LL=-15.4°，TK=10.6°.

(c, d) MRI revealed L4/5 disc herniation.

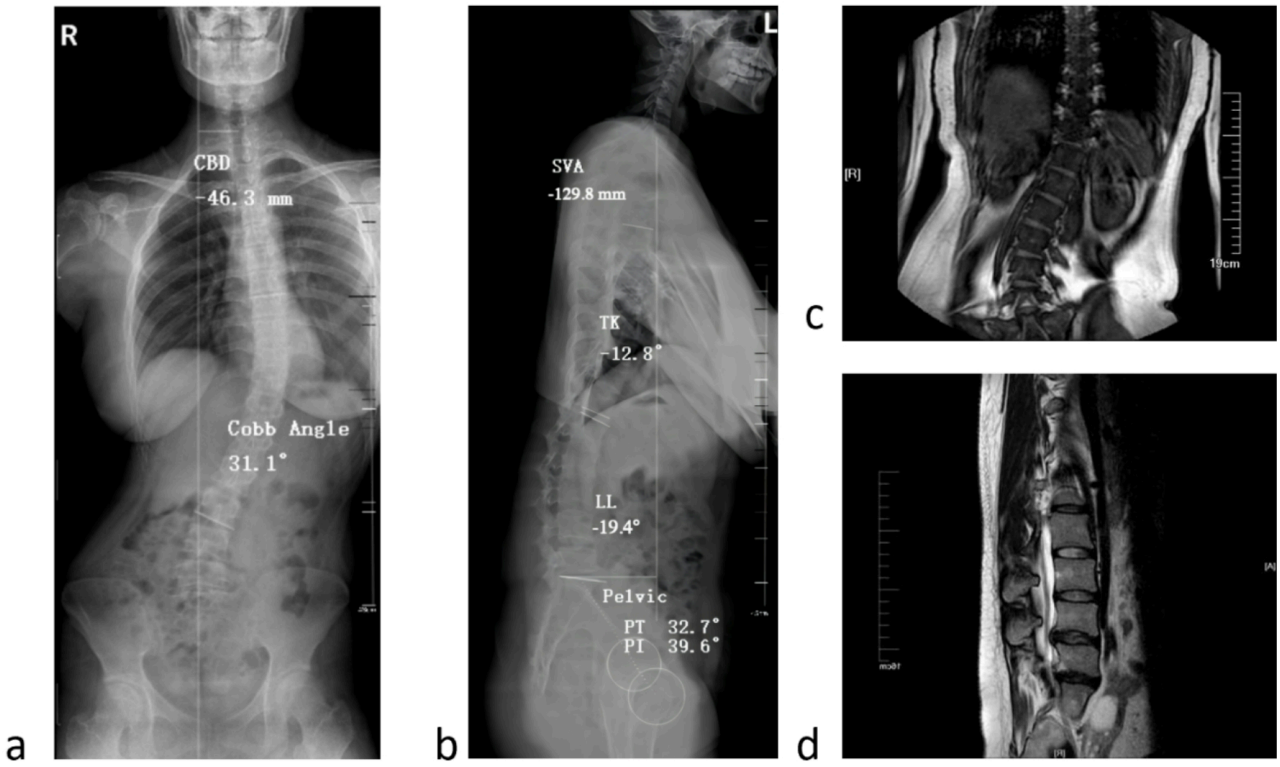


Figure 4

Patient with L4/5 disc herniation and trunk shift.

(a) Preoperative AP radiograph showed the Cobb Angle=31.1°,CBD was 46.3 mm, and C7PL located on the convex side of the major curve,which belongs to Type C in coronal morphology.

(b)Preoperative lateral radiograph showed theSVA=-129.8mm,SS=6.9°,LL=-19.4°，TK=-12.8°.

(c,d) MRI revealed L4/5 disc herniation.