ADOLESCENT IDIOPATHIC SCOLIOSIS WITH LENKE TYPE V AND VI CURVES: POSSIBILITIES OF MODERN SEGMENTAL INSTRUMENTATION

M.V. Mikhaylovskiy[1], A.S. Vasyura[1], V.V. Novikov[1], V.N. Sarnadsky[2], E.V. Gubina[1]
[1]Novosibirsk Research Institute of Traumatology and Orthopaedics n.a. Ya.L. Tsivyan, Novosibirsk, Russia
[2]METOS Medical Topographic Systems Ltd, Novosibirsk, Russia

Objective. To analyze long-term results of surgical correction and postoperative quality of life in patients with Lenke type V and VI deformities of the spine.
Material and Methods. The treatment results of 61 patients (average age 15 years) with Lenke type V–VI spinal deformities and mean follow-up period of 3.3 years were analyzed. The average length of anterior fusion was 12.7 segments. The average length of the primary curve instrumented with pedicle screws was 4.9 segments.
Results. The primary curve was 56.6°, after surgical intervention it was reduced to 15.1° (73.3 % correction). Postoperative progression within 3.3 years was 2.1°. Thoracic countercurve was 40.6°, after surgery it was corrected to 15.0° (63.0 % correction). At the final follow-up examination, the thoracic curve was 17.3° (progression 2.3°). Thoracic kyphosis and lumbar lordosis were within the normal ranges. The frontal imbalance was 22.1 mm before surgery and 12.2 mm at the final follow-up examination. The SRS-24 questionnaire data showed a significant score increase in all seven domains.
Conclusion. Transpedicular fixation allows achieving a high degree of Lenke type V–VI spinal deformity correction with a stable result and significant improvement in the quality of life of patients.
Key Words: idiopathic scoliosis, segmental instrumentation, correction of deformity.

Please cite this paper as: *Mikhaylovskiy MV, Vasyura AS, Novikov VV, Sarnadsky VN, Gubina EV. Adolescent idiopathic scoliosis with Lenke type V and VI curves: possibilities of modern segmental instrumentation. Hir. Pozvonoc. 2017;14(4):18–26. In Russian.*
DOI: http://dx.doi.org/10.14531/ss2017.4.18-26.

Adolescent idiopathic scoliosis of lumbar and thoracolumbar localization presents a special branch of spine surgery due to its small extent, relatively high mobility, and pronounced rotational component of torsion.

For a long period of time, surgical correction of such deformities was carried out with the help of various types of anterior instrumentation [7, 15, 24]. Disadvantages of these corrective systems (kyphogenic effect, bone block pseudathrosis, etc.) have been noticed by surgeons rather quickly [10, 12], while new methods of solving this problem appeared with the development of posterior instrumentation of the third generation.

Suk et al. [21] were the first to make an attempt to compare the corrective and stabilizing capabilities of anterior and posterior types of instrumentation (with transpedicular fixation) in the treatment of type V and VI scoliosis according to Lenke et al. [16] and discovered both advantages and disadvantages of the two systems. Later, a series of similar studies appeared [6, 8, 11, 13, 14, 17–23], the results of which were rather homogeneous and enabled one to understand the state of the problem quite precisely. All of these articles are written in English, half of them were published in the Southeast Asia [13, 14, 17, 18, 21–23]. There are also a number of publications concerning this issue [1–5] in the domestic literature.

HRQOL (Health Related Quality of Life) evaluation based on the data of specialized questionnaires provides vitally important information and is nowadays widely used in the surgery of spinal deformities. However, the data obtained using SRS questionnaires have been presented in the literature only twice [6, 19].

The aim of the study is to analyze the long-term results of surgical correction and postoperative quality of life in patients with Lenke type V and VI deformities of the spine.

Material and Methods

Since 1996, more than 3,700 patients with spinal deformities of various etiologies have been operated on in the

hospital. Of these cases, patients have been selected for the study according to the following criteria:

– idiopathic scoliosis;

– age ranging from 11 to 20 years inclusive;

– lumbar or thoracolumbar localization of the primary curve (types V–VI by Lenke);

– postoperative follow-up period lasted for at least 2 years;

– patient had no previous spine surgeries;

– hybrid segmental instrumentation: transpedicular fixation along the primary curve, hook fixation along the thoracic countercurve.

A total of 61 patients (59 females and 2 males) corresponded to these criteria, the mean age was 15 (range: 10.3–19.5) years; the average period of follow-up was 3.3 (range: 2.1–7.1) years.

Left-sided and right-sided primary curve deformities were observed in 46 and 15 cases, respectively. The incidence rate of thoracolumbar deformities (T12 or L1 level of the apical vertebra) was 45 cases, while the incidence of lumbar localization (L2 or L3 level of the apical vertebra) was 16 cases. Thoracic countercurve was noted in 52 patients.

Comorbidities were diagnosed in 40 patients: cardiovascular system, 9 cases; gastrointestinal tract, 16 cases; kidneys, 1 case; musculoskeletal system, 4 patients; skin, 2 patients; organ of vision, 2 patients; ENT, 5 cases; blood, 1 case. One patient was subjected to surgery for extravertebral pathology prior to admission.

The surgical approach was standard. In all cases, intraoperative axial traction was used with a weight not exceeding 50 % of the patient's body weight. In 58 cases, the intervention was two-staged: skeletal traction to the cranial bones and supramalleolar regions + correction of the spinal deformity with hybrid segmental instrumentation. Prior to surgery, three patients were subjected to releasing discectomy at the level of thoracic countercurve, and two patients underwent costal hump resection for cosmetic indications in a period of more than two years after primary intervention. Reassembly of the construct was performed three times due to mechanical complications. Thus, a total of 67 interventions have been performed. In all patients, spinal fusion (posterior and anterior) was conducted using an autologous bone graft only, which was either local or harvested from a rib resected by thoracotomy.

The average extension of posterior spinal fusion was 12.7 (range: 11–15) segments, the position of the upper instrumented vertebra ranged from T1 to T6. The lower instrumented vertebra was located at the L3 level in 22 cases, at the L4 level in 31 cases, and at the L1 in 8 patients. The average length of the primary curve instrumented with pedicle screws was 4.9 (range: 4–11) segments.

Results

The primary curve (lumbar/thoracolumbar) was 56.6°, while it was 27.0° in the lateral flexion position. As a result of surgery, deformity was reduced to 15.1°. Postoperative progression for a period of 3.3 years was 2.1° (Table 1, Fig. 1).

Thoracic countercurve was 40.6°, it amounted to 22.1° in the lateral flexion position. Corrective intervention led to reduction of the secondary curve to 15.0°. The thoracic curve was 17.3° by the end of the follow-up period.

Thoracic kyphosis decreased as a result of surgery from 31.0° to 21.6 ° and achieved 22.0° by the end of the follow-up. Lumbar lordosis demonstrated the following dynamics: it was initially equaled to 60.0°, achieved 49.3° after surgery, and was 51.1° at the end of the follow-up period.

Frontal imbalance was 22.1 mm before surgery and remained almost unchanged (22.8 mm) immediately after intervention, while correction to 12.2 mm was achieved in the long-term follow-up. Inclination of the lower instrumented vertebra was reduced from 22.6° to 5.1° as a result of corrective intervention and remained without changes 3 years later – 5.2° (Fig. 2).

The average duration was 180.6 (range: 125–295) min for the two-stage intervention (skeletal traction, deformity correction) and 227 (range: 175–295) min for the three-stage surgery (discectomy at the level of thoracic countercurve, skeletal traction, deformity correction), while the blood loss was 850.6 (range: 250–2250) ml and 943 (range: 350–1850) ml, respectively.

The mean patients' height was 160 (range: 130–183) cm at admission, 163.9 (range: 35–188) cm immediately after surgery and achieved 165.2 (range: 152–189) cm at the end of the follow-up. The patients' weight changed as follows: it averaged 48.6 (range: 31–69) kg prior to surgery, 48.7 (range: 31–69) kg immediately after surgery and was 53.6 (range: 41–73) kg at the end of the follow-up.

Mechanical complications (rod fractures, screw displacement, untwisted nuts) were detected in seven patients. In three patients, the instrumentation was reinstalled. One case was diagnosed with a mild degree of acute renal failure of prerenal genesis in the nearest postoperative period, which was then arrested.

There were no inflammation or neurological complications.

Self-assessment of the results of surgical treatment by patients with spinal deformities was firmly included in the complex of postoperative examinations. We used a translated and adapted version of the SRS-24 questionnaire [9] with definition of the parameters that most reflect the patient's satisfaction with the results of surgical treatment.

The questionnaire includes 24 questions combined into seven groups (domains): back pain, the general appearance, appearance after surgery, the level of motor functions after surgery, general activity, professional activity, and satisfaction with the results of surgical treatment. Each question is evaluated on a 5-point scale (1 is the lowest score, while 5 is the highest score). Filling of the questionnaire is considered during each control examination, including consultations by correspondence.

Dynamic improvement in the parameters was obtained for the group of patients operated on using hybrid instrumentation with an increase in the period between the first and the latest control examinations after surgery for this

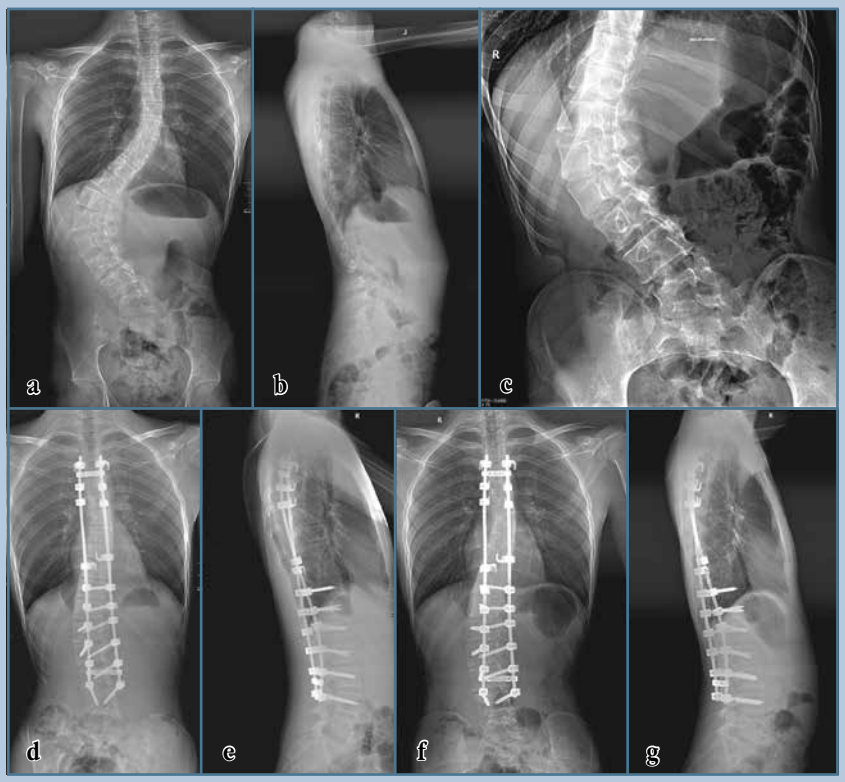

Fig. 1
Patient A., aged 19, with idiopathic thoracic right-sided progressive uncomplicated subcompensated rigid grade IV scoliosis: the surgery was perfumed on 02.13.2014, it included deformity correction using hybrid instrumentation (doctor, V.V. Novikov), thoracic spine up to the level of T4 was included in the block since, otherwise, the instrumented cranial vertebra would be located 1–2 segments caudal to the apex of physiological kyphosis, which is a risk factor for the development of junctional kyphosis; prior to surgery, the Cobb's angle of the primary curve in the upright position was 79°, inclination of the L4 vertebra was 36° **(a)**, thoracic kyphosis was 17°, lumbar lordosis was 59° **(b)**, the Cobb's angle of the primary curve was 61° in the lateral flexion **(c)**; the Cobb's angle of the primary curve was 19° on control radiographs dated 02.21.2014, inclination of the L4 vertebra was 12° **(d)**, thoracic kyphosis was 17°, lumbar lordosis was 46° **(e)**; the Cobb's angle of the primary curve was 19° on control radiographs dated 08.22.2016, inclination of the L4 vertebra was 12° **(f)**, thoracic kyphosis was 17°, lumbar lordosis was 46° **(g)**; the patient has no complaints, bone block is formed, non-displaced fracture of the right screw at L4 level cannot be excluded

patient. The most pronounced dynamics was noted for such domains as "pain" (+0.39), "general activity" (+0.79), and "professional activity" (+0.64). Satisfaction with the surgery results was high in the immediate (4.25 ± -0.60) and long-term (4.48 ± -0.42) postoperative periods. Therefore, the dynamics is not so apparent in this domain as in the others (Table 2).

Discussion

There are papers in the domestic literature devoted to the results of pedicular fixation in the surgical treatment of lumbar and thoracolumbar scoliosis. The article by S.T. Vetrile et al. [2] contains rather diverse data both from the point of view of the etiology of spinal deformities and the patients' age, and from the point of view of the treatment approach. The authors used different types of spinal instrumentation, which makes it difficult to study their application in comparison with other papers.

The article by A.S. Vasyura et al. [1] presents the results of correction of the discussed deformities and a comparative analysis of the effectiveness of hook and pedicle types of fixation. Unfortunately, the terms of postoperative follow-up for many patients of both groups are significantly shorter than two years, although the conclusions on the advantages of pedicular fixation made by the authors are quite reasonable.

Publications by S.V. Vissarionov et al. [3–5] appeared within a year and, apparently, contain information obtained during the study of the same cohort of patients. The authors convincingly demonstrated the established advantages of pedicular fixation but, unfortunately, did not provide any data regarding pre- and postoperative state of the thoracic countercurve.

We found it advisable to present a review of English-written literature for the period of 1994–2014 in the form of a commentary to the tables containing the data of 12 articles [6, 8, 11, 13, 14, 17–23]. Most of the clinical groups are small (11–30 patients), only one group includes 72 patients [19], almost all of them are younger than 20 years of age. The mean angle of the primary curve (Table 3) varies within a very narrow range: from 42° to 55°, i.e., these are mainly deformities characterized as moderate by the foreign colleagues. Correction in the lateral flexion position allows achieving 50–75 % of the initial angle value, which confirms the high degree of mobility typical for scoliosis of this type of localization. Almost half of the authors [8, 18–20, 22] managed to reduce the deformity to less than 10° by surgery, which is clinically insignificant. During the postoperative follow-up of 24 to 60 months, progression of the primary curve within 4.9° was noted. However, in most cases, this parameter remained within 3°.

Thoracic countercurve (Table 4) is not mentioned in 4 out of 12 papers due to

Table 1

Dynamics of radiographic parameters of the studied group of patients

Parameter	Prior to surgery in upright position	Prior to surgery in lateral flexion	Immediately after surgery in upright position	At the end of the follow-up in upright position
Primary curve, degrees	56.6 (27–101)	27.0 (-14–100). correction 29.6 (52.3 %)	15.1 (1–39). correction 41.5 (73.3 %)	17.2 (2–49). progression 2.1 (5.1 %)
Secondary curve, degrees	40.6 (2–90)	22.1 (1–70). correction 18.5 (45.6 %)	15.0 (1–49). correction 25.6 (63.0 %)	17.3 (3–53). progression 2.3 (8.9 %)
Thoracic kyphosis, degrees	31.0 (4–55)	–	21.6 (4–50)	22.0 (3–65)
Lumbar lordosis, degrees	60.0 (16–117)	–	49.3 (28–73)	51.1 (28–77)
Frontal imbalance, mm	22.1 (10–28)	–	22.8 (10–29)	12.2 (1–19)
Inclination of the lower instrumented vertebra, degrees	22.6 (5–36)	–	5.1 (1–27)	5.2 (1–15)

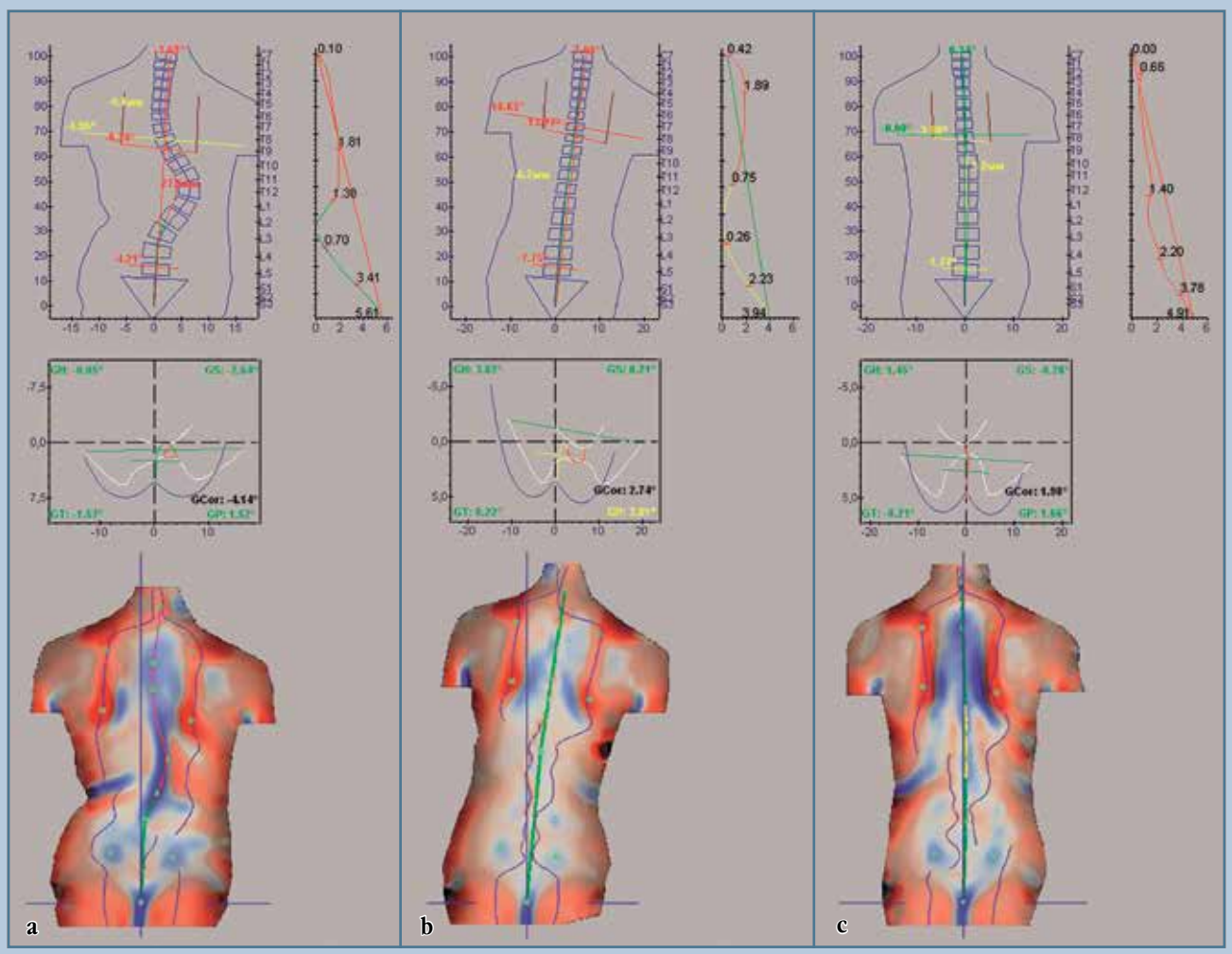

Fig. 2

Computed tomography images obtained prior to surgery **(a)**, immediately after surgery **(b)** and 2.5 years after **(c)**: increased frontal imbalance of the trunk in the immediate postoperative period and almost complete balance recovery at the end of the follow-up

Table 2
Self-assessment of the results of surgical treatment by patients with idiopathic scoliosis

Domain	After surgery up to 12 months	After surgery ≥24 months
Pain	3.78 (0.53)	4.17 (0.24)
General appearance	3.37(0.47)	3.61 (0.53)
Appearance after surgery	4.25 (0.44)	4.50 (0.37)
Function after surgery	1.29 (0.56)	1.61 (0.78)
General activity	3.04 (0.91)	3.83 (0.50)
Professional activity	3.51 (0.85)	4.15 (0.26)
Satisfaction with the results of surgery	4.25 (0.60)	4.48 (0.42)

Brackets contain standard deviation.

its absence, while its mean value does not exceed 30° in most of the other papers. Since there is only one out of the 12 works [20] where authors blocked the primary and secondary curves (hybrid instrumentation), while all the others were limited to spinal fusion along only the Cobb's angle (4.8–7.5 segments), then it is the case of self-correction of the thoracic countercurve. The extent of self-correction can reach up to 60 % [6], although it is usually lower, with postoperative progression being insignificant (1–2°).

The value of the thoracic kyphosis and lumbar lordosis (Table 5) undergoes very little changes during treatment. Attention is drawn to the fact that the initial value of thoracic kyphosis is less than 20° in nine studies, i. e., it can be interpreted as hypokyphosis. It can be slightly higher or lower than the initial value at the end of the postoperative follow-up period. However, in general, it changes very little. This also applies to lumbar lordosis, i. e., the sagittal contour of the spine is not seriously affected.

The frontal balance (Table 6) was initially disturbed (the C1 centroid was 17–28 mm dislocated from the median sacral line) and became much closer to the normal position (5–9 mm) at the end of the follow-up. This also applies to the inclination of the lower instrumented vertebra, although these data are presented by only three authors [11, 18, 23], with normalization being significant (from 25–28° to 8–9°).

Intraoperative blood loss (212–1692 ml) and duration of surgical intervention (139–244 min) have an implicit but still visible tendency to decrease with the age (Table 6), which can probably be explained by the collective accumulation of work experience with the III generation instrumentation.

Thus, we can state that the results obtained by us are quite comparable with the data of modern literature. The only difference is that we used hybrid instrumentation (a combination of pedicular and hook fixation) and included some motor segments of the thoracic spine in the area of the instrumented spinal fusion. This approach is dictated by the presence of thoracic countercurve in most of the cases, the average value of which does not exceed 40°. It decreases to 22.1° in the lateral flexion position, which allows us to characterize it as a structural deformity according to the criteria by Lenke et al. [16]. We believe that self-correction of the thoracic curve is almost impossible in this situation if it is not included in the block. One should not forget about the risk of developing proximal junctional kyphosis, as confirmed by Hee et al. [13], who noted this deformity in 27 % of cases.

Table 3
Dynamics of the radiological parameters of the primary curve in the frontal plane according to the literature

Authors	Patients, n (mean age)	Cobb's angle, degrees			
		before surgery	in lateral flexion	immediately after surgery	at the end of the follow-up
Suk et al. [21]	20 (18.5)	52.0	20.0	16.0	19.0
Halm et al. [11]	12 (–)	52.5	30.4	18.6	21.4
Shufflebarger et al. [20]	61 (–)	52.0	–	10.0	–
Hee et al. [13]	11 (14.5)	46.0	–	14.0	15.0
Wang et al. [22]	16 (14.9)	42.7	10.2	5.8	7.6
Ming et al. [17]	24 (13.6)	52.2	–	23.5	–
Geck et al. [8]	31 (16.0)	50.3	25.0	9.7	8.0
Bennett et al. [6]	26 (14.6)	55.4	27.5	14.7	17.3
Wang et al. [23]	30 (17.0)	49.1	–	25.2	30.1
Jiayu et al. [14]	39 (14.5)	48.5	14.9	–	13.7
Okada et al. [18]	29 (16.8)	46.5	–	8.1	12.2
Roberts et al. [19]	72 (16.7)	46.0	19.5	10.0	–

Table 4
Dynamics of radiological parameters of the countercurve in the frontal plane according to the literature

Authors	Patients, n (mean age)	Cobb's angle, degrees			
		before surgery	in lateral flexion	immediately after surgery	at the end of the follow-up
Suk et al. [21]	20 (18.5)	34.0	19.0	–	22.0
Halm et al. [11]	12 (–)	28.7	12.0	12.8	13.9
Shufflebarger et al. [20]	61 (–)	–	–	–	–
Hee et al. [13]	11 (14.5)	28.0	–	19.0	17.0
Wang et al. [22]	16 (14.9)	–	–	–	–
Ming et al. [17]	24 (13.6)	22.9	–	18.25	–
Geck et al. [8]	31 (16.0)	–	–	–	–
Bennett et al. [6]	26 (14.6)	46.4	14.4	16.5	17.4
Wang et al. [23]	30 (17.0)	29.3	–	20.6	21.4
Jiayu et al. [14]	39 (14.5)	–	–	–	–
Okada et al. [18]	29 (16.8)	24.7	–	13.2	15.9
Roberts et al. [19]	72 (16.7)	26.4	13.1	–	–

Analysis of the questionnaires (SRS-24) filled in by the patients demonstrates a very high level of satisfaction with the results of surgical treatment. For all the seven domains, a significant increase in the parameters was noted at the end of the follow-up period by the first year of intervention. Patients are well-adapted to the new conditions of statics and dynamics and show a high level of satisfaction with a new quality of life.

Conclusion

Posterior instrumentation with the use of pedicular fixation provides stable positive results of surgical correction of adolescent idiopathic scoliosis of thoracic and thoracolumbar localization and significantly improves the quality of the patients' life. The presence of a pronounced structural thoracic countercurve makes its inclusion into the area of the spinal fusion reasonable.

The study was not supported by a specific funding.
The authors declare no conflict of interest.

Table 5
Dynamics of radiological parameters in the sagittal plane according to the literature

Authors	Patients, n (mean age)	Thoracic kyphosis, degrees		Lumbar lordosis, degrees	
		before surgery	after surgery	before surgery	after surgery
Suk et al. [21]	20 (18.5)	17.0	20.0	21.0	22.0
Halm et al. [11]	12 (–)	19.7	26.8	34.4	42.8
Shufflebarger et al. [20]	61 (–)	–	–	–	42.0
Hee et al. [13]	11 (14.5)	15.0	17.0	51.0	50.0
Wang et al. [22]	16 (14.9)	15.6	21.6	33.7	39.8
Ming et al. [17]	24 (13.6)	16.0	16.0	47.0	50.0
Geck et al. [8]	31 (16.0)	18.0	22.0	55.0	60.0
Bennett et al. [6]	26 (14.6)	27.7	23.1	60.0	58.2
Wang et al. [23]	30 (17.0)	31.0	28.1	43.7	42.9
Jiayu et al. [14]	39 (14.5)	–	–	46.1	46.4
Okada et al. [18]	29 (16.8)	12.2	14.6	41.6	39.1
Roberts et al. [19]	72 (16.7)	37.9	–	48.0	44.0

Table 6

Clinical and radiographic characteristics of the operated patients according to the literature

Authors	Patients, n (mean age)	Frontal balance, mm		Blocked vertebrae, n	Inclination of the lower instrumented vertebra, degrees	Complications	Blood loss, mm	Surgery duration, min	Follow-up period, months
		before surgery	after surgery						
Suk et al. [21]	20 (18.5)	–	–	7.4	–	Hook displacement, 2	1692	234	25
Halm et al. [11]	12 (–)	28.0	9.0	4.8	28.5–9.4	Pain – 2; junctional kyphosis – 1; adding-on – 2; reoperation – 1	1425	234	52
Shufflebarger et al. [20]	61 (–)	24.0	7.0	–	81 % correction	–	–	–	36
Hee et al. [13]	11 (14.5)	–	–	4.8	–	PJK 27 %	305	189	32
Wang et al. [22]	16 (14.9)	–	–	–	–	–	443	244	28
Ming et al. [17]	24 (13.6)	–	–	7.0	–	–	500	163	49
Geck et al. [8]	31 (16.0)	27.0	8.0	5.5	–	PJK –1	430	–	–
Bennett et al. [6]	26 (14.6)	17.0	8.0	–	–	–	–	–	60
Wang et al. [23]	30 (17.0)	20.5	4.9	–	25.9–8.5	–	–	–	24
Jiayu et al. [14]	39 (14.5)	–	–	7.8	–	–	–	–	24
Okada et al. [18]	29 (16.8)	19.7	8.6	–	25.9–8.3	Superficial suppuration – 1	212	156	28
Roberts et al. [19]	72 (16.7)	–	–	6.2	–	Transient brachial plexopathy	419	139	–

References

1. **Vasyura AS, Novikov VV, Belosyorov VV, Udalova IG.** Efficacy of laminar and transpedicular fixation in surgical treatment of thoracolumbar and lumbar idiopathic scoliosis. Hir. Pozvonoc. 2012;(1):48–53. In Russian. DOI: http://dx.doi.org/10.14531/ss2012.1.48-53.
2. **Ветрилэ С.Т., Кулешов А.А., Ветрилэ М.С., Кисель А.А.** Хирургическое лечение грудопоясничного и поясничного сколиоза // Хирургия позвоночника. 2004. № 2. С. 12–18. [Vetrile ST, Kuleshov AA, Vetrile MS, Kisel' AA. Surgical treatment of thoracolumbar and lumbar scoliosis. Hir Pozvonoc. 2004;(2):12–18. In Russian.
3. **Vissarionov SV, Nadirov NN, Belyanchikov SM, Kokushin DN, Murashko VV, Kartavenko KA.** Surgical treatment of children with idiopathic thoracolumbar scoliosis using transpedicular spinal systems. Pediatric Traumatology, Orthopaedics, and Reconstructive Surgery. 2015;3(3):15–20. In Russian. DOI: 10.17816/PTORS3315-20.
4. **Vissarionov SV, Nadirov NN, Belyanchikov SM, Kokushin DN.** Surgical correction of spine deformity in children with idiopathic lumbar scoliosis with the use of transpedicular spinal systems. Russian Journal of Pediatric Surgery. 2015;19(6):4–7. In Russian.
5. **Vissarionov SV, Sobolev AV, Nadirov NN, Kokushin DN, Efremov AM, Beljanchikov SM.** Comparative analysis of surgical treatment of children with idiopathic scoliosis of thoracolumbar and lumbar spine. Fundamental Research. 2015;(1–6):1132–1137. In Russian.
6. **Bennett JT, Hoashi JS, Ames RJ, Kimball JS, Pahys JM, Samdani AF.** The posterior pedicle screw construct: 5-year results for thoracolumbar and lumbar curves. J Neurosurg Spine. 2013;9:658–663. DOI: 10.3171/2013.8.SPINE12816.
7. **Dwyer AF, Schafer MF.** Anterior approach to scoliosis: results of treatment in fifty-one cases. J Bone Joint Surg Br. 1974;56:218–224.
8. **Geck MJ, Rinella A, Hawthome D, Macagno A, Koester L, Sides B, Bridwell K, Lenke L, Shufflebarger H.** Comparison of surgical treatment in Lenke 5C adolescent idiopathic scoliosis: anterior dual rod versus posterior pedicle fixation surgery: a comparison of two practices. Spine. 2009;34:1942–1951. DOI: 10.1097/BRS.0b013e3181a3c777.
9. **Haher TR, Gorup JM, Shin TM, Homel P, Merola AA, Grogan DP, Pugh L, Lowe TG, Murray M.** Results of the Scoiliosis Research Society instrument for evaluation of surgical outcome in adolescent idiopathic scoliosis. A multicenter study of 244 patients. Spine. 1999;24:1435–1540. DOI: 10.1097/00007632-199907150-00008.
10. **Hall J, Gray J, Allen M.** Dwyer instrumentation and spinal fusion. A follow-up study. J Bone Jt Surg. 1977;1:117.
11. **Halm H, Niemeyer T, Link T, Liljenqvist U.** Segmental pedicle screw instrumentation in idiopathic thoracolumbar and lumbar scoliosis. Eur Spine J. 2000;9:191–197. DOI: 10.1007/s005860000139.
12. **Hsu LC, Zucherman J, Tang SC, Leong JC.** Dwyer instrumentation in the treatment of adolescent idiopathic scoliosis. J Bone Joint Surg Br. 1982;64:536–541.
13. **Hee HT, Yu ZR, Wong HK.** Comparison of segmental pedicle screw instrumentation versus anterior instrumentation in adolescent idiopathic thoracolumbar and lumbar scoliosis. Spine. 2007;32:1533–1542. DOI: 10.1097/BRS.0b013e318067dc3d.
14. **Chen J, Yang C, Ran B, Wang Y, Wang C, Zhu X, Bai Y, Li M.** Correction of Lenke 5 adolescent idiopathic scoliosis using pedicle screw instrumentation: does implant density influence the correction? Spine. 2013;38:E946–E951. DOI: 10.1097/BRS.0b013e318297bfd4.
15. **Kaneda K, Shono Y, Satoh S, Abumi K.** New anterior instrumentation for the management of thoracolumbar and lumbar scoliosis. Application of the Kaneda two-rod system. Spine. 1996;21:1250–1262. DOI: 10.1097/00007632-199605150-00021.
16. **Lenke LG, Betz RR, Harms J, Bridwell KH, Clements DH, Lowe TG, Blanke K.** Adolescent idiopathic scoliosis: a new classification to determine extent of spinal arthrodesis. J Bone Joint Surg Am. 2001;63:1169–1181. DOI: 10.2106/00004623-200108000-00006.
17. **Li M, Ni J, Fang X, Liu H, Zhu X, He S, Gu S, Wang X.** Comparison of selective anterior versus posterior screw instrumentation in Lenke 5C adolescent idiopathic scoliosis. Spine. 2009;34:1162–1166. DOI: 10.1097/BRS.0b013e31819e2b16.
18. **Okada E, Watanabe K, Pang L, Ogura Y, Takahashi Y, Hosogane N, Toyama Y, Matsumoto M.** Posterior correction and fusion surgery using pedicle-screw constructs for Lenke type 5C adolescent idiopathic scoliosis: a preliminary report. Spine. 2015;40:25–30. DOI: 10.1097/BRS.0000000000000652.
19. **Roberts SB, Tsirikos AI, Subramanian AS.** Posterior spinal fusion for adolescent idiopathic thoracolumbar/lumbar scoliosis: clinical outcomes and predictive radiological factors for extension of fusion distal to caudal end vertebra. Bone Joint J. 2014;96:1082–1089. DOI: 10.1302/0301-620X.96B8.33837.
20. **Shufflebarger HL, Geck MG, Clark CE.** The posterior approach for lumbar and thoracolumbar adolescent idiopathic scoliosis: posterior shortening and pedicle screws. Spine. 2004;29:269–276. DOI: 10.1097/01.BRS.0000109881.63411.48.
21. **Suk SI, Lee CK, Chung SS.** Comparison of Zielke ventral derotation system and Cotrel-Dubousset instrumentation in the treatment of idiopathic lumbar and thoracolumbar scoliosis. Spine. 1994;19:419–429.
22. **Wang Y, Fei Q, Qiu G, Lee CI, Shen J, Zhang J, Zhao H, Zhao Y, Wang H, Yuan S.** Anterior spinal fusion versus posterior spinal fusion for moderate lumbar/thoracolumbar adolescent idiopathic scoliosis: a prospective study. Spine. 2008;33:2166–2172. DOI: 10.1097/BRS.0b013e318185798d.
23. **Wang Y, Bunger CE, Zhang Y, Wu C, Li H, Dahl B, Hansen ES.** Lowest instrumented vertebra selection for Lenke 5C scoliosis: a minimum 2-year radiographical follow-up. Spine. 2013;38:E894–E900. DOI: 10.1097/BRS.0b013e31829537be.
24. **Zielke K, Pellin B.** [Results of surgical management of scoliosis and kyphoscoliosis in adults (author's transl)]. Z Orthop Ihre Grenzgeb. 1975;113:157–174. In German.

Address correspondence to:
Mikhaylovskiy Mikhail Vitalyevich
NNIITO, Frunze str., 17,
Novosibirsk, 630091, Russia,
MMihailovsky@niito.ru

Received 13.07.2017
Review completed 26.07.2017
Passed for printing 31.07.2017

Mikhail Vitalievich Mikhaylovskiy, DMSc, Prof., Head of Department of Children and Adolescent Spine Surgery, Novosibirsk Research Institute of Traumatology and Orthopaedics n.a. Ya.L.Tsivyan, Novosibirsk, Russia, MMihailovsky@niito.ru;
Aleksandr Sergeyevich Vasyura, MD, PhD, senior researcher, traumatologist-orthopedist in the Department of Children and Adolescent Spine Surgery, Novosibirsk Research Institute of Traumatology and Orthopaedics n.a. Ya.L. Tsivyan, Novosibirsk, Russia, niito@niito.ru;
Vyacheslav Viktorovich Novikov, DMSc, senior researcher, traumatologist-orthopedist in the Department of Children and Adolescent Spine Surgery, head of functional unit of children and adolescent spine surgery, Novosibirsk Research Institute of Traumatology and Orthopaedics n.a. Ya.L. Tsivyan, Novosibirsk, Russia, niito@niito.ru;
Vladimir Nikolayevich Sarnadskiy, PhD in Technical Science, managing director of the METOS Medical Topographic Systems Ltd, Novosibirsk, Russia, niito@niito.ru;
Elena Vladimirovna Gubina, MD, PhD, senior researcher in the Clinic of Pediatric Orthopaedics, Novosibirsk Research Institute of Traumatology and Orthopaedics n.a. Ya.L. Tsivyan, Novosibirsk, Russia, niito@niito.ru.