THE EFFECT OF SURGICAL CORRECTION OF LENKE TYPES I AND III SCOLIOTIC DEFORMITIES ON THE SPINAL BALANCE IN PATIENTS AGED 15–35 YEARS

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Objective. To analyze the effect of spinal deformity correction on the parameters of the frontal and sagittal balance in patients aged 15—35 years with Lenke types I and III idiopathic scoliosis.

Material and Methods. The dynamics of sagittal and frontal parameters of the spinal balance was assessed in 268 patients aged 15 to 35 years with Lenke type I and III idiopathic scoliosis before and after surgical treatment. The patients' quality of life and the number of postoperative complications were assessed depending on the imbalance severity.

Results. More than half of patients (55.6 %) with Lenke types I and III idiopathic scoliosis have initial balance disorders, and 14.6 % of them have pronounced abnormalities. Significant balance disorders are predicted by severe scoliosis (85.3° ± 30.3°), greater L5 tilt (10.3 ± 7.9 before surgery; 5.3 ± 4.8 after surgery) and initial sagittal imbalance (32.75 ± 27.7), large residual scoliotic curve (43.3° ± 23.1°), large angle of residual thoracic kyphosis (32.3° ± 15.9°), and smaller angle of lumbar lordosis after surgery (52.3° ± 14.1°); $p < 0.05$. The main compensatory elements, in addition to PT and SS, are the angle of L5 tilt in the frontal plane and the L5—S1 angle in the sagittal plane. In young patients aged 15-35 years, disc mobility at the L5—S1 level is sufficient to achieve a more balanced body position, even with a significant change in the PI-LL ratio.

Conclusion. In the long-term postoperative period, a pronounced imbalance of the spine increases the risk of mechanical postoperative complications up to 50 %, while the quality of life of patients does not decrease, and repeated surgical interventions are required in singular cases. Correction of scoliotic deformity allows increasing the number of patients without balance disorders by 6 %, and reducing the number of gross deviations by 2 times.

Key Words: frontal and sagittal balance, idiopathic scoliosis, quality of life, imbalance predictors.

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Until recently, the problem of sagittal balance has been studied only in adult patients suffering from osteochondrosis. A lot of papers described normal balance parameters in adults and formulated types of posture, formulas and techniques for calculating optimal lumbopelvic correlations. Also, recommendations and classifications reflecting the degree of imbalance and allowing surgical treatment to be planned with consideration of the initial condition of patients have been introduced into clinical practice [1].

The aims of surgical correction of adolescent idiopathic scoliosis and spinal deformities in adults (adult spinal deformity, or ASD) differ significantly. In ASD, improvement of the functional outcomes of surgical therapy is impossible without achieving optimal parameters of sagittal balance. In the case of adolescent idiopathic scoliosis, most of the patients are initially in a compensated state according to the parameters of balance, and the main goal of treatment is to correct the external view, i.e., an aesthetic defect. In the case of ASD, most patients experience a progressive decrease in lumbar lordosis (LL) compensated by pelvic retroversion, a more or less flexible thoracic spine, and sometimes by lower extremities [2]. If compensation mechanisms are insufficient, an anterior imbalance occurs associated with cervical hyperlordosis and correlating with unsatisfactory functional indicators [3, 4]. In idiopathic scoliosis, the preoperative situation does not correspond to any of the abnormal patterns in ASD [5].

To date, one of the main effective classifications of scoliosis that is a guide to choosing the level of fixation and the correction technique is the Lenke classification. Not every aspect of the spinal sagittal contour is covered by this classification. In this context, there have been numerous studies indicating that scoliosis correction is done out of this classification's recommendations (up to 26 %). Clements et al. [4] reflect this in a multicenter study.

Surgical correction of scoliotic deformity is associated with the large number of risks of postoperative complications. These include proximal junctional kyphosis (PJK), distal junctional kypho-

sis (DJK), the adding-on phenomenon (associated with the progression of the scoliotic curve in segments adjacent to the spinal fusion area), and instrumentation fracture and instability. The disturbances of the frontal and sagittal balance of the spine can result in the development of pain and cause patient's dissatisfaction with the surgical outcomes [6–9]. Of particular interest for the study are young patients whose lumbopelvic correlations and physiological curves of the spine have already been definitively formed, though pronounced degenerative changes in the lower lumbar spine have not yet developed. Despite the age limits set by the WHO for young people, which are 18–44 years, there are many reports in the literature stating that after 35 years, the number of patients suffering from lower back pain increases multiply times. A series of studies describes degenerative changes of the spine under the radiographs and MRIs in patients after 35 years old [10–15]. On the contrary, attention is drawn to papers reporting that by the age of 15–16, the PI parameter is no longer dynamic in 90 % of cases. The closure of the triradiate cartilage occurs, and the neurovegetative system enables an adequate and balanced response of the body to spatial changes [16, 17]. In this regard, it is reasonable to evaluate the balance using adult standards starting at the age of 15, but with consideration the unique age characteristics of bone tissue maturation, and the Risser test can be used as an extra criterion. Under the age of 15, the lumbopelvic relationships may differ significantly from adult norms [18].

The objective is to analyze the effect of spinal deformity correction on the parameters of the frontal and sagittal balance in patients aged 15–35 years with Lenke type I and III idiopathic scoliosis.

Design: a single-center retrospective cohort study (with historical control).

Evidence level: III.

Material and Methods

In 1997–2021, 3,343 patients with idiopathic scoliosis applied to the Pediatric and Adolescent Vertebrology Clinic of the Novosibirsk Research Institute of Traumatology and Orthopaedics n.a. Ya.L. Tsivyan, to correct spinal deformity.

Patients

To evaluate the spine balance, the patients with Lenke types I and III scoliotic curves with main curve localized in the thoracic spine were selected. The fundamental point in selecting the type of scoliotic deformity was the willingness to exclude the direct influence of scoliosis on the parameters of the lumbopelvic balance. Even in case with Lenke type III curves that had a lumbar counter-curve, the lower end vertebra was located no lower than the L4 vertebra in most cases.

In order to evaluate the parameters of the spine balance, 15–35-year-old patients were selected who had Risser stage no lower than 2 and underwent correction of scoliotic deformity with segmental third-generation instrumentation. Medically ill patients previously operated on the spine with early manifestation of surgical site infection with subsequent removal of the instrumentation, as well as patients without dynamic postural radiographs were excluded from the study. The minimum follow-up period was 2 years. Therefore, a retrospective analysis of radiological parameters and data from SRS-24 questionnaires was performed on 268 patients. The mean age of patients at the time of admition was 19.6 ± 5.1 years.

Techniques

The sagittal balance was evaluated using a sagittal SRS-Schwab classification modifier [19]. Despite this classification being developed for degenerative scoliosis, it has several grades of imbalance that can be applied to idiopathic scoliosis without degenerative changes. The frontal balance was defined by the CSVL parameter. A dislocation of up to 20 mm was considered a variant of norm; a dislocation of 20 to 40 mm was taken as a moderate imbalance and marked with "+"; changes of more than 40 mm indicated a significant imbalance and were marked with "++". According to the degree of imbalance, the patients were divided into 4 groups. Patients without balance deviations were attributed to the first group, with a moderate disorder of one of the parameters marked with "+" – to the second group, with a moderate disorder of two or more parameters ("+", "+") – to the third group, and with gross disorders of the parameters marked with "++" – to the fourth group.

To evaluate the impact of the level of the low instrumented vertebra (LIV) on the parameters of sagittal balance and quality of life, the patients were divided into 3 groups: 1) L3 vertebra and more proximal regions; 2) L4 vertebra; 3) L5 vertebra. In any case, the fixation did not reach the S1 level.

Statistical analysis

Predictors of complications and insufficient correction were defined by the building of logistic regression models. Pairwise numerical associations of goals and covariates of any type were identified with building of univariate models. Multiple numerical associations were identified by building of multivariate models. Statistical hypotheses were tested at a critical significance level of $p = 0.05$, i.e., the difference was considered statistically significant if $p < 0.05$. Statistical calculations were made in R programming language (version 4.1.3, 2022-03-10), Vienna, Austria. URL: https://www.R-project.org/).

All patients signed informed consent for surgical treatment and statistical data processing.

Results

The initial parameters of sagittal lumbopelvic balance in patients of the study group and healthy individuals were compared according to Schwab [19] (Table 1).

The data obtained are similar to the values in the group of conditionally healthy patients according to Schwab. The presence of the main scoliotic curve in the thoracic spine does not result in statistically significant changes in the parameters of the global (frontal) and sagittal lumbar balance.

While using the technique of assessing the balance parameters according to the sagittal modifier of the SRS-Schwab classification with an additional evaluation of the parameters of the frontal

balance, only 119 (44.4 %) out of 268 patients had no disorders in the parameters; 81 patients had minor balance disorders according to only one of the criteria ("+"), which was 30.2 % of the total. Moderate balance disorders with the presence of deviations in two or more parameters "+" were found in 29 (10.8 %) patients, and pronounced deviations of parameters "++" were found in 39 (14.6 %).

The structure of balance parameter disorders was dominated by a mismatch of PI-LL (n = 118, 37 of them are patients with gross disorders "++"). Disorders of the frontal balance (n = 51) were in second place. Then there were disorders of the global sagittal balance (SVA; n = 43), with a predominance of the deflection of the trunk posteriorly. In the total group, 177 patients out of 268 had an initial negative SVA. Only a small group of patients initially had high PT values (n = 9; Fig. 1).

The correlation dependence of the assessed balance parameters (PI-LL, CSVL, SVA and PT) on the basic preoperative radiological findings was analyzed. It was discovered that PI-LL correlates with magnitudes of thoracic kyphosis and lumbar lordosis and the L5-S1 angle, as well as with PI, PT and negative SVA values ($p < 0.05$). PT correlates with PI. The CVSL value shows the correlation with such a parameter as the L5 tilt, and the SVA value indicates the correlation with the L5-S1 angle ($p < 0.05$).

All patients underwent surgical correction of scoliotic deformity with third-generation instrumentation in accordance with the standard procedure. The mean angle of the main scoliotic curve before surgery was 64.4° ± 21.0°, after surgery: 28.0° ± 17.0°, correction: 61.5 ± 16.1 %, loss of correction: 3.1 ± 1.8 %. The angle of the secondary scoliotic curve before surgery was 39.0° ± 18.1°, after surgery: 11.4° ± 13.3°, correction: 78.9 ± 21.9 %, loss of correction: 3.3 ± 17.9 %. Thoracic kyphosis before surgery was 30.5 ° ± 18.6°; at the end of the follow-up period it was 27.4° ± 12.3°. Lumbar lordosis before surgery was 58.2° ± 11.3°; at the end of the follow-up period it was 53.8° ± 9.7°. As the result of the surgical treatment of idiopathic scoliosis it was possible to achieve a satisfactory correction with minimal loss of the achieved result in the long term. Surgical treatment of idiopathic scoliosis results in a decrease in thoracic kyphosis and lumbar lordosis, preserving the mean values within the conditional norm. The mean follow-up period was 3.99 ± 1.96 years.

The clinical progress of the parameters of the sagittal and frontal balances was assessed depending on the fixation level. The PI value for patients with fixation on L3 and L4 vertebrae was 50°, and in the group with fixation on L5 this parameter was 56°.

The clinical progression of the pelvic tilt (PT) showed the same dependencies in the three groups. In the early postoperative period, there was a slight rise in this parameter and then a gradual restoration to almost the initial level (PT for the L3 and L4 levels was 7° at the end of the follow-up period; for the L5 level, it was 15°).

The sacral slope (SS) remained stable in patients with spinal fusion to the L4 level (42°), and in patients with fixation to the L3 and L5 vertebrae, it showed a slight rise by the end of the follow-up period (44° and 45°).

During the assessment of the global sagittal balance (SVA), positive and negative values of the parameter were considered. The most stable values were found in the group with fixation at the level of the L4 vertebra. The highest values of SVA with a trend towards imbalance were observed in the group with spinal fusion to the L5 level, especially with a negative balance (SVA = -45 mm).

The global frontal balance (CSVL) originally fell within the linits of the conditional norm for the mean values in all groups. Immediately after surgery, this parameter underwent the greatest changes, and at the last examination it practically corresponded to the preoperative indicators.

The most stable lumbar lordosis (LL) was in the group with fixation to the L3 vertebra; a more pronounced reduction in lordosis followed by restoration occurred in the group with fixation to the L5 vertebra (51° immediately after surgery, 55° at the last examination). Lordosis corresponded to the conditional norm in all groups.

Thoracic kyphosis in all studied groups was slightly reduced in the postoperative period and amounted to 27° initially and 23° at the end of follow-up for the group with fixation to the level of L3; 31° and 26°, respectively, for the group with spinal fusion to L4; 29° and 27° in the group with fixation to the L5 vertebra.

During the study of additional parameters, attention is drawn to the L5–S1 angle and the L5 vertebra tilt. These parameters are the most varied in the group with fixation up to L5.

The L5-S1 angle in the sagittal plane in patients with fixation to the L5 vertebra at the end of the follow-up period was 28° (versus 23° and 25° in groups with fixation to the L3 and L5 vertebrae).

The L5 vertebra tilt is initially considerably higher in patients from the group with fixation up to the L5 vertebra (15.5° versus 4° in the group with fixation up to L3 and 8° in the group with fixation up

Table 1

Parameters of sagittal balance in healthy patients aged 15–35 years according to Schwab and in patients with idiopathic scoliosis in the study group

Parameters	Norm according to Schwab	Idiopathic scoliosis
PI, degrees	52 ± 10	50.4 ± 10.1
PT, degrees	13 ± 7	7.9 ± 6.6
SS, degrees	39 ± 9	42.4 ± 8.0
LL, degrees	60 ± 14	58.2 ± 11.3
TK, degrees	38 ± 12	30.5 ± 18.6
SVA, mm	36 ± 33	27.3 ± 18.3

to L4) that makes a longer fixation more reasonable.

During the postoperative balance assessment, 135 (50.4 %) out of 268 patients had no disorders in the parameters, and 87 (32.5 %) patients had mild balance disorders according to the only one of the criteria ("+"). Moderate balance disorders with the presence of deviations in two or more parameters "+" were found in 29 (10.8 %) patients, and pronounced deviations "++" were found in 17 (6.3 %) patients. The structure of balance parameter disorders remained similar to the preoperative one. The mismatch of PI-LL values considerably prevailed (n = 83). Disorders of the frontal balance (n = 47) is in second place. Then follow disorders of SVA (n = 41) with the predominance of the formation of a negative balance.

An initial negative SVA was observed in 177 patients. A small group of patients had high PT values (n = 16). The increased number of patients with an imbalance in PT parameter suggests excessive compensatory responses of the body in the form of pelvic tilt to achieve a more balanced condition. The number of patients with global frontal and sagittal imbalances (in terms of SVA and CSVL parameters) remains roughly at the same level as before surgery. Surgical correction of scoliotic deformity contributes to a more balanced PI-LL correlation by attempting to simulate the physiological lumbar lordosis.

We also analyzed the correlation between radiological and age parameters in group without imbalance and in groups with different degrees of imbalance. Tables 2 and 3 demonstrate the data before surgery and at the last control examination (at least after two years).

Despite that there is a correlation between increasing values of a large number of parameters (age, main curve, secondary curve, thoracic kyphosis, lumbar lordosis, the angle of inclination of L5, the L5–S1 angle, negative SVA and the degree of imbalance), only a few parameters showed statistically significant correlation. The risk of a pronounced imbalance with a high level of confidence may be the initial more severe scoliotic deformities with a large angle of inclination of the L5 vertebra and the initial disorder of the frontal balance (CSVL; $p < 0.05$).

In the postoperative period, statistically significant indicators associated with the development of a pronounced imbalance were the following: residual scoliotic curve and thoracic kyphosis, as well as a smaller angle of lumbar lordosis ($p < 0.05$).

There was no statistically significant correlation between the level of the low instrumented vertebra and the degree of imbalance.

According to the survey findings, the quality of life was evaluated depending on the level of the low instrumented

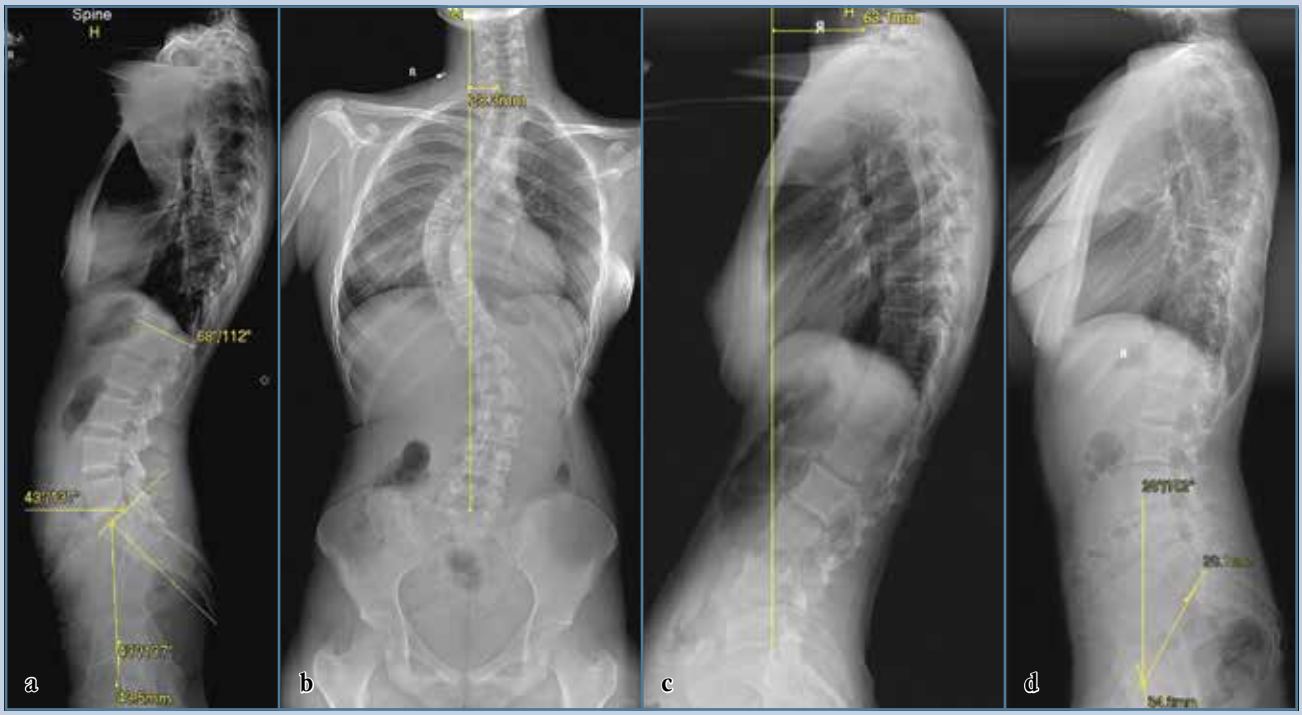

Fig. 1
Types of balance disorders in idiopathic scoliosis: **a** – discrepancy between PI-LL indicators (PI = 43°, LL = 68°); **b** – frontal balance disorder (CSVL – 28 mm); **c** – global sagittal balance disorder (SVA = -28 mm); **d** – high PT values (28°)

vertebra. As a result, there is a tendency of a decrease in scores within 6 months after surgery for almost all domains in the group with fixation to the L5 vertebra. However, no statistically significant difference was obtained. During the last control examination, the situation was largely improving. The scores of pain and external view domain were slightly lower in the group with fixation to the L5 vertebra (the total score was 91 when fixed at L5; 92 when fixed at L3 and higher; 94 when fixed at L4; Fig. 2).

An evaluation of the quality of life depending on the degree of imbalance indicates that within 6 months after surgery, the values for most of the domains in the group with a pronounced imbalance are considerably lower. Nevertheless, only the pain syndrome domain is statistically significant ($p < 0.05$). At the last control examination, the indicators were improved for all the domains of the questionnaires and even exceeded those in more balanced groups (Fig. 3).

In the postoperative period, 53 complications were identified which amounted to 19.8 %. Such a high percentage is because all the parameters that do not permit a postoperative period to be called even are considered. Complications are divided into mechanical and non-mechanical to assess the influence of balance parameters. The first ones include fractures of the instrumentation, instability of the grip and bone tissue resorption. Non-mechanical ones consist of PJK, the adding-on, and the progression of scoliosis. Instrumentation instability was noted in 20 (7.5 %) cases, and in 14 of them, the impairment was in the area of the lower part of the instrumentation. Bone tissue resorption manifested around the instrumentation elements in 5 (1.7 %) cases, fracture of the instrumentation in 10 (3.7 %) cases, PJK, the adding-on phenomenon, and the progression of scoliosis associated with instrumentation (with hook fixation) in 18 (6.7 %). PJK was the most common (13 cases), and the progression of scoliosis manifested in 1 case. Repeated surgery was indicated and performed only in one case (remounting of the distal part of the hook structure with replacement by transpedicular fixation). The remaining complications were identified in the long-term period during postoperative examination; they did not cause pain syndrome and had no external clinical manifestations. An assessment of the number of complications depending on the degree of imbalance is shown in Table 4.

We have estimated the number of complications depending on the level of fixation (Table 5).

Hook fixation was used in 38 (14.3 %) cases during surgical correction of scoliosis. The number of complications in this group was 12 (31.6 %). Surgeries with hybrid fixation (pedicle screws in the lumbar spine and hook fixation in the thoracic spine) were performed in 178 (66.9 %) patients in whom complications were identified in 31 (17.4 %) cases. Total transpedicular fixation was used in 52 (18.8 %) cases; 10 (19.2 %) patients had complications.

In patients with fixation up to the L5 vertebra, one complication of hook fixation in the form of rod fracture and one complication of transpedicular fixation in the form of a screw fracture at the L5 level on the left and bone resorption on the right were found. No clinical manifestations in the form of pain syndrome were detected in the patient, and there was no rise in the resorption area and an increase in diastasis between the fragments over time.

Despite the small number of cases in groups with a pronounced imbalance and with fixation at the L5 level, there is a considerably high number of mechanical complications in these groups.

Discussion

Many authors associate the main imbalance problems with hypokyphosis of the thoracic spine that, in turn, can trigger such complications as PJK, DJK, and the formation of a decompensated negative sagittal balance [20, 21]. The data we

Table 2

Influence of radiological and age parameters before surgery on the imbalance degree

Parameters	No imbalance	Mild imbalance	Moderate imbalance	Pronounced imbalance
Age, years old	19.0	19.6	20.6	21.9
Main curve, degrees	59.7	68.5	61.8	85.3
Secondary curve, degrees	35.4	43.5	35.3	49.1
Thoracic kyphosis, degrees	27.7	20.2	27.5	44.8
Lumbar lordosis, degrees	58.0	58.6	55.3	61.3
L5 tilt, degrees	6.0	6.5	7.5	10.3
L5–S1, degrees	23.1	23.0	23.4	25.6
PI, degrees	49.8	51.5	47.3	51.1
PT, degrees	7.8	8.1	6.6	8.8
SS, degrees	42.0	43.4	40.7	41.7
SVA (+), mm	17.2	22.6	18.9	19.8
SVA (-), mm	28.1	24.1	31.3	32.8
CSVL, mm	10.8	13.7	14.7	8.2

Table 3
The influence of radiological parameters at the end of the follow-up period on the imbalance degree

Parameters	No imbalance	Mild imbalance	Moderate imbalance	Pronounced imbalance
Main curve, degrees	25.1	30.6	25.5	43.3
Secondary curve, degrees	11.0	12.5	8.0	18.4
Thoracic kyphosis, degrees	24.3	30.8	27.6	32.3
Lumbar lordosis, degrees	51.8	56.2	53.9	52.2
L5 tilt, degrees	3.5	4.1	3.5	5.3
L5–S1, degrees	23.9	25.2	25.0	23.0
PI, degrees	49.8	51.5	47.3	51.1
PT, degrees	7.2	7.8	6.0	8.6
SS, degrees	42.5	43.8	41.1	42.4
SVA (+), mm	14.1	18.6	25.8	26.3
SVA (-), mm	19.2	31.1	42.0	36.1
CSVL, mm	7.7	14.2	16.7	15.9

have obtained suggests the opposite: insufficient correction of kyphosis in the postoperative period may result in imbalance.

During the assessment of the mean values of the balance parameters, we receive data comparable to the conditional age norm. Similar outcomes are often found in modern publications [22, 23]. According to our data, more than half of the patients suffer from an initial imbalance in the structure of idiopathic scoliosis of thoracic localization. Nevertheless, gross deviations in parameters were found only in 14.6 % of patients. The formation of the scoliotic curve may undoubtedly affect the formation of lumbar lordosis, since even with isolated thoracic scoliotic curves, the rotational component of the deformity migrates into the lumbar spine, making both a projection and a true change in this parameter. A change in lumbar lordosis provides a deviation in the PI-LL difference and may also cause the formation of a negative global sagittal contour.

The question left pending is whether it is essential to strive for the preservation of as many free segments in the lumbar spine as possible. Some authors give data on impaired balance parameters with a more extended fusion [24]. On the contrary, there are reports that even a low level of fixation does not downgrade the quality of life in the long term [25]. During the analysis of the causes of the imbalance, it was found that the impairment of the general sagittal contour is associated with such a parameter as the L5–S1 angle, and the impairment of the frontal balance depends on the initial angle of inclination of L5. This fact should be considered when planning surgical treatment, since the goals of surgeries may differ significantly. For one group of patients it is essential not to upset the balance at the time of correction of scoliotic deformity, and for the second group it is essential to select techniques for restoring parameters. The dynamics of such parameters as PT, SS and LL in the postoperative period indicates the triggering of compensatory mechanism for optimal balance, and these changes occur even when the spine is fixed up to L5 vertebra. For balanced position

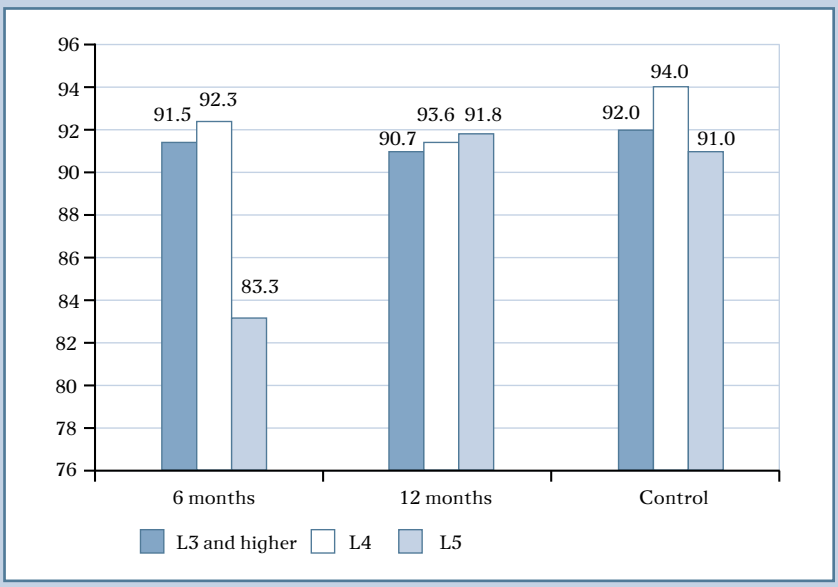

Fig. 2
Assessment of quality of life using SRS-24 questionnaires depending on the level of the lower instrumented vertebra over time

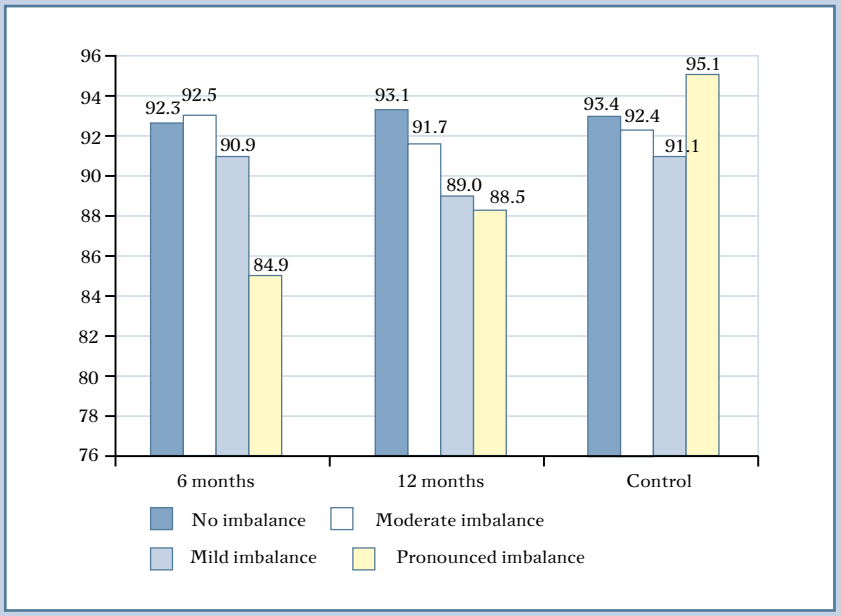

Fig. 3
Assessment of quality of life depending on the degree of imbalance over time

of the body in the frontal plane during the procedure, there should be an urge to achieve a more horizontal position of the vertebra. The main condition for maintaining the global sagittal balance should be the preservation of lumbar lordosis. In patients aged 15–35 years, the L5–S1 disc mobility is sufficient for increasing the angle in the postoperative period to achieve the balance normalization. Apparently, with the development of degenerative processes in this section, the possibility of compensation will be lower, and consequently, a postoperative imbalance is possible due to incorrect planning of lordosis.

The fact remains indisputable that surgical treatment of scoliotic deformities is, first of all, the correction of aesthetic manifestations of the disease [26]. In this regard, even with pronounced deviations in the balance parameters, patients give high ratings of the quality of life according to the questionnaire. Lower scores are associated with insufficient correction of the primary and secondary scoliotic curves. Nevertheless, a high percentage of complications does not give the right to ignore the balance parameters, despite the fact that repeated surgeries were required only in isolated cases. Even in the presence of mechanical complications, most of the patients did not need repeated surgeries since the formed bone block and a set of support points did not permit a gross displacement of unstable elements.

Conclusion

Therefore, more than half of patients (55.6 %) suffering from Lenke types I and III idiopathic scoliosis have initial balance disorders, and pronounced imbalance occur in 14.6 % of cases. The predictors of pronounced balance disorders are the following: severe scoliosis, greater L5 tilt both before and after surgery, large residual scoliotic curve, large angle of residual thoracic kyphosis, as well as a smaller angle of lumbar lordosis after surgery ($p < 0.05$). In addition to PT and SS, the main compensatory elements are the angle of inclination of L5 in the frontal plane and the L5–S1 angle in the sagittal plane. In young patients aged 15–35 years, the disc mobility at the L5–S1 level Is quite sufficient to achieve a more balanced body position, even with a substantial change in the PI-LL ratio.

Correction of scoliotic deformity allows increasing the number of patients without balance disorders by 6 % and reducing the number of gross deviations by two times. In the long-term postoperative period, a pronounced imbalance of the spine does not decrease the quality of life, but herewith increases the risk of developing mechanical postoperative complications by up to 50 %.

The study had no sponsors.
The authors declare that they have no conflict of interest.
The study was approved by the local ethics committee of the institution.

Table 4
Complications depending on the imbalance degree, n (%)

Complications	No imbalance (126 patients)	Mild imbalance (91 patients)	Moderate imbalance (29 patients)	Pronounced imbalance (16 patients)
Mechanical	15 (11.9)	9 (9.9)	4 (13.8)	8 (50.0)
Non-mechanical	7 (5.6)	9 (9.9)	1 (3.5)	–
Total	22 (17.5)	18 (19.8)	5 (17.3)	8 (50.0)

Table 5
Complications depending on the lower level of fixation, n (%)

Complications	L3 and higher (140 patients)	L4 (121 patients)	L5 (5 patients)
Mechanical	20 (14.3)	20 (16.5)	2 (40.0)
Non-mechanical	11 (7.9)	6 (5.0)	–
Total	31 (22.2)	26 (21.5)	2 (40.0)

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