

Retrospective Review

Sciatic Scoliosis Evolution after Lumbar Discectomy: A Comparison Between Adolescents and Young Adults

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Disclaimer: This work was supported by the National Natural Science Foundation of China (grant no. 81171672).
Conflict of interest: Each author certifies that he or she, or a member of his or her immediate family, has no commercial association (i.e., consultancies, stock ownership, equity interest, patent/licensing arrangements, etc.) that might pose a conflict of interest in connection with the submitted manuscript.

Manuscript received:
12-09-2018
Revised manuscript received:
02-23-2019
Accepted for publication:
03-12-2019

Free full manuscript:
www.painphysicianjournal.com

Background: Scoliosis secondary to lumbar disc herniation (LDH) may occur in both adolescents and adults. As the spine is more flexible in adolescents than in adults, the curve features and curve evolution could be different between these 2 cohorts, which were unclear.

Objectives: To compare the radiologic features of scoliosis secondary to LDH between adolescents and adults, and to further characterize the curve evolution after lumbar discectomy in 2 cohorts.

Study Design: A retrospective study.

Setting: An inpatient surgery center.

Methods: Patients with scoliosis secondary to LDH who underwent surgical intervention between 2010 and 2016 were reviewed. Radiographic parameters were measured on standing whole spine radiographs. The apical vertebral translation was measured on serial radiographs taken before surgery, one month and 6 months after surgery, and at last follow-up to evaluate the curve evolution. Meanwhile, the patients' reported outcomes were evaluated. According to age, patients were divided into adolescent and adult group. Comparisons between the 2 groups were made with regards to the preoperative and postoperative radiographic parameters and clinical outcomes.

Results: A total of 42 adolescent and 41 adult patients were included in this study. The incidence of scoliosis secondary to LDH in the adolescents was significantly higher than that in the adults. Adolescent patients present remarkably higher incidence of coronal balance as compared with the adult patients preoperatively. No significant difference was observed between the 2 groups in terms of preoperative radiographic parameters. A total of 85.7% of the adolescent patients and 92.7% of the adult patients achieved resolution of scoliosis within 6 months after surgery.

Limitations: This was a retrospective study with a small series of cases and relatively short-term follow-up.

Conclusions: The incidence of scoliosis secondary to LDH in adolescents is significantly higher than in adults. Moreover, adolescent patients are more likely to present coronal balance before surgery. The 2 cohorts could have comparable curve evolution, and resolution of scoliosis generally occurred within 6 months after surgery.

Key words: Sciatic scoliosis, lumbar disc herniation, adolescent, adult, resolution, lumbar discectomy

Pain Physician 2019; 22:E457-E465

Besides low back pain and leg pain, patients with lumbar disc herniation (LDH) commonly present with scoliotic posture with a trunk shift and a relatively straight sagittal profile (1). Even in

some adolescent patients, an obvious spinal deformity was their chief complaint. Although the mechanism is not well understood, there was a broad consensus that sciatic scoliosis could be a compensatory posture to

relieve nerve root irritation (2-5). Commonly, lumbar discectomy is recommended to treat such a situation (6), and it has been well demonstrated that sciatic scoliosis would be reversible once the painful stimulus is removed (2,3,7,8). Kim et al (9) reported 29 patients with scoliosis secondary to LDH who underwent percutaneous endoscopic discectomy and observed that scoliosis could be reversed to normality in > 50% of patients within 6 months after surgery. Suk et al (5) performed lumbar discectomy for 45 patients with LDH-associated scoliosis and found that the Cobb angle could be corrected from 9.8° preoperatively to 1.8° at 7 days after surgery. Zhu et al (8) reported that 26 adolescents with sciatic scoliosis secondary to LDH had obvious curve improvement immediately after surgery. A total of 92.3% (24 of 26) of the cases recovered to normality at the final follow-up. Scoliosis secondary to LDH can occur in both adolescents and young adults (3,10-12). Although the earlier mentioned studies have investigated the curve feature and documented the natural history of sciatic scoliosis after surgery, patients included in these studies had a broad age range, and the influence of age on scoliosis resolution was not considered. As the spine is more flexible in adolescents than in adults, the curve features and evolution could be different between these 2 cohorts, which have yet to be determined. The aim of this study was to compare the radiologic features of sciatic scoliosis secondary to LDH between adolescents and young adults, and to investigate whether the patients with different age groups have different curve evolution after surgery.

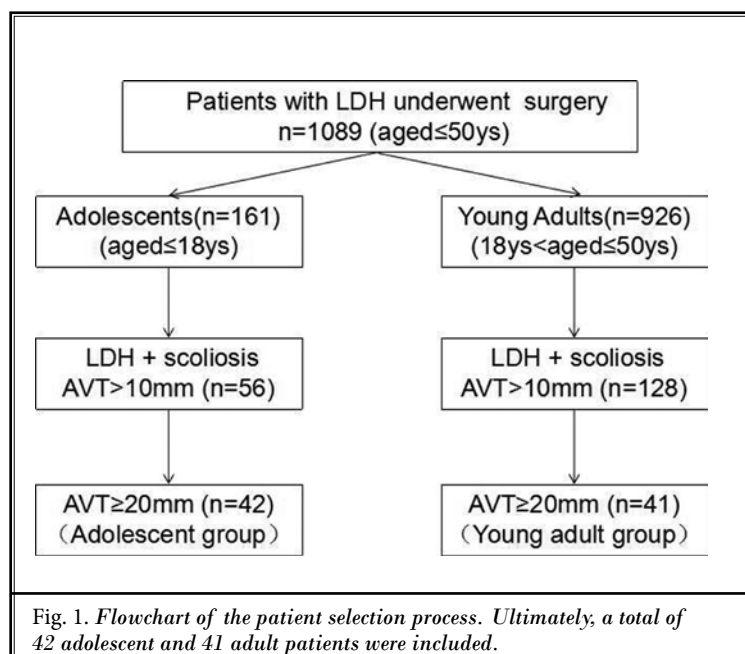
METHODS

Baseline Characteristics of Patients

After obtaining institutional review board approval, a total of 1,087 patients with LDH (aged < 50 years) who underwent open lumbar discectomy were reviewed between December 2010 and January 2016, including 161 adolescent patients (aged 13-18 years) and 926 young adult patients (aged 19-50 years). Sciatic scoliosis (apical vertebral translation [AVT] > 10 mm) was observed in 34.8% (56 of 161) of adolescent patients, whereas in 13.8% (128 of 926) of adult patients. Among them, those who met the following criteria were further investigated: (1) scoliosis with AVT \geq 20 mm; (2) a negative Adams forward bend test (nonstructural scoliosis); and (3) with a minimum of 2 years follow-up. Patients with congenital spinal deformity or degenerative scoliosis were excluded. Ultimately, a total of 42 adolescent and 41 adult patients were included (Fig. 1.).

Radiographic Evaluation

Radiographic parameters were measured on standing anteroposterior and lateral radiographs of the whole spine taken before surgery, 1 month and 6 months after surgery, and at last follow-up. The radiologic examination protocol was standardized for all patients. All patients were instructed to stand in a comfortable position with hips and knees fully extended. The arms were flexed with the hands rested on supports at the level of their shoulders (13). Measurements were performed with Surgimap spine software, Version 2.2.9.9.6 (Nemaris Inc., New York, NY) by 2 residents (Z.Y. and L.W.). AVT was measured as the horizontal distance from the center of the maximum deviated vertebra to the central sacral vertical line (CSVL). Cobb angle was measured as the angle between the superior endplate of S1 and the maximally tilted vertebra. The horizontal distance between C7 plumb line (C7PL) and CSVL was measured as the



CSVL-C7PL. Sagittal vertical axis (SVA) was measured as the horizontal distance from C7 plumb to the posterior-superior corner of S1. Lumbar lordosis (LL) was measured with Cobb angle between the superior endplate of T12 and S1 (Fig. 2A and B). Scoliosis evolution was assessed by variation of AVT and resolution rate (RR). The resolution of scoliosis was defined as AVT \leq 10 mm during follow-up (14,15). Coronal balance was defined as CSVL-C7PL \leq 20 mm, as stated in previous literature (16-19). RR was defined as the percentage of patients with AVT \leq 10 mm in this series.

Clinic Outcomes Assessment

All patients completed questionnaires for the Oswestry Disability Index (ODI) and Visual Analog Scale (VAS) pain scores for the back and leg before surgery and at postoperative follow-up. For the ODI, section 8 (sex life) was omitted for adolescents.

Statistical Analysis

Statistical analysis was performed using SPSS Version 21 (IBM Corporation, Armonk, NY). The Student t test was used to evaluate the differences of continuous variables and the chi-square test was used to evaluate the differences of categorical variables. The Fisher exact test was applied to detect the differences of RR between the adolescent and the adult group. P value $<$ 0.05 was considered statistically significant.

RESULTS

Baseline Characteristics of the Patients

Adolescent patients included 24 boys and 18 girls, with a mean age of 17.6 years (range, 13-18 years). Adult patients included 29 men and 12 women with a mean age of 34.5 years (range, 19-50 years).

The characteristics of the patients are summarized in Table 1. More ado-

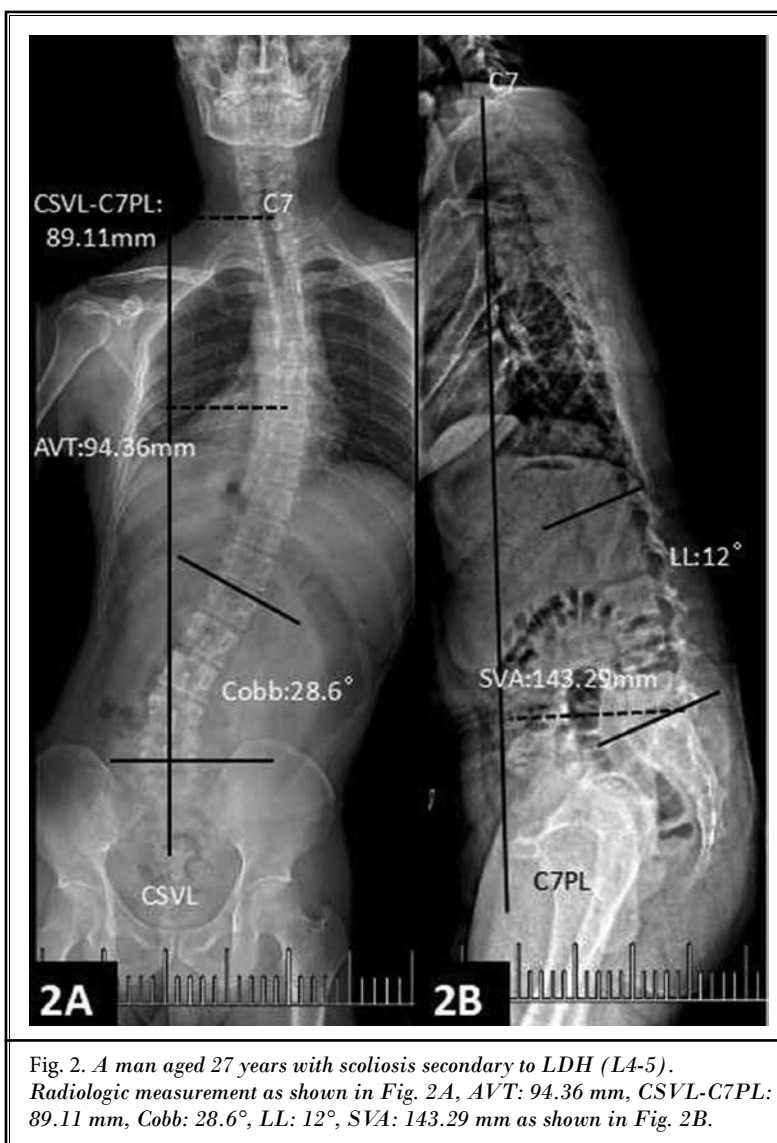


Fig. 2. A man aged 27 years with scoliosis secondary to LDH (L4-5). Radiologic measurement as shown in Fig. 2A, AVT: 94.36 mm, CSVL-C7PL: 89.11 mm, Cobb: 28.6°, LL: 12°, SVA: 143.29 mm as shown in Fig. 2B.

lescent patients were found to have a history of traumatic injury compared with the adult group (28.6% vs. 9.7%; $P = 0.031$). The incidence of positive contralateral straight-leg raise test in adolescents was significantly higher than in the adults (23.8% vs. 12.2%; $P = 0.039$). The mean duration of follow-up was 28.2 ± 9.2 months (range, 24-60 months) for the adolescents, and 28.4 ± 8.6 months (range, 24-56 months) for the adults.

Preoperative Radiographic Evaluation

Table 2 shows the preoperative radiographic characteristics of the patients in the 2 groups. No significant difference was observed in Cobb angle, AVT, CSVL-C7PL, LL, and SVA between the 2 groups ($P > 0.05$). The mean preoperative CSVL-C7PL were lower in the adolescent group than in the adult group (36.9 ± 27.6 vs. 45.5 ± 25.7 ; P

Table 1. The characteristics of the 2 cohorts.

Variables	Adolescents (n = 42)	Adults (n = 41)	P value
Age (years)	17.6 ± 2.1	34.5 ± 7.3	-
Gender (male:female)	24:18	29:12	0.127
Traumatic history, n (%)	12 (28.6%)	4 (9.7%)	0.031*
Follow-up duration (months)	28.2 ± 9.2 (24-60)	28.4 ± 8.6 (24-56)	NS
Pain (n)			
Low back + leg	28	31	NS
Low back only	5	3	NS
Leg only	9	7	NS
Straight-leg raise test (+), n (%)	32 (76.2%)	27 (65.9%)	NS
Contralateral straight-leg raise test (+), n (%)	10 (23.8%)	5 (12.2%)	0.039*
Level of disc herniation, n (%)			
L4-5	30 (71.4%)	26 (63.5%)	NS
L5-S1	7 (16.7%)	9 (21.9%)	NS
Otherwise	5 (11.9%)	6 (14.6%)	NS

*Statistically significant if P < 0.05. Abbreviations: NS, not significant.

Table 2. Preoperative radiographic parameters in 2 cohorts.

Variables	Adolescent Group (n = 42)	Adult Group (n = 41)	P value
Cobb angle (°)	15.2 ± 5.4	15.9 ± 6.9	0.612
AVT (mm)	46.52 ± 23.54	52.07 ± 24.18	0.293
CSVL-C7PL (mm)	36.95 ± 27.61	45.53 ± 25.78	0.147
LL (°)	28.8 ± 12.2	26.4 ± 11.6	0.356
SVA (mm)	35.53 ± 49.91	51.22 ± 45.52	0.144

Abbreviations: AVT indicates apical vertebral translation; CSVL-C7PL indicates horizontal distance from the center of C7 to CSVL; LL indicates Lumbar lordosis; SVA indicates sagittal vertical axis.

= 0.147). The mean CSVL-C7PL was < 20 mm in 31% (13 of 42) of the adolescents, and in 7.3% (3 of 41) of the adults (P = 0.007). The preoperative sagittal spinal alignment of the 2 groups both exhibited a large SVA (35.5 ± 49.9 mm, 51.2 ± 45.5 mm, respectively) and small LL (28.8 ± 12.2°, 26.4 ± 11.6°, respectively).

Evolution of Scoliosis at Follow-Up

For the adolescent group, the mean AVT decreased from 46.52 mm (20.1-122.02 mm) to 6.8 mm (1.25-20.93 mm) at final follow-up. The mean CSVL-C7PL decreased from 36.95 mm (0.44-114.21 mm) to 6.62 mm (0.32-17.96 mm) at final follow-up. For the adult group, the mean AVT decreased from 52.07 mm (24.29-119.85 mm) to 6.87 mm (0.58-17.23 mm) at final follow-up. The mean CSVL-C7PL decreased from 45.53 mm (5.22-109.14 mm) to 6.51 mm (0.33-19.28 mm) at final follow-up (Fig. 3). The RR at different time points was comparable between the adolescent and the adult group as shown in Table 3.

The LL increased from 28.8 ± 12.2° to 44.6 ± 3.8°, and SVA decreased from 35.53 ± 49.91 mm to -7.02 ± 25.63 mm at final follow-up for the adolescents. The LL increased from 26.4 ± 11.6° to 42.8

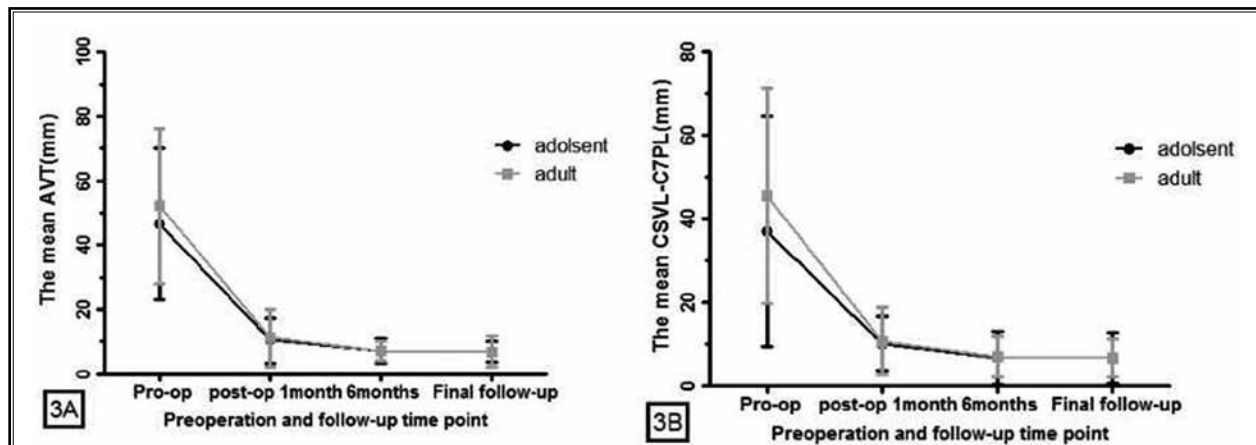


Fig. 3. Time course of scoliosis evolution in terms of AVT and CSVL-C7PL (as shown in A and B, respectively) after lumbar discectomy. Results showed scoliosis significant improvement occurred within one month, mild improvement occurred from one month to 6 months. After 6 months, the AVT and CSVL-C7PL tend to be stable in adolescents and adults.

Table 3. The evolution of scoliosis in 2 cohorts.

	Adolescent Group			Adult Group			P value	
	AVT (mm)	CSVL-C7PL (mm)	RR (%)	AVT (mm)	CSVL-C7PL (mm)	RR (%)	Adolescent vs. Adult	
							AVT	CSVL-C7PL
Preoperation	46.53 ± 23.54	36.95 ± 27.61	–	52.07 ± 24.18	45.53 ± 25.78	–	0.293	0.147
Postoperation								
One month	10.34 ± 6.88	10.04 ± 6.53	54.76	11.21 ± 8.91	10.58 ± 8.03	56.01	0.621	0.698
6 months	6.96 ± 3.73	6.56 ± 6.25	85.71	7.12 ± 3.08	6.81 ± 4.79	92.68	0.531	0.762
Final follow-up	6.80 ± 3.28	6.62 ± 6.02	90.47	6.87 ± 4.78	6.51 ± 4.53	95.12	0.408	0.216

Abbreviations: AVT indicates apical vertebral translation; CSVL-C7PL indicates horizontal distance from the center of C7 to CSVL; RR indicates Resolution Rate

± 6.8°, and SVA decreased from 51.22 ± 45.51 mm to -2.04 ± 11.61 mm at final follow-up for the adults.

A total of 85.7% (36 of 42) of adolescent patients and 92.68% (38 of 41) of adult patients achieved resolution of scoliosis within 6 months after surgery. The time course of scoliosis evolution for adolescents and adults are shown in Figs. 4 and 5.

Clinical Outcomes

The clinical outcomes are summarized in Table 4. Both groups had significant improvement of ODI, VAS back, and VAS leg scores at the final follow-up (P < 0.001). One case in the adolescent group presented with postoperative complication of toe numbness, and recovered within 2 months after surgery. No patient underwent reoperation in both groups during follow-up.

DISCUSSION

Patients with LDH may suffer from sciatic scoliosis, which is known as a nonstructural scoliosis secondary to nerve root irritation (4,5). Although the exact mechanism underlying the development of sciatic scoliosis remains unclear, it was hypothesized that the trunk tilted laterally in response to irritation of the nerve root or hyperactivity of paraspinal muscles spasm (2,5,16,20). Based on the anatomic feature that the adolescents have a more flexible spine than the adults, the incidence of sciatic scoliosis secondary to LDH could be different in these 2 cohorts. Sciatic scoliosis shows a higher incidence rate (9%-82%) for adolescent patients compared with adult patients (9,12,21-22). Matsui et al (21) reported a scoliosis rate of approximately 9% in 446 patients with LDH with an average age of 31.0 years. Kim et al (9) observed that 18% of the 164 adult patients with LDH had sciatic scoliosis. Although for adolescent cases of LDH, Ozgen et al (22) reported that

47% of the patients presented with scoliosis. Comparably, we observed that the incidence of sciatic scoliosis was significantly higher in the adolescent patients with LDH than in the adult patients. The incidence of sciatic scoliosis was 34.6% (45 of 131) in the adolescent patients and 13.8% (128 of 926) in the adult patients, respectively. It is possible that the pediatric spine may have better adaptive capacity to protect nerve tissue via lateral bending.

LDH is rarely seen in the adolescent population. Trauma and genetic factors are believed to be the most common causes, whereas the main risk factors for LDH in adults is degeneration (10,12). In the present study, more adolescent patients were found to have a higher incidence of a history of traumatic injury compared with the adult group (28.6% vs. 9.7%). Clinical presentations of LDH in adolescents are typically different from those for adults. Neurologic symptoms such as numbness and weakness are less commonly seen in adolescents. The goal of the treatment of LDH is to relieve symptoms and allow an early return to routine life. Earlier surgery helps avoid the persistent nonstructural curve progressing into a structural scoliosis and provides a greater opportunity for the correction of scoliotic posture (8).

To the best of our knowledge, for the first time preoperative radiographic parameters were compared between the 2 groups in our study. The mean CSVL-C7PL was found lower in the adolescent group than in the adult group. As indicated by a higher rate of CSVL-C7PL < 20 mm, adolescent patients with sciatic scoliosis had better coronal balance than adult patients. We speculated the different curve pattern could be attributed to different flexibility of the spine between the 2 groups. It appeared that adolescent patients are more inclined to develop thoracic compensatory curve to maintain spinal coronal balance. It is noteworthy that this curve

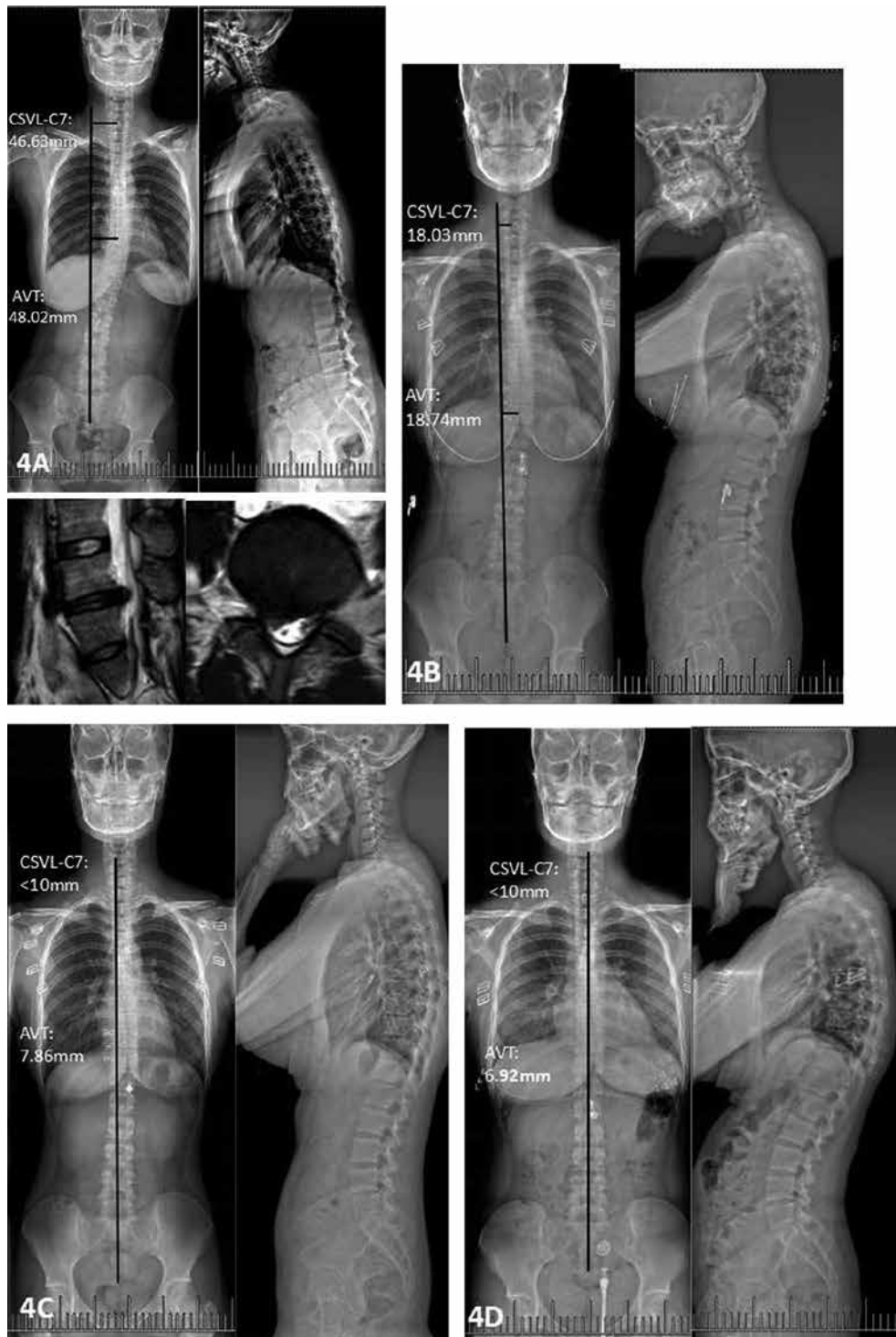


Fig. 4. A girl aged 16 years with L4-5 disc herniation and scoliosis. (A) Preoperative anteroposterior radiograph of the whole spine showed the AVT was 48.02 mm, and lateral radiograph presented small LL and larger SVA. Magnetic resonance imaging revealed L4-5 herniation right disc protrusion. (B) Anteroposterior and lateral radiographs taken at one month after surgery showed the AVT was 18.74 mm; LL and SVA reversed to normality. (C and D) Anteroposterior and lateral radiographs taken at 6 and 24 months postoperatively, the AVT was < 10 mm, considered as being in normal condition.

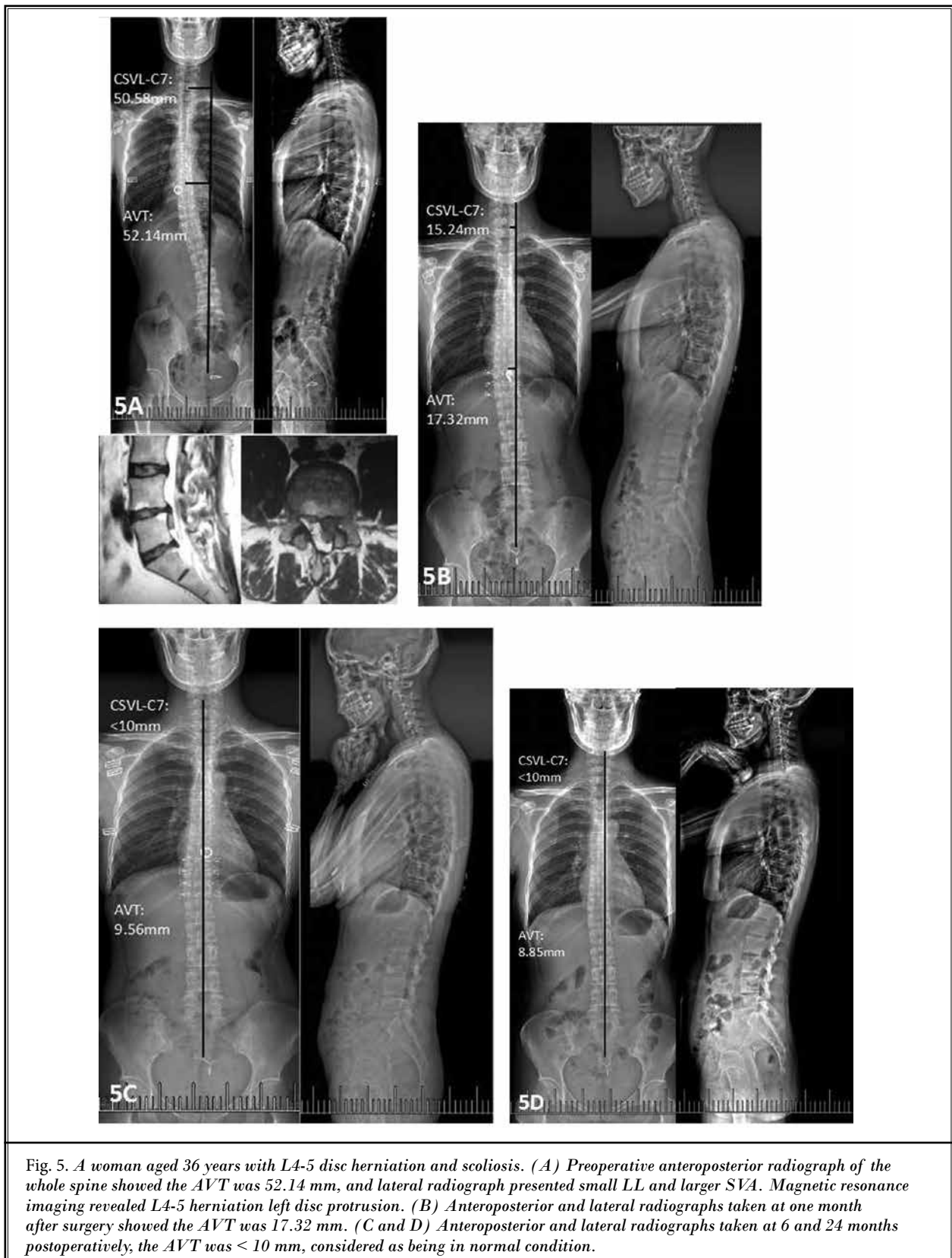


Fig. 5. A woman aged 36 years with L4-5 disc herniation and scoliosis. (A) Preoperative anteroposterior radiograph of the whole spine showed the AVT was 52.14 mm, and lateral radiograph presented small LL and larger SVA. Magnetic resonance imaging revealed L4-5 herniation left disc protrusion. (B) Anteroposterior and lateral radiographs taken at one month after surgery showed the AVT was 17.32 mm. (C and D) Anteroposterior and lateral radiographs taken at 6 and 24 months postoperatively, the AVT was < 10 mm, considered as being in normal condition.

Table 4. *The clinic outcomes of 2 cohorts.*

	Adolescents			Adults		
	VAS back	VAS leg	ODI	VAS back	VAS leg	ODI
Preoperation	2.64 ± 1.52	5.14 ± 1.89	31.78 ± 19.9	2.97 ± 1.99	5.49 ± 2.25	40.94 ± 21.18
Final follow-up	0.72 ± 0.64	0.41 ± 0.35	7.52 ± 3.65	1.12 ± 0.75	0.43 ± 0.41	10.15 ± 4.27
P value	< 0.001*	< 0.001*	< 0.001*	< 0.001*	< 0.001*	< 0.001*

VAS leg and VAS back indicates VAS pain score in the leg and back. *Statistically significant if P < 0.05.

pattern is similar to King type IV curve of idiopathic scoliosis (long span curve). Differentiating them is very critical to avoid misdiagnosis. Sciatic scoliosis in adults mostly exhibited a short lumbosacral curve accompanied by a long thoracic or thoracolumbar curve toward the opposite side, together with a relatively straight sagittal profile. These findings were in accordance with previous studies (8,23).

Sciatic scoliosis was more frequently observed in patients with LDH at the L4-5 segment in the present study, which was consistent with previous literature (5,9,21). The bilateral iliolumbar ligaments originated from the L5 transverse process, and each side had 2 branches, both of which stopped at the ipsilateral iliac crest, which played an important role in the stabilization of L5/S1 (24-25). Biomechanical studies also showed that the ligaments restricted the activity of L5/S1 and maintained its stability (24-26). In contrast, L4-5 was not confined to the pelvic cavity, therefore, compared with L5-S1, the L4-5 segment might be more vulnerable to shift and develop scoliosis. Moreover, Kim et al (9) explored the risk factors for sciatic scoliosis in LDH, and concluded that L4-5 disc herniation was a risk factor for sciatic scoliosis.

There is accumulating evidence that the sciatic scoliosis can be reversible with the improvement of the symptoms (2-5,12). However, the period of curve resolution has varied widely in previous studies. Kim et al (9) reported that trunk shift was reversible in > 50% of patients within 6 months. Matsui et al (21) reported that trunk shift completely disappeared in 18 of 40 patients (45%), and the average time to disappearance of sciatic scoliosis was 107 days after surgery. Suk et al (5) reported 45 patients with LDH and scoliosis, and they found that the mean preoperative Cobb angle was 9.8° (range, 5°-25°) and was reversible to 1.8° (range, 0°-14°) at 7 days after surgery. A Cobb angle of < 5° was observed in 37 of 45 cases (82.2%). Zhu et al (8) reported that

92.3% (24 of 26) of adolescent patients with sciatic scoliosis who underwent open discectomy recovered to normal at 2.5 years postoperatively. Former studies employed different standards to evaluate resolution of scoliosis. In the present study, we defined $ATV \leq 10$ mm as resolution of scoliosis. After surgery, significant improvement of the curve was observed within one month postoperatively in both groups. A total of 54.76% of adolescent patients and 56.01% of adult patients obtained scoliosis resolution within the first month after surgery. Six months after surgery, 85.71% of adolescent patients and 92.68% of adult patients obtained scoliosis resolution. Comparing the time course of scoliosis evolution in 2 groups, no significant difference was found in terms of the mean AVT and CSVL-C7PL. Although the adolescent has more flexibility of the spine and adolescent patients with scoliosis are more likely to present coronal balance before surgery, the 2 different age groups have similar curve evolution after surgery. The age was not a prognostic factor for resolution of sciatic scoliosis.

Some limitations existed in the present study. The surgeries were performed in a tertiary referral hospital, in which incidence of scoliosis may be higher in our center. In addition, few postoperative complications such as recurrence or reoperation was not detected, mainly resulting from our study performed with relatively short-term follow-up and contained a small series of cases.

CONCLUSIONS

The incidence of scoliosis secondary to LDH in adolescents is significantly higher than in adults. Moreover, adolescent patients with scoliosis are more likely to present with coronal balance before surgery. The 2 cohorts of patients could have comparable curve evolution, and resolution of scoliosis generally occurred within 6 months after surgery. This information may be valuable for surgeons and patients in consultation.

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