THE ADDING-ON PHENOMENON IN LENKE TYPE I ADOLESCENT IDIOPATHIC SCOLIOSIS

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Objective. To analyze the incidence of adding-on phenomenon in the surgery of Lenke type 1 idiopathic scoliosis.
Material and Methods. The study included prospective analysis of radiographs of 89 patients (82 females and 7 males) with idiopathic scoliosis who met the criteria for inclusion. The age of patients at the time of surgery ranged from 12 to 25 years (mean: 16.3 ± 4.4 years). The average follow-up period was 2.3 ± 0.4 years. Scoliotic deformity corresponded to grade III according to V.D. Chaklin's classification in 24 patients, and to grade IV in 65. The magnitude of the primary thoracic curve varied from 30° to 103° of Cobb angle (mean: 61.1° ± 17.1°). In all cases, segmental third generation instrumentation (hybrid or laminar) was used in combination with intraoperative skeletal traction with an afford equal to 50 % of the patient's body weight. Laminar fixation was used in 6 patients, and hybrid fixation with different extent of screw installation in 83.
Results. The following parameters showed significant increase: the magnitude of thoracic curve according to Cobb — 16.0° ± 4.3°, the distance from the center of the vertebra located one level distal to the lowest instrumented vertebra, to the central sacral vertical line (LIV+1-CSVL) — 3.6 ± 2.5 mm, the tilt of the lower instrumented vertebra in the coronal plane (LIV tilt angle) — 3.6° ± 2.8°, the tilt of the vertebra located one level distal to the lowest instrumented vertebra (LIV+1 tilt angle) — 4.6° ± 2.5°, and the distance from the center of the apical vertebra of the primary curve to the central sacral vertical line (AV-CSVL) — 17.2 ± 12.0 mm. A significant correlation was found between postoperative magnitude of the scoliotic curve and AV-CSVL distance, postoperative LIV+1-CSVL distance and postoperative LIV+1 tilt angle. An increase in LIV+1 tilt angle in combination with an increase in LIV+1-CSVL distance by more than 4 mm (or degrees) could be a parameter for measuring the adding-on phenomenon.
Conclusion. The indication for reoperation may probably be a significant tilt of the vertebra located below the lowest instrumented vertebra, accompanied by pain syndrome and coronal imbalance.
Key Words: adding-on, idiopathic scoliosis, scoliosis surgery.

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Scoliotic deformity of Lenke type I is one of the most common forms of idiopathic scoliosis in adolescents [3]. This deformity is characterized by the presence of primary thoracic structural curve and upper thoracic or lumbar nonstructural compensatory curve. The use of selective fusion in this type of deformity involves fixation of thoracic curve only, while compensatory curve is left non-instrumented with an eye to spontaneous self-correction [2]. According to published data [1, 4, 5], adding-on phenomenon can be caused by incorrect choice of the lower instrumented vertebra, when area of fusion with metal constructs is too short and compensatory curve cannot balance the achieved correction.

There is no consensus on the definition of adding-on pathological condition in the literature. Wang et al. [9, 10] define adding-on phenomenon as a progressive increase in the number of vertebrae included distally within the primary curve combined with either an increase of more than 5 mm in deviation of the first vertebra below instrumentation from the central sacral vertical line, or an increase of more than 5° in the angulation of the first disc below the instrumentation at 1 year follow-up. Sponseller et al. [8] define adding-on phenomenon as an increase in the number of vertebrae in the measured curve either proximally or distally combined with a curve increase of more than 6° from the first postoperative radiograph. Schlechter et al. [6] defined adding-on as progression of the primary Cobb below the level of instrumentation due to either an increase in the number of vertebra included within the curve, or an increase in disc angulation distal to the instrumentation. In our practice, we use the definition proposed by Wang et al. [9, 10].

The rate of adding-on occurrence is very variable and ranges from 2 to 51 % [6–8, 10]. The development of this complication can lead to an unsatisfactory clinical outcome and the risk of repeated operations. We have not found any papers devoted to this issue in the Russian literature. In routine practice, we do not use selective fusion algorithms [2, 3] and follow the recommendations by Cotrel and Dubousset. These authors identified the lowest instrumented vertebra according to functional spondylography and used the vertebra located immediately above the disc showing symmetrical wedging on left/right lateral bending

radiographs as the lowest instrumented vertebra.

The aim of the study was to analyze the occurrence rates of adding-on in surgery of Lenke type I idiopathic scoliosis.

Material and Methods

This study retrospectively analyzed radiographs of patients with idiopathic scoliosis operated on at the specialized Spine Surgery Clinic. Selective fusion was not used.

The study group inclusion criteria: Lenke type I deformity, patient age below 25 years, postoperative follow-up period at least 2 years. A total of 89 patients met these criteria: 82 females and 7 males . The age of the patients at the time of surgery ranged from 12 to 25 years, approximately 16.3 ± 4.4 years. The mean postoperative follow-up was 2.3 ± 0.4 years. Scoliotic deformity corresponded to grade III according to V.D. Chaklin's classification in 24 patients and to grade IV in 65. Magnitude of the primary thoracic curve according to Cobb varied from 30 to 103° and was approximately 61.1° ± 17.1°. In all cases, segmental third generation instrumentation (hybrid or laminar) was used in combination with intraoperative skeletal traction with a 50% tractive force of the patient's body weight. Laminar fixation was used in 6 patients, hybrid fixation with different extent of screw installation in 83. Standing coronal and lateral radiographs of the thoracic and lumbar spine, including pelvic crests, as well as supine side-bending views were made.

Preoperative radiographs, 2-weeks post-op final follow-up radiographs were assessed.

Based on the literature data, the following radiographic parameters were evaluated: primary thoracic curve magnitude, compensatory lumbar curve magnitude, fusion length, the lowest instrumented vertebra, the distance from center of the first thoracic vertebra to the central sacral vertical line (T1-CSVL), the tilt of the lowest instrumented vertebra in the coronal plane (LIV tilt angle), the tilt of the vertebra located one level distal to the lowest instrumented vertebra (LIV+1 tilt angle), the distance from the center of the apical vertebra of the primary curve to the central sacral vertical line (AV-CSVL), the distance from center of the lowest instrumented vertebra to the central sacral vertical line (LIV-CSVL), the distance from the center of the vertebra located one level distal to the lowest instrumented vertebra, to the central sacral vertical line (LIV+1-CSVL; Fig. 1).

Statistical analysis of the data was performed using Microsoft Excel software. The standard error of the mean was indicated in the parameter estimation. Pair comparison was performed using a standard T-test. The Pearson coefficient was estimated in order to identify a correlation between radiographic parameters. The significance level was set at $P < 0.05$.

Results and Discussion

In 2 (2.25 %) cases, the lowest instrumented level was L5, in 22 (24.70 %) – L4, in 57 (64.04 %) – L3, in 7 (7.87 %) – L2, in 1 (1.14 %) – L1. Only 5 (5.62 %) of 89 patients can be categorized as having adding-on (Fig. 2). They showed a significant increase in 5 radiographic parameters at the last follow-up examination compared to early postoperative radiographs: thoracic curve magnitude according to Cobb, LIV+1-CSVL, LIV tilt angle, LIV+1 tilt angle, and AV-CSVL. The grade of increase in these parameters is presented in Table 1. The rest radiographic parameters did not change significantly (Table 2, Fig. 3). No significant changes in radiographic parameters were found in patients without adding-on signs during the postoperative period (Table 3). In the study, 5 of 7 radiographic parameters showed significant increase in postoperative period and can be potential criteria for detection of adding-on. A significant correlation was found for some of the parameters under study: between the postoperative scoliotic curve magnitude and AV-CSVL distance, postoperative LIV+1-CSVL distance and postoperative LIV+1 tilt angle; less significant parameters were LIV+1-CSVL and the postoperative angle of the primary curve. Therefore, these parameters can be used for evaluation of adding-on. Other parameters showed the correlation level close to 0.1 and were regarded as insignificant (Table 4).

Several authors described adding-on phenomenon in their research. Suk et al. [7] revealed adding-on in 17 of 203 patients. Schlechter et al. [6] noted this phenomenon in 52 of 407 operated patients. It was found that this pathology often occurs in the presence of thoracic curve with lumbar compensatory curvature in Lenke type IA and IIA deformities. In the literature, there is no consensus on radiological and clinical parameters to measure the grade of adding-on as well as on clear criteria for repeated interventions directed at its elimination.

Conclusion

An increase in the LIV+1 tilt angle in combination with an increase in the LIV+1-CSVL distance by more than 4 mm (or degrees) can be a parameter to measure the adding-on phenomenon. However, the high measurement error is a drawback of this parameter. Significant criteria for repeated surgery in patients with adding-on are difficult to identify. In this study, none of the patients with adding-on phenomenon were reoperated because deviations from the norm were clinically insignificant. Nevertheless, the significant tilt of the vertebra located under the lower instrumented vertebra associated with pain syndrome and frontal imbalance may probably be an indication for repeated surgery.

The study was not sponsored. The authors declare no conflict of interest.

Fig. 1
Radiographic parameters under study, a female patient A. aged 10 years with grade IV right-sided thoracic idiopathic scoliosis: *1* – thoracic curve according to Cobb; *2* – LIV tilt angle; *3* – LIV+1 tilt angle; *4* – CSVL; *5* – T1-CSVL distance; *6* – AV-CSVL distance; *7* –LIV-CSVL distance; *8* – LIV+1-CSVL distance

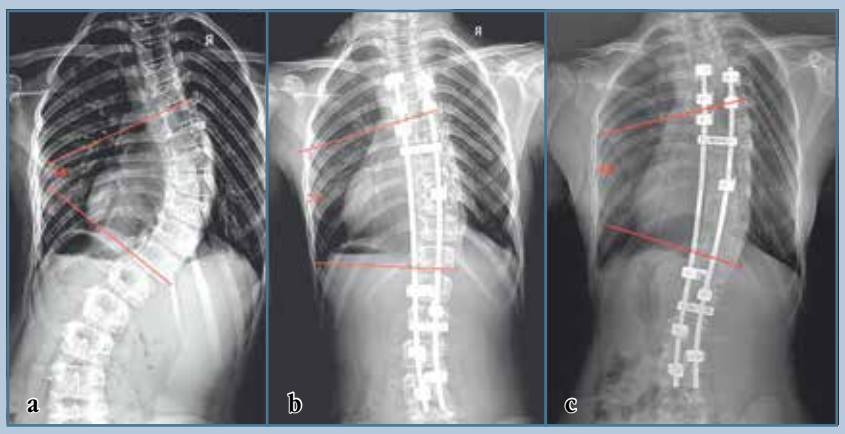

Fig. 2
Radiographs of a female patient A., 10 years, with grade IV right-sided thoracic idiopathic scoliosis: **a** – before surgery; **b** – 2 weeks after surgery; **c** – 2 years after surgery

Table 1
Radiographic parameters in patients with adding-on

Thoracic curve according to Cobb, degrees	LIV+1-CSVL, mm	LIV tilt angle, degrees	LIV+1 tilt angle, degrees	AV-CSVL, mm
16.0 ± 4.3	3.6 ± 2.5	3.6 ± 2.8	4.6 ± 2.5	17.2 ± 12.0

Table 2
Changes in radiographic parameters in patients with adding-on

Parameters	Preoperative	Postoperative	In 2 years after surgery	P
Thoracic curve according to Cobb, degrees	64.0 ± 9.1	21.2 ± 5.0	37.2 ± 8.7	0.002
LIV-CSVL, mm	16.2 ± 10.6	13.6 ± 5.8	14.2 ± 3.4	0.8
LIV+1-CSVL, mm	9.2 ± 5.6	8.8 ± 3.4	12.4 ± 3.5	0.02
LIV tilt angle, degrees	10.4 ± 5.0	2.0 ± 3.4	5.6 ± 3.1	0.06
LIV+1 tilt angle, degrees	6.6 ± 9.1	3.2 ± 0.0	7.8 ± 4.6	<0.001
T1-CSVL, mm	16.2 ± 19.7	17.2 ± 14.8	9.8 ± 9.2	0.4
AV-CSVL, mm	51.8 ± 26.0	8.0 ± 5.2	25.2 ± 11.7	0.05

Mean and standard error of the mean, significant difference (P < 0,05).

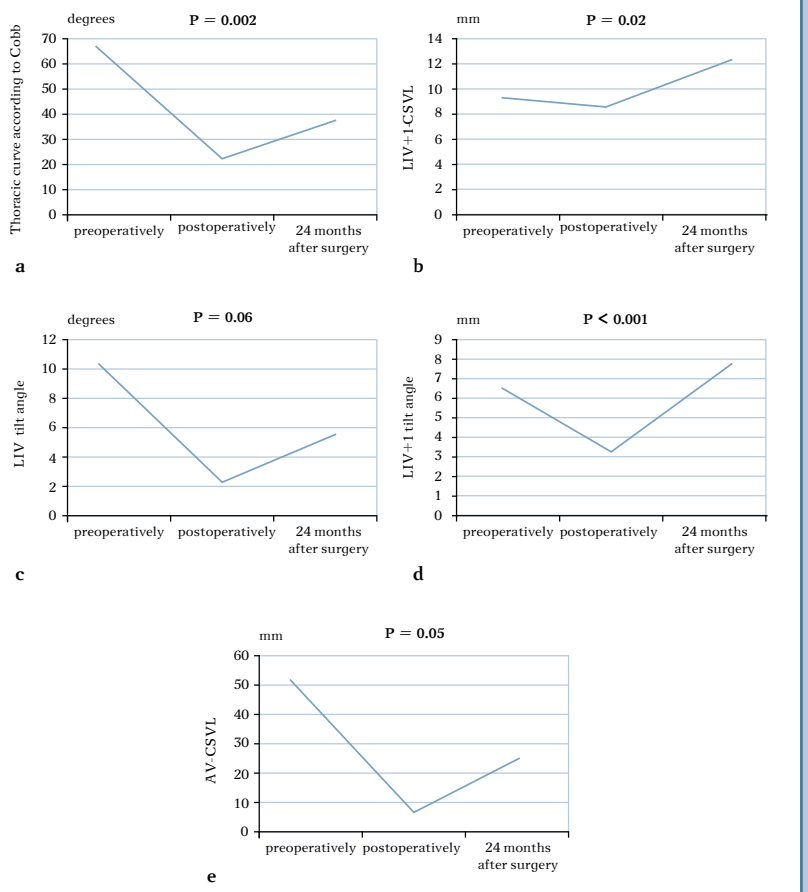

Fig. 3
A change in the studied parameters in patients with adding-on at follow-up: **a** – thoracic curve according to Cobb; **b** – LIV+1-CSVL distance; **c** – LIV tilt angle; **d** – LIV+1 tilt angle; **e** –AV-CSVL distance

Table 3
Changes in radiographic parameters in patients without adding-on

Parameters	Preoperative	Postoperative	In 2 years after surgery	P
Thoracic curve according to Cobb, degrees	60.9 ± 17.5	21.0 ± 10.6	22.6 ± 10.4	0.01
LIV-CSVL, mm	14.1 ± 9.9	6.6 ± 6.6	6.1 ± 6.2	0.33
LIV+1-CSVL, mm	7.7 ± 6.6	5.1 ± 5.8	4.1 ± 4.9	0.02
LIV tilt angle, degrees	12.8 ± 8.1	2.5 ± 2.7	3.3 ± 3.8	0.02
LIV+1 tilt angle, degrees	8.3 ± 6.1	2.1 ± 2.9	3.2 ± 4.2	0.04
T1-CSVL, mm	12.0 ± 8.5	14.9 ± 11.2	10.0 ± 7.8	<0.001
AV-CSVL, mm	43.8 ± 23.0	9.8 ± 7.3	11.3 ± 9.8	0.1

Mean and standard error of the mean, significant difference (P < 0,05).

Table 4
Correlation of postoperative radiographic parameters in patients with adding-on

Parameters	Curve angle	LIV+1-CSVL	LIV tilt angle	LIV+1 tilt angle	AV-CSVL
Postoperative curve angle		R = 0.23	R = 0.36	R = 0.1	R = 0.4
LIV+1-CSVL	R = 0.23		R = 0.1	R = 0.47	R = 0.12
LIV tilt angle	R = 0.36	R = 0.1		R = 0.11	R = 0.11
LIV+1 tilt angle	R = 0.1	R = 0.47	R = 0.11		R = 0.1
AV-CSVL	R = 0.4	R = 0.12	R = 0.11	R = 0.11	

R from 0.1 to 0.3 — weak positive correlation; R from 0.3 to 0.7 — moderately positive correlation.

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