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Anterior Dynamic Versus Posterior Transpedicular Spinal Fusion for Lenke Type 5 Idiopathic Scoliosis: A Comparison of Long-term Results

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Abstract

Background. Despite the active implementation of dynamic correction in case of idiopathic scoliosis, there are no comparative studies of results of posterior and anterior dynamic correction in patients with completed and near-completed growth.

Aim of the study — to compare clinical and radiological results of anterior dynamic correction and conventional posterior transpedicular correction of Lenke type 5 scoliotic deformities in patients with completed or near-completed growth.

Methods. Eighty-six patients with Lenke type 5 scoliotic deformities were enrolled in the study. The first group (54 patients) underwent deformity correction via posterior approach using a rigid transpedicular system; the second group (32 patients) — using dynamic correction system. Mean patients' age was 22.6±12.8 and 27.3±10.9 years, respectively. We studied radiological data before surgery, immediately after surgery, and 2 or more years after surgery. Blood loss volume, duration of hospital stay, and duration of narcotic analgesics intake in the early postoperative period were analyzed. Functional results were assessed using SRS-22 questionnaire.

Results. Preoperative Cobb angle in the first group was 65.5°, and 27.5° at the long-term follow-up. Junctional kyphosis of T10-L2 before surgery was 21.0° and 13.2° at the long-term follow-up. Preoperative Cobb angle of the initial curve in the second group was 52.5° and 24.5° at the long-term follow-up. Junctional kyphosis of T10-L2 before surgery was 19.5°, and 19.0° at the long-term follow-up. Nash and Moe apical vertebral rotation in the first group before surgery was 1.62 and 0.17 at the last follow-up; in the second group, it was 1.80 and 0.81, respectively. Mean number of fixed levels was 6.4±1.0 in the first group and 5.6±1.5 in the second group. Mobility of the thoracolumbar/lumbar curve was higher in the second group, 28.2±9.1°, compared with 36.0±7.2° in the first group. Preoperatively, lumbar lordosis in the second group was 42.5°, in the long-term period — 43.5°, and in the first group — 43.4° and 44.3°, respectively.

Conclusion. Both posterior rigid and anterior dynamic correction in case of Lenke type 5 idiopathic scoliosis can provide satisfactory radiological results with initially similar thoracolumbar deformities in patients with completed or near-completed growth. However, dynamic approach can reduce blood loss, duration of hospital stay, duration of narcotic analgesics intake after surgery, and improve quality of life in the long-term period.

Keywords: lumbar scoliosis, spinal fusion, Lenke type 5, anterior dynamic fusion, transpedicular fusion..

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Вентральная динамическая или дорсальная транспедикулярная коррекция и фиксация при хирургическом лечении идиопатического сколиоза типа Lenke 5: сравнение отдаленных результатов

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Реферат

Актуальность. Несмотря на активное внедрение динамической коррекции при идиопатическом сколиозе, отсутствуют сравнительные исследования результатов дорсальной и вентральной динамической коррекции у пациентов с завершенным и завершающимся ростом.

Цель исследования — сравнить клинические и рентгенологические результаты вентральной динамической коррекции и традиционной дорсальной транспедикулярной коррекции сколиотических деформаций типа Lenke 5 у пациентов с завершенным или завершающимся ростом.

Материал и методы. В исследование было включено 86 пациентов со сколиотическими деформациями типа Lenke 5. В первой группе (54 пациента) выполняли коррекцию деформации из дорсального доступа с использованием ригидной транспедикулярной системы, во второй группе (32 пациента) — с применением системы для динамической коррекции. Средний возраст пациентов составил 22,6±12,8 и 27,3±10,9 лет соответственно. Изучали рентгенологические данные до операции, сразу после операции и через 2 и более года после операции. Анализировали объем кровопотери, сроки пребывания в стационаре, длительность приема наркотических анальгетиков в раннем послеоперационном периоде. Функциональные результаты оценивали с использованием опросника SRS-22.

Результаты. В первой группе угол Кобба до операции составил 65,5°, при отдаленном наблюдении — 27,5°. Переходный кифоз Th10–L2 до операции составил 21,0°, при отдаленном наблюдении — 13,2°. Предоперационный угол Кобба основной дуги во второй группе 52,5°, а в отдаленные сроки — 24,5°. Переходный кифоз Th10–L2 до операции — 19,5°, в отдаленные сроки — 19,0°. Ротация апикального позвонка по Nash — Moe в первой группе до операции составила 1,62, при последнем осмотре — 0,17, во второй группе — 1,80 и 0,81 соответственно. Среднее количество фиксированных уровней составило в первой группе — 6,4±1,0, во второй — 5,6±1,5. Мобильность грудопоясничной/поясничной дуги была выше во второй группе — 28,2±9,1° по сравнению с первой группой — с 36,0±7,2°. До операции поясничный лордоз у пациентов второй группы составил 42,5°, в отдаленные сроки — 43,5°, у пациентов первой группы — 43,4° и 44,3° соответственно.

Заключение. Как задняя ригидная, так и вентральная динамическая коррекция при идиопатическом сколиозе Lenke 5 могут обеспечить удовлетворительный рентгенологический результат при изначально схожей величине грудопоясничных деформаций у пациентов с завершенным или завершающимся ростом. Однако динамический подход позволяет сократить объем кровопотери, срок пребывания в стационаре, длительность приема наркотических анальгетиков после операции, а также улучшить качество жизни в отдаленном периоде.

Ключевые слова: поясничный сколиоз, коррекция сколиоза, Lenke 5, вентральная динамическая коррекция, транспедикулярная фиксация.

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BACKGROUND

One of the frequent problems faced by spine surgeons managing idiopathic scoliosis is the choice of treatment tactics for patients with completed growth who have radiological indication for a surgery and moderate degree of deformity with asymptomatic course of disease. Patients and their families discuss and evaluate the benefits of surgical treatment and search for alternative (both surgical and nonsurgical) methods, especially if there is no pain, pulmonary dysfunction, or other problems associated with the spinal deformity [1]. In addition, surgical correction in patients with completed growth often raises concerns about possible various complications, especially palsy. Therefore, studies comparing the results of surgical treatment of scoliosis in adolescents and adults have begun to appear in order to prove the advantages of performing surgical correction at a younger age.

Patients who undergo surgical treatment of idiopathic scoliosis via posterior approach at a younger age have less fixed segments, lower blood loss, shorter duration of surgery, and fewer complications in comparison with adults who had natural history of scoliosis and its progression and sought medical attention later, although X-ray data of correction are similar and improvement in quality of life after surgery is observed in both cohorts [2]. However, methods of surgical treatment of idiopathic scoliosis remain controversial. In particular, there is no agreement upon the choice of approach (anterior or posterior) [3], optimal points of fixation [4, 5], prevention of complications [6], and, importantly, the choice of instruments in case of surgical treatment of scoliosis with main curve in the lumbar or thoracolumbar part (Lenke type 5). According to Lenke classification, type 5 deformity is optimal for anterior correction [7]. When hooks were used in posterior surgery, anterior approach provided better results, since screws enabled to improve derotation effect [8, 9]. However, with the beginning of use of transpedicular screws, the situation changed: efficacy of posterior correction increased and became comparable to the anterior one. Most surgeons in the world began to use posterior transpedicular correction and fixation because they are technically easier to be performed [10, 11]. In general, no difference was found in radiological and clinical outcomes in patients after anterior or posterior correction with the use of rigid fixation for Lenke type 5 scoliosis [12]. However, risks and advantages of each approach are considered by the surgeon and the patient individually [12].

Since recently, surgeons have begun to use dynamic correction systems, first in pediatric patients to modulate growth [13, 14, 15] and later in patients with completed or near-completed growth as an option [6, 16]. Using dynamic correction system preserves mobility in the area of fixation, as confirmed by biomechanical studies [17]. Dynamic correction also allows patients to return to their usual physical and sports activities in a short period of time [18].

Despite active implementation of dynamic correction systems in the treatment of idiopathic scoliosis, there are few reports on the results of using this method in patients with completed or near-completed growth, as well as comparative studies concerning the use of posterior correction (spine fusion) and anterior dynamic correction.

Aim of the study — to compare clinical and radiological results of anterior dynamic correction and conventional posterior transpedicular correction of Lenke type 5 scoliotic deformities in patients with completed or near-completed growth.

METHODS

Study design

A retrospective non-randomized cohort comparative study was performed basing on data analysis of patients with Lenke type 5 idiopathic scoliosis who underwent deformity correction via posterior approach using rigid transpedicular system (with spine fusion) and dynamic correction system (without spine fusion).

Inclusion criteria:

1) Lenke type 5 idiopathic scoliosis;

2) one-stage surgery for Lenke type 5 scoliosis via posterior approach with transpedicular fixation and spine fusion or dynamic fixation using transcorporal screws connected by a flexible polyethylene terephtholate cord;

3) follow-up period of more than 2 years.

Exclusion criteria:

1) non-selective fixation;

2) incomplete radiological data.

The study enrolled 86 patients operated between 2013 and 2021 by the same surgeon who

had experience in both anterior and posterior scoliosis correction.

The first group included 54 patients with lumbar or thoracolumbar idiopathic scoliosis aged 16 to 41 years: 48 women and 6 men. Classic posterior correction with the use of transpedicular screws was performed in this group. Posterior approach with stripping of the posterior vertebral elements was performed, transpedicular screws were inserted using the free-hand method with subsequent X-ray examination, and posterior release (Ponte osteotomy at several levels) was carried out in some patients. Three-plane correction using rods and posterior spine fusion were performed (Fig. 1).

The second group consisted of 32 patients aged 14 to 44 years: 29 women and 3 men. Thoracophrenolumbotomy without rib resection was performed in this group. Two screws with staples (buttress plates) were inserted into the vertebral bodies, and correction was performed using two cords (Fig. 2). Zimmer Dynesis system was used in this group.

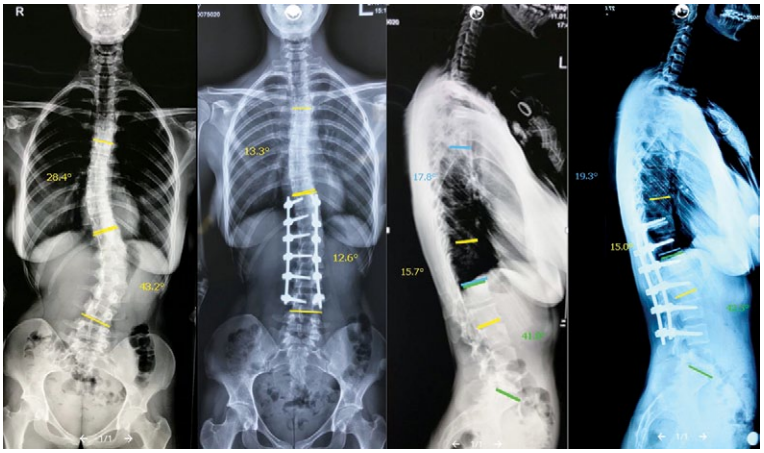

Fig. 1. X-rays of a 31-year-old patient with left-sided lumbar scoliosis before and 2 years after posterior correction and T11-L4 fixation. Satisfactory result was achieved. No loss of correction was observed at the long-term follow-up

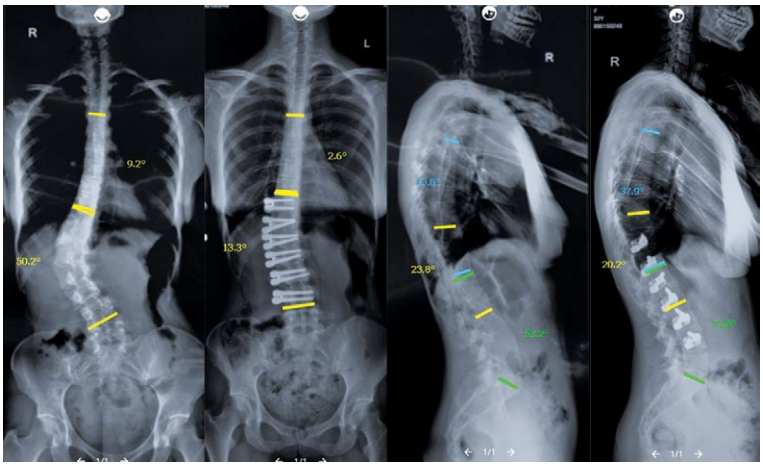

Fig. 2. X-rays of a 32-year-old patient before and 2 years after posterior correction and T11-L4 fixation. No loss of correction was observed. No signs of bone block formation were noted

Both groups included only patients who had undergone a single-stage surgical intervention for correction of deformity without the use of preoperative halo-traction. In both groups, indication for surgical treatment was the deformity of more than 40°.

Type of deformity was assessed according to Lenke classification. Lenke type 5 includes deformities in which the apex of the main (structural) curve is between T12 and L4 vertebrae, i.e. T12, L1, L2, and L3. Thoracic and upper thoracic curves are not structural. This means that their magnitude is less than that of the initial main curve, which are corrected by less than 25° on lateral tilt X-rays.

End vertebrae were included in the area of fixation according to radiological data. The lower point of fixation of L3 was selected if the L3-L4 disc was parallel or "open" on the concave side; neutral; with a tilt to the opposite side on X-rays;

and L3 was centered above the sacrum. In the remaining cases, L4 was selected as the most distal fixed vertebra. In one case, L2 was selected as the lower point of fixation. If two lower vertebrae were parallel, the more caudal vertebra was chosen as the most distal instrumented vertebra.

Evaluation methods

Preoperative, postoperative, and final (at the time of the last examination) spine X-rays in the standing position were analyzed using Cobb method in the frontal and sagittal planes. X-rays with left and right tilt, traction test (spinal traction along the axis with a load of 40% of the patient's weight, but not more than 30 kg), magnitude of lumbar lordosis and thoracic kyphosis before and after surgery, spinal derotation using Nash-Moe method were used to assess spinal flexibility before surgery [19].

Due to no access to postural X-rays at the time of preoperative examination and surgery in patients with rigid constructs, we had to refuse to assess sagittal parameters in the groups. X-ray parameters were measured as follows: T5-T12 thoracic kyphosis; T10-L2 thoracic-lumbar junctional kyphosis; L1-S1 lumbar lordosis; fixed segmental angle (frontal Cobb angle between the upper fixed vertebra and the lower fixed vertebra); Risser staging. Radiological measurement was performed by one and the same expert, who was independent of the surgical team.

Blood loss volume, duration of hospital stay, and duration of narcotic analgesics intake in the early postoperative period were analyzed.

Functional results were assessed using SRS-22 (Scoliosis Research Society) questionnaires. Loss of correction was considered as an increase in the fixed curve by more than 5° for all methods of fixation.

Statistical analysis

Statistical analysis was performed using SPSS Statistics software package. Data on the variables were presented using descriptive statistics (mean value, standard deviation) to assess differences between the groups at baseline and during two years of follow-up. Pearson's chi-squared test was used to compare groups according to qualitative variable (gender).

Normality of distribution of quantitative variables was assessed using Kolmogorov-Smirnov one-sample test. After testing, a decision was made whether to use parametric or nonparametric methods of comparison.

Distribution of all variables was nonparametric (except for T5-T12 thoracic kyphosis, number of fixed segments, and SRS-22 questionnaire values obtained 2 years after the surgical intervention). Differences between the groups for all relevant variables were analyzed using Mann-Whitney test. Data with parametric distribution were analyzed using Student's t-test. Comparability of gender distribution of patients in the groups was assessed using Pearson's chi-squared test.

RESULTS

Characteristics of patients in both groups are presented in Table 1. Magnitude of the main curve deformity in the lumbar or thoracolumbar spine, thoracic compensatory curve, and sagittal parameters were comparable between the groups. Radiological parameters are presented in Table 2.

Mean number of fixed segments was 6.4±1.0 in the first group and 5.6±1.5 in the second group (p = 0.047). Comparable number of segments were fixed in both groups, but slightly fewer in the anterior correction group. In the dynamic correction group, fixation ended at the L3 segment in 13 pa-

Table 1

Characteristics of patients in the groups

Parameter	First group	Second group	*p*
Age, y. o.	22.6±12.8	27.3±10.9	0.744
Risser test, grade	4.4±1.2	4.2±1.7	0.556
Observation period, mos.	46.4±23.2 (24–84)	39.2±14.1 (24–42)	0.377

tients (40.7%) and at the L4 segment in 19 (59.3%) patients; in the posterior correction group, fixation ended at the L3 segment in 29 patients (53.7%) and at L4 in 25 patients (46.3%). Mobility of the thoracolumbar/lumbar curve was higher in the group with dynamic correction — 28.2±9.1° compared to the rigid fixation — 36.0±7.2°.

Thoracic kyphosis increased during the long-term follow-up in both groups, both immediately after surgery and in the long-term period (see Table 2).

Patients in both groups demonstrated no significant loss of deformity correction during the follow-up period.

Blood loss in the first group was (Me and Q1-Q3, respectively): 382 (249; 503) mL; in the second group 156 (102.3; 204) mL (p = 0.023).

Patients in the second group spent less time in the hospital after surgery, and there was also a decrease in duration of narcotic analgesics intake to 2 days after the intervention, which is reflected in Table 3.

Table 2

Radiological parameters in the groups, deg.

Observation period	First group	Second group	*p*
Cobb angle in the frontal plane (main curve), Me (95% CI)			
Before surgery	65.5 (50.4; 79,5)	52.5 (43.2; 63.1)	0.259
After surgery	24.0 (11.4; 37.2)	29.0 (17.5; 41.2)	0.039
Two years after surgery	27.5 (22.4; 32.9)	24.5 (18.6; 32.8)	0.046
T10-L2 junctional kyphosis angle, Me (95% CI)			
Before surgery	21.0 (15.3; 29.0)	19.5 (13.5; 24.2)	0.289
After surgery	15.3 (13.8; 17.1)	18.5 (16.4; 21.1)	0.048
Two years after surgery	13.2 (11.8; 15.1)	19.0 (18.6; 19.7)	0.032
Apical vertebral rotation (Nash-Moe method), Me (95% CI)			
Before surgery	1.62 (1.41; 1.89)	1.80 (1.52; 2.08)	0.369
After surgery	0.15 (0.01; 0.63)	0.83 (0.51; 1.12)	0.013
Two years after surgery	0.17 (0.01; 0.53)	0.81 (0.49; 1.19)	0.028
Lumbar lordosis, Me (95% CI)			
Before surgery	42.5 (36.7; 50.1)	43.4 (31.8; 53.2)	0.548
After surgery	43.5 (35.8; 55.9)	42.3 (34.10; 52.03)	0.396
Two years after surgery	43.5 (32.4; 51.8)	44.3 (32.7; 55.3)	0.569
T5-T12 thoracic kyphosis, M±σ*			
Before surgery	19.0±5.8	21.2±7.0	0.249
After surgery	17.4±8.3	20.2±4.6	0.070
Two years after surgery	18.6±6.5	22.3±6.8	0.375

* Given the normality of data distribution, results are presented as M±σ, where M — the mean value, σ — the standard deviation.

There were no complications such as infection, damage of vessels, and deterioration of neurological status in both groups. Among early complications, hematoma of the postoperative wound was revealed in 5 patients of the first group, which required additional treatment and prolongation of hospital stay. Three patients with dynamic correction had pneumothorax - the pleural cavity was drained according to Bülau. No complications, such as cord rupture during dynamic correction, screw instability, or fractures of the elements of rigid constructs, were observed. Neuropathic pain syndrome was diagnosed in two patients in the first group and in four patients in the second group. There was a correlation with the patients' age: neuropathy developed at an older age. This problem was solved with the use of gabapentin 300 mg twice a day for 2-3 months, after which the condition was resolved. In the first group, 3 patients had a rod fracture more than a year after surgery, which required its replacement, but the functional outcome was not significantly affected by revision surgery.

Results of SRS-22 questionnaire 2 years after the intervention are presented in Table 4.

Table 3

Duration of hospital stay and narcotic analgesics intake

Parameter	First group	Second group	*p*
Postoperative bed day, days	8.2 (6.4; 10.3)	5.0 (4.1; 6.5)	0.017
Narcotic analgesics intake, days	3.5 (2.1; 5.2)	2.5 (1.5; 3.7)	0.043

Table 4

Results of SRS-22 questionnaire in the groups

Parameter	First group	Second group	*p*
Function	3.9±0.5	4.8±0.3	0.038
Pain syndrome	4.6±0.4	4.2±0.7	0.041
Mental function	4.0±0.7	4.4±0.4	0.049
Satisfaction with the result	3.8±0.5	4.3±0.8	0.021
Self-assessment	4.3±0.5	4.6±0.4	0.034

DISCUSSION

According to the literature and our own experience, there is still insufficient objective data proving the advantages of dynamic correction in case of idiopathic scoliosis compared to standard spine fusion [6, 20]. The question of indications remains to be debated: what type of deformity, its magnitude, mobility of the main curve, or age of patients would be the best indications for dynamic approach, in particular in conditions of completed growth [16, 21]. In addition, patients with completed growth usually have more rigid deformities than growing patients. Therefore, growth modulation is not possible. On the other hand, during modulation, it is difficult to predict the response of the growing spine to a dynamic implant, while in case of completed growth, spine correction is more predictable, because the surgeon attempts to perform it as efficiently as possible.

Although dynamic correction has become an innovative strategy for managing scoliosis without spine fusion, it has not been clearly defined how and when to use dynamic or rigid fixation in case of completed growth either [22].

It is known that posterior rigid correction is efficient but is associated with blood loss and does not allow to preserve motions in operated segments, which negatively affects the functional state of the spine [23, 24]. Peak of publication

activity on the problem of posterior scoliosis correction using transpedicular fixation only was observed in 2010-2013. At the same time, there was an increase in publications on anterior scoliosis correction with the use of rigid systems as well, and later, the interest in anterior approach in case of lumbar/thoracolumbar idiopathic scoliosis among spine surgeons decreased a lot. This is due to the proven lack of significant differences between radiological and functional results of anterior and posterior approaches [3, 11, 12, 24].

Currently, there are studies evaluating the results of dynamic scoliosis correction in adults, where the authors suggest that the radiological results of ASC (Anterior Scoliosis Correction) in patients with completed or near-completed growth are better than those of VBT (Vertebral Body Tethering) due to aggressive surgical techniques applied during surgery to achieve satisfactory correction [6]. These studies evaluate the lower point of fixation for anterior scoliosis correction [26, 27], but there are no data on the choice of the upper point. The same situation is observed for dynamic fixation.

Posterior transpedicular correction in our study gave results similar to anterior dynamic correction, but required a longer surgery duration and was associated with significantly greater intraoperative blood loss. This was due to more traumatic nature of the surgery and the necessity to perform posterior release and sometimes posterior Ponte osteotomy, while dynamic correction involved only nucleotomy at the apex of deformity. Mean angle of the main curve in rigid fixation was 64.4° and was corrected to 26.9° at the long-term follow-up, and in dynamic correction, from 52.4±9.6° to 24.2±12.3°. Preoperative deformities in this group were more mobile by about 10%. There was also a certain improvement in the long-term period comparing with the postoperative data, apparently due to the preserved growth potential in some patients of the second group. However, it should be noted that the degree of correction in both groups depended on the initial deformity angle and spine mobility; the degree of correction with rigid and dynamic correction was identical for angles up to 50-55°. For more severe deformities, it depended on the spine mobility.

In 2021, P.D. Trobisch and A. Baroncini published the data on patients who underwent dynamic correction at the thoracolumbar/lumbar level with satisfactory results, but the incidence of rupture was quite high. This confirms the hypothesis that lumbar VBT is indeed associated with a higher incidence of rupture than thoracic VBT [27]. This may be due to the use of the first cord and aggressive derotation manipulations, as well as to the greater mobility of the lumbar spine compared to the thoracic spine, which may affect the strength of the construct. Spine growth is also not taken into account. In our dynamic correction group, there were no cases of cord rupture, which is common in growing patients. This is probably due to the routine use of double cords, which provides greater tensile strength and prevents material wear. However, there are no biomechanical studies to assess the strength of single and double cords nowadays, although such suggestion was made by A. Baroncini et al. [29]. Recent biomechanical study showed that surgical constructs with one or two cords insignificantly limited global and L1-L2 spinal movements in flexion or extension (<10%) of the left or right axial rotation (<14%) [18]. In addition, intervertebral discs and facet joints did not change degeneratively when dynamic fixation was used after an average of 29 months of follow-up [28].

Lumbar lordosis was one of evaluated parameters that changed significantly after surgery in the group with rigid fixation. Anterior correction appears to have a certain kyphosogenic effect, but provides a harmonious sagittal profile while preserving the back muscles and posterior ligaments, which explains the low incidence of PJK (proximal junctional kyphosis) development with this method [27, 29, 30]. Although the importance of assessing, interpreting and restoring the "ideal" parameters of global balance in dynamic correction is not entirely clear, since unlike rigid systems, the dynamic approach implies preserving certain mobility in the fixation and amortization area. This, in turn, should reduce the risk of adjacent segment disease, fatigue fractures of implants, and other implant-dependent complications that are observed in rigid fixation in conditions of severe spinal balance disorders. In addition, correction loss, pseudarthrosis, and

fractures of implants are rare in adolescence when using posterior transpedicular rigid systems, but the risk of these complications increases at an older age [22, 31].

According to our data, the use of double cord in the lumbar spine had no kyphosogenic effect on lumbar lordosis. This supports the hypothesis that lumbar VBT is indeed associated with a higher incidence of ruptures than the thoracic one [28, 32]. However, dynamic compression has lesser derotating effect compared to rigid systems according to Nash and Moe assessment of apical vertebral rotation (see Table 1). Improvement of T10- L2 junctional kyphosis was achieved in both groups.

In the study on functional outcome of Lenke type 5 scoliosis correction performed by F. Tao et al., all SRS-22 domains were significantly higher in the group with rigid anterior scoliosis correction compared to posterior correction [33]. Still, there is some evidence that there are no significant differences between these approaches [25, 34]. Nevertheless, dynamic correction provides better functional outcome according to the results of SRS-22 questionnaire in our patients. There were no significant differences between two groups in terms of patients' perception of function, pain, self-assessment, mental function, or satisfaction. However, functional scores, satisfaction with surgery, and mental health were higher in the anterior dynamic correction group, indicating that this method of treatment met the patients' expectations (see Table 3).

Limitations

Sample size was limited by retrospective type of the study. Outcome assessment tool was not used consecutively to allow comparisons with clear preoperative and postoperative intervals, and randomization was not applied.

CONCLUSION

Both posterior rigid and anterior dynamic correction in Lenke type 5 idiopathic scoliosis can provide satisfactory radiological results with initially similar thoracolumbar deformities in patients with completed or near-completed growth. However, dynamic approach is characterized by lower blood loss, shorter hospital stay, shorter duration of postoperative narcotic analgesics intake, and better quality of life in the long-term period.

DISCLAIMERS

Author contribution

Pereverzev V.S. — the conception and design of the study, the analysis and interpretation of data, the writing of the text.

Kolesov S.V. — the analysis and interpretation of data, the drafting of the text.

Kazmin A.I. — data collection and processing.

Morozova N.S. — the statistical analysis of results, the drafting of the article.

Shvets V.V. — the search and analysis of literature sources, the analysis and interpretation of data, the drafting of the article.

All authors have read and approved the final version of the manuscript of the article. All authors agree to bear responsibility for all aspects of the study to ensure proper consideration and resolution of all possible issues related to the correctness and reliability of any part of the work.

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