CORRECTION OF SAGITTAL IMBALANCE AFTER PREVIOUS SURGICAL INTERVENTIONS FOR DEGENERATIVE LUMBAR SPINE DISEASE

E.S. Baikov[1], A.V. Peleganchuk[2], A.J. Sanginov[2], O.N. Leonova[1], A.V. Krutko[1]
[1]Priorov National Medical Research Center for Traumatology and Orthopedics, Moscow, Russia
[2]Novosibirsk Research Institute of Traumatology and Orthopaedics n.a. Ya.L. Tsivyan, Novosibirsk, Russia

Objective. To analyze clinical and radiological results of corrective fusion in the lumbar spine in the treatment of patients with sagittal imbalance after previous surgical interventions.

Material and Methods. A retrospective monocentric study, clinical case series. The data of 18 patients operated on using a combination of surgical methods with obligatory anterior corrective fusion at the L4—L5 and/or L5—S1 levels to achieve optimal parameters of the sagittal balance disturbed or developed after previous interventions were analyzed. Clinical and radiological parameters were assessed during hospital stay and at least 10 months later.

Results. The study presents data from 3 (16.7 %) men and 15 (83.3 %) women with an average age of 57.5 ± 9.1 years. Average length of hospital stay was 26.9 ± 10.1 days. In 7 (38.9 %) cases, the deformity occurred at the previously operated level and in 11 (61.1 %) — at the adjacent one. The duration of surgery was 481.4 ± 101.7 minutes, and blood loss was 1028.9 ± 594.9 ml. Back and leg pain VAS scores decreased in 10—19 months after surgery from 6.4 ± 0.9 and 4.8 ± 1.3 to 3.2 ± 1.2 and 0.9 ± 0.8, respectively ($p < 0.001$). The ODI score decreased from 59.6 ± 5.9 to 39.9 ± 7.7 ($p < 0.001$). The ideal Roussouly type was restored in 11 (61.1 %) cases, below ideal — in 3 (16.7 %), and overcorrection — in 4 (22.2 %). LL increased from 48.1 ± 13.6 ° to 56.9 ± 11.6 ° ($p < 0.001$), and LDI — from 40.1 ± 16.9 to 58.8 ± 10.3 ($p < 0.001$); SVA decreased from 5.1 ± 1.9 to 3.4 ± 2.1 cm ($p < 0.001$), PT — from 23.9° ± 7.2° to 19.1° ± 3.8° ($p < 0.001$). According to GAP score, the number of patients with severe and moderate disproportion was reduced ($p < 0.001$). Perioperative complications were observed in 12 (66.7 %) patients.

Conclusion. Multi-stage surgical correction of the residual and aggravated sagittal imbalance with obligatory anterior corrective interbody fusion after instrumental correction of degenerative spinal deformity through the posterior approach significantly improves clinical and radiological parameters and allows restoring a harmonious sagittal profile in 61.1 % of cases.

Key Words: spinal deformity, degenerative scoliosis, sagittal balance, vertebrotomy, repeated surgical interventions.

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Year over year, the number of surgical interventions on the lumbar spine due to degenerative lesions is growing steadily [1]. This is facilitated by the availability of surgical care, satisfaction with its outcomes, and the aging of the population in developed countries. According to American researchers [1], the number of surgeries increased by 2.4 times from 1998 to 2008. The number of patients requiring surgical re-intervention after previous surgeries, however, is also increasing [2]. Repeated surgeries can be required due to troubles at the intervention level (pseudoarthrosis, structural fracture, loss of correction) or at the adjacent segment (adjacent segment pathology, proximal junctional kyphosis, distal junctional kyphosis). In most cases, this outcome is due to an error in planning of the extent and type of surgery from the standpoint of the contemporary understanding of surgical treatment of degenerative spine disease. Important components in surgical interventions on the lumbar spine are the normalization of segmental and harmonization of lumbar lordosis [3]. Several authors [4–6] revealed a relationship between segmental kyphotization after stabilization surgeries and the adjacent segment involvement. Loss of lumbar lordosis during spinal fusion has a significant association with sagittal imbalance and related clinical manifestations [7].

According to studies [8–10], the restoring of segmental lumbar lordosis that has a significant relationship with the patients' quality of life, is an important strategic component. It should be taken into account that L4–S1 levels should constitute about 70 % of the lumbar lordosis. Pizones et al. [11] found out the necessity to restore the ideal Roussouly type in order to improve the results of surgical treatment in patients with sagittal imbalance. One of the best ways to restore lumbar lordosis and, therefore, the sagittal balance of the spine, is a combination of surgical methods aimed at harmonious correction of the initial disorders: ALIF – anterior lumbar interbody fusion with hyperlordotic cages, LLIF – lateral lumbar interbody fusion, TLIF – transforaminal lumbar interbody fusion, posterior screw fixation [3].

Due to the a small number of papers focusing on the surgical treatment of patients with spinal deformities that arose or worsened as a result of previous surgeries with instrumentation in the lumbar spine, there is currently no clear understanding and unified approaches to surgical treatment for this pathology.

The objective is to analyze the clinical and radiological results of corrective fusion in the lumbar spine for treating patients with sagittal imbalance after previous interventions with instrumentation for degenerative lumbar spine disease.

Material and Methods

Design: retrospective monocentric study, a series of clinical cases.

Patients

Data of 18 patients who underwent the surgery from February 2017 to September 2019 were analyzed. All patients had previously undergone lumbar spine surgery with posterior screw fixation and/or interbody fusion from the posterior approach only. The indications for current surgical intervention were recurrence or prolonged vertebrogenic pain syndrome in combination with compression syndrome and/or neurological deficit or without this combination, neurogenic intermittent claudication syndrome, resistant to conservative therapy.

Causes of clinical manifestations:

1) at the level of the previous surgical intervention: pseudoarthrosis, fracture of the metal structure elements (pedicle screw, rod) with loss of segmental correction, subsidence of the interbody implant(s);

2) at the levels adjacent to the previously operated level: degenerative stenosis of the spinal canal, segmental instability, degenerative spondylolisthesis, PJK.

Radiological inclusion criteria. All patients had a sagittal spine imbalance that required at least 20° correction at the lower lumbar level (Low LL – L4–S1) and corresponded to two or more of the following criteria: SVA > 5 cm, PI-LL > 10°, PT > 20°, lordosis distribution index (LDI < 40 %). SRS-Schwab type N (deformity in the frontal plane < 30°).

Thechniques

The goals of surgical intervention were: harmonious restoration of lumbar lordosis and elimination of the morphological substrate of clinical manifestations at the previously operated and/or adjacent level(s). This was achieved through anterior corrective interbody fusion with hyperlordotic cages on L4–L5 and/or L5–S1 levels. We used cages with a lordotic angle of 15° and 18° made of PEEK (Polyetheretherketone). In a number of cases, the surgical approach involved extension of both screw and interbody fixation to L2–L3, L3–L4 levels if they were clinically significant and/or if additional correction was required. In this case, direct lateral or transforaminal interbody fusion (with banana-shaped cage) was used. At the levels where spinal fusion was performed, SRS-Schwab osteotomy of the 1st or 2nd type was necessary. Decompression was performed at clinically significant levels. In case of failure of the bone block at the previously operated levels, the metal structures were dismantled and the interbody implants were removed and replaced with others that helped to achieve the main goal of the surgical intervention. The surgery was performed on one day or was divided into several stages with intervals of 5 days or longer to reduce the risk of perioperative complications by minimizing one-stage surgical injury in somatically burdened patients.

The follow-up period ranged from 10 to 19 months. Demographic, clinical, surgical and radiological parameters were analyzed.

Radiological and clinical data were analyzed before the surgery, at the time of discharge, and at least 10 months after discharge.

Clinical data: age, gender, VAS data in the back and leg, Oswestry Disability Index. Surgical data: duration of the surgery (with staged treatment – the sum of all stages), total blood loss, levels of surgical intervention, peri- and postoperative complications.

The preoperative examination included functional X-ray study, spine X-ray study with a patient standing in one's usual position, in two standard planes from C0 to the middle third of the femur, the position of the hands on the opposite clavicles, MRI and MSCT of the lumbar spine. After the surgery, spine X-ray study was taken with the patient standing in the usual position, in two standard planes from C0 to the middle third of the femur, the position of the hands on the opposite clavicles, MSCT and/or MRI of the lumbar spine, if necessary. 10 months after the discharge – spine X-ray study of the patient standing in a normal position, in two standard planes from C0 to the middle third of the femur, the position of the hands on the opposite clavicles, MSCT of the lumbar spine.

Estimated radiological parameters of sagittal balance: PI, PT, SVA, LL, Low LL, PI-LL, Roussouly type, GAP (Global Alignment and Proportion). The Roussouly type was determined according to the PI value: types I and II – PI < 45°, type III – PI – 45–60°, type IV – PI > 60° [11]. The degree of recovery of the ideal Roussouly type after the surgery was assessed as uncorrected, corrected, or hypercorrected [11]. GAP is a new scoring individualized method for assessing sagittal balance presented in 2017 by Yilgor et al. [12]. It is based on an assessment of pelvic position, lumbar lordosis, lordosis distribution index, global spino-pelvic ratio, and age. The proposed method is positioned as an option to reduce the limitations of the SRS-Schwab classification. GAP has three gradations: 0–2 scores – proportional balance; 3–6 scores – moderate disproportional balance; more than 7 scores – severe disproportional [12]. Segmental lordosis was assessed at the level of ALIF performed with hyperlordotic cages in order to determine the dependence of their angle and the final angle in the segment.

Statistical analysis

The results of the study were processed using descriptive statistics calculations (for quantitative variables, the mean value is M, the standard deviation is m; the results are presented as M ± m; for ordinal variables, the frequency values are given and percentages relative to the number of valid observations) and by comparing quantitative and qualitative indicators in the studied patient groups.

Nonparametric methods were used for the analysis. The differences between the compared mean values of the studied parameters in the groups were assessed using the nonparametric Mann-Whitney U-test. The correlation between qualitative indicators was identified using the Fisher's F-test. The association between two indicators was assessed using Spearman's correlation analysis. The correlation ratio of the correlation coefficient was accounted under the following scale of the value intervals (ρ): less than 0.19 – a very weak correlation; 0.20–0.29 – weak correlation; 0.30–0.49 – moderate correlation; 0.50–0.69 – medium correlation, more than 0.70 – strong correlation. Significant was considered the correlation ratio between the indicators of at least 0.3 (>0.3). The level of threshold statistical significance (p) was taken less than or equal to 0.05 ($p < 0.05$). SPSS 15.0 software was used for statistical data processing.

Results

The analyzed group of patients included 3 (16.7 %) men and 15 (83.3 %) women. The age of the patients was 57.5 ± 9.1 years. Postoperative bed-days – 26.9 ± 10.1 (from 15 to 43 days).

Types of previous surgical interventions: TLIF and transpedicular fixation (TPF) on L4–L5 level – 9 cases; TLIF and TPF on L5–S1 level – 3 cases, PLIF (posterior lumbar interbody fusion) and TPF on L4–L5 level – 2 cases; PLIF and TPF on L5–S1 level – 1 case; TPF and posterior fusion with autobone on L4–L5 level –1 case; TPF and posterior fusion with autobone on L5–S1 level – 1 case; PLIF without TPF on L4–L5 level – 1 case. In 7 (38.9 %) cases, the surgical problem arose at the previously operated level, in 11 (61.1 %) cases, at adjacent levels.

In 10 (55.6 %) cases, the treatment was performed in one surgical session, in 8 (44.4 %) cases – in two or three sessions. On average, the interval between the surgical stages was 9.0 ± 20.9 (0.5 [0; 12]) days. However, due to the development of pulmonary artery thromboembolism (PATE) and thrombosis of the left iliac vein in two patients, the period between the 1st and 2nd stages increased to 3 months. These patients were not included in the calculation of the mean interval. The distribution by the number of TPF levels and types of interbody fusion is presented in Table 1.

The duration of the surgical intervention was 481.4 ± 101.7 minutes (from 360 to 680 minutes). The mean blood loss was 1,028.9 ± 594.9 ml (from 420 to 2,200 ml). Four (22.2 %) patients required blood transfusion.

Clinical data improved significantly after surgery, this trend persisted for at least 10 months after discharge (Table 2). ODI after surgery was not analyzed, since during the discharge period the patients need analgesic therapy due to surgical injury.

While evaluating the radiological parameters of the sagittal spine balance, a significant improvement was noted at the time of discharge and at the final control examination (Table 3). None of the patients had Roussouly types I and II, type III was in 10 (55.6 %) cases, and type IV in 8 (44.4 %). The Roussouly type was restored to the ideal in 11 (61.1 %) cases, hypocorrected – in 3 (16.7 %), hypercorrected – in 4 (22.2 %) cases.

We assessed the dependence of the final angle of segmental lordosis (SL) on the angle of the hyperlordotic cage, placed from the anterior approach (Table 4). Segmental lordosis after the surgery on L4–L5 level was 66 % and 63 % of the 15 and 18 cage angle, respectively; on L5-S1 level – 59 % and 67 %, respectively. A decrease in the angle of segmental lordosis was noted during the final control visit.

The distribution of the types of complications and their treatment are presented in Table 5. Peri- and postoperative complications were noted in 12 (66.7 %) patients. In 4 (22.2 %) cases, repeated surgical intervention was performed due to the development of complications: 1 (5.6 %) – implant migration, 1 (5.6 %) – infection in the posterior approach site, 1 (5.56 %) – fracture of the rod, 1 (5.6 %) – eventration of loops of the small intestine.

Clinical case. Patient T., 55 y.o., female, underwent a surgery in 2017 due to pain syndrome in the lumbar spine, neurogenic intermittent claudication syndrome caused by grade 1 degenerative spondylolisthesis of L4, degenerative stenosis at L4–L5 level. The scope of surgical intervention: decompression, transpedicular and interbody (TLIF) fixation at L4– L5 level. The patient had the following sagittal balance parameters before the surgery (Fig. a): PI – 64°, PI-LL – 14°, PT – 19°, SVA – 5.9 cm, LDI – 30 %, GAP – 4 points. Thus, initially, besides a compression of intracanal neurovascular formations, there were impaired parameters of the sagittal balance and spinopelvic relationships. After the surgery, neurogenic intermittent claudication regressed; the lumbar spine pain syndrome decreased at the time of discharge (VAS score – 4, these data may not reflect the true values of the pain syndrome due to the use of painkillers during this period). Six months after surgery, the pain syndrome in the lumbar spine increased and was resistant to conservative therapy. The patient was examined again (MRI, MSCT): no data on compression of intracanal neurovascular formations, no signs of impaired integrity of the metal structure and pseudarthrosis were found. There sagittal balance parameters are as follows (Fig. b): PI – 64°, PI-LL – 10°, PT – 19°, SVA – 4.4 cm, LDI –31 %, GAP – 4 points. Thus, there was a significant lack of lower lumbar lordosis (LDI should be 50–80 %). The patient was admitted to Neurosurgery Department No. 2 of Novosibirsk Research Institute of Traumatology and Orthopaedics n. a. Ya.L. Tsivyan on September 6, 2019, complaining about lumbar spine pain, because of which she could not walk more than 300 m without stopping, and took painkillers daily (up to two times a day). Clinical parameters: VAS (back) score– 7, VAS (leg) score – 1, ODI – 64 %. Taking into account the clinical data and the results of additional examinations, the patient underwent repeated surgical intervention in order to restore the optimal values of the lower lumbar lordosis. This was achieved through a 3-stage surgical intervention: stage 1 – dismantling the transpedicular structure (removing of the rods) at the L4–L5 level, additional

Table 1

Distribution of patients according to number of levels and metal fixation type, n (%)

TPF			ALIF		DLIF/TLIF		
2 levels	3 levels	4 levels	1 level	2 levels	No	1 level	2 levels
11 (61.1)	6 (33.3)	1 (5.6)	9 (50.0)	9 (50.0)	8 (44.4)	8 (44.4)	2 (11.1)

installation of screws into the body of the S1 vertebra, Schwab grade 2 osteotomy at the L4–L5 and L5–S1 levels; stage 2 – cage removal at the L4–L5 level and anterior fusion with hyperlordotic cages at the L4–L5 and L5–S1 levels; stage 3 – mounting the transpedicular structure with contraction on the screw heads. After the surgery, the following target indicators of sagittal spinopelvic and global balance were achieved (Fig. c): PI – 64°, PI-LL – -2°, PT – 20°, SVA – -1.6 cm, LDI – 62 %, GAP – 0 points. Clinical data at discharge: VAS (back) score – 4, VAS (leg) score – 0; during the control visit (October 2020): VAS (back) score – 2, VAS (leg) score – 0 points, ODI – 22 %; X-ray data (Fig. d): PI – 64°, PI-LL – 1°, PT – 21°, SVA – -0.9 cm, LDI – 59 %, GAP – 0 points.

Table 2

The results of clinical data analysis in patients of the study group

Parameters	Before surgery	After surgery	p-value	After 10–19 months	p-value
VAS (back)	6.4 ± 0.9	3.0 ± 0.8	0.000196*	3.2 ± 1.2	0.000293*
VAS (leg)	4.8 ± 1.3	0.5 ± 0.6	0.000196*	0.9 ± 0.8	0.000196*
ODI	59.6 ± 5.9	–	–	39.9 ± 7.7	0.000196*

* Changes are statistically significant.

Discussion

Year over year expansive growth of surgical interventions using metal structures in patients with degenerative lumbar spine disease steadily leads to an increase in the number of repeated surgeries [2]. In some cases, repeated interventions require correction of sagittal imbalance, the significance of which was not assessed during the primary surgery, or it was direct effect of a surgery. Troubles after primary instrumentation of the spine that are the cause or consequence of the sagittal spine imbalance, include fracture of metal structures, pseudarthrosis, resorption around pedicle screws, deformity of the adjacent segment (degenerative stenosis of the spinal canal, segmental instability, PJK and etc.). The papers focused on correction of sagittal spine imbalance after previous instrumental surgeries are few in number, so there is no clear understanding of the tactics for this cohort of patients.

Traditionally, to correct decompensated sagittal imbalance, three-column osteotomies are used. They have proven to be effective in patients of this profile [13]. This type of surgical treatment, however, is quite aggressive and has a high incidence of peri- and postoperative complications. The level of such complications can reach 50 % or more. That leads to repeated surgeries in almost 30 % of cases [13–16]. In addition, this intervention does not always enable harmonious restoration of lumbar lordosis, that is one of the fundamentals for normalizing sagittal balance. According to European researchers on spine surgery, the main principles that should be observed when correcting deformity in adults with a predominant change in the sagittal plane are to restore the ideal Roussouly type and lumbar lordosis, based on the data of the PI constant parameter, while 2/3 of its angle should fall on L4–S1 level [9, 11]. Achieving these goals is quite effective when using combinations of surgical techniques that are not inferior to three-column osteotomies in terms of corrective capabilities [2, 13, 17]. One of the key points of this approach is performance of corrective interbody fusion with hyperlordotic cages on L4–S1 level with posterior column osteotomy and posterior screw fixation, if necessary, extended to the superjacent spine departments. It is the underlying principle for treatment of patients in this study.

As a rule, if it is necessary to correct the sagittal balance in patients with previous instrumentation, a 3-stage approach (540° fusion) is used. The 1st stage is dismantling and reinstalling of the metal structures from the posterior approach. The 2nd stage is removing of previously installed interbody implants and performing of corrective spinal fusion through the anterior approach. The 3rd stage is completing of the final installation of the dorsal fixation structure [18]. Kadam et al. [18] proposed a different tactics aimed to reduce the number of stages. The surgical approach they described consisted in performing the primary anterior stage without preliminary dismantling of the transpedicular construction. The interbody space was expanded with a dosed force using a distractor, the blades of which covered a significant part of the endplates in order to prevent their damage. Next, a hyperlordotic cage was installed and the posterior stage of the surgery was performed. A considerable improvement in the parameters of the sagittal and global balance in the postoperative period was noted, while significant damage to the endplates was detected only in 8.3 %

Table 3

Analysis of changes in sagittal balance parameters

Parameters	Before surgery	After surgery	p-level	After 10–19 months	p-level
PI	60.5 ± 10.1	–	–	–	–
PT, degrees	23.9 ± 7.2	16.8 ± 3.3	0.000196*	19.1 ± 3.8	0.000438*
SVA, sm	5.1 ± 1.9	1.9 ± 2.4	0.000196*	3.4 ± 2.1	0.001177*
LL, degrees	48.1 ± 13.6	59.8 ± 11.9	0.000196*	56.9 ± 11.6	0.000276*
LDI, %	40.1 ± 16.9	62.3 ± 12.2	0.000233*	58.8 ± 10.3	0.000386*
PI-LL, degrees	12.4 ± 11.0	0.7 ± 10.3	0.000196*	2.8 ± 9.7	0.000276*
GAP, points:			0.002218*	–	0.001496*
0–2	0 (0 %)	11 (61.1 %)	0.00005*	10 (55.6 %)	0.00034*
3–6	14 (77.8 %)	7 (38.9 %)	0.02342*	8 (44.4 %)	0.05053
More than 7	4 (22.2 %)	0 (0 %)	0.05195	0 (0 %)	0.05195

* Changes are statistically significant.

Table 4

Dependence of the final segmental angle on the cage angle

Segmental angle	L4–L5 level		L5–S1 level	
	Cage angle 15°	Cage angle 18°	Cage angle 15°	Cage angle 18°
After surgery, degrees	9.9 ± 2.0	11.3 ± 1.9	8.8 ± 0.9	12.0 ± 1.7
After 10–9 months, degrees	8.7 ± 2.0	9.3 ± 1.8	7.8 ± 0.9	10.6 ± 1.9
p-level	0.011719*	0.027709*	0.108810	0.027709*

* Changes are statistically significant.

Table 5

Types of complications in the studied cohort of patients

Complications	Number, n (%)
Mechanical	2 (11.1)
Infectious	1 (5.6)
Neurological	3 (16.7)
Thromboembolic	4 (22.2)
Other	7 (38.9)
Patients with complications	12 (66.7)

of cases that did not exceed the same parameter for the standard ALIF that is about 10 % [19].

In our study, in the case of anterior corrective fusion in the area of a previous intervention, or, if necessary, of removing of the interbody implant through the anterior approach, the revision surgical treatment was performed traditionally in three stages: posterior – anterior – posterior.

Corrective spinal fusion of the anterior column with a wide release of the annulus fibrosus and with the removal of the anterior longitudinal ligament has proven to be an alternative to three-column osteotomies through the posterior approach [17, 20, 21]. Its capabilities in some cases are comparable in terms of normalizing spinal and pelvic parameters and global balance. At the same time, hyperlordotic cages enable a more harmonious restoration of the sagittal profile.

Lui et al. [21] conducted a comparative analysis of the treatment results of 34 patients with Pedicle Subtraction Osteotomy (PSO) method and Oblique Lumbar Interbody Fusion (OLIF) with hyperlordotic implants. They noted that correcting anterior column greatly increased SVA value ($p = 0.018$), value of L4–S1 lower lumbar lordosis ($p = 0.043$), and improved C7–CSVL value ($p = 0.037$). In a series of 31 patients, Murray at al. [22] revealed an increase in LL from 32.3° to 49.9°, a decrease in PI-LL from 26.5° to 11.0°, and a decrease in SVA from 10 to 6.2 cm. Despite of revision type of surgery, there was a significant improvement in the parameters of the sagittal balance (SVA, PT, LL, LL – L4–S1, PI-LL) in our cohort of patients. These parameters maintained throughout the entire follow-up period ($p > 0.05$). The ideal Roussouly type was restored in 61.1 % of patients. According to Pizones et al. [11], this parameter is important in terms of preventing mechanical complications.

The choice of the cage angle should be aimed at achieving the optimal values of the local and global sagittal balance parameters. According to the literature [17, 18, 23], the final segmental lordosis is about 50 % of the cage angle. In a cadaver study, Uribe et al. [23] obtained segmental lordosis of 11.6°, 9.5° and 4.1° when installing cages with an angle of 30°, 20° and 10°, respectively. Kadam et al. [18] noted an increase in the angle of lordosis in a series of 20 patients by 6.1°, 12.5° and 17.7° during fusion with cages 12°, 20° and 30°, respectively. Leveque et al. [17] found an average increase in segmental lordosis by 54 % when using 20° and 30° cages. In our study, interbody implants with an angle of 15° and 18° were installed at two lower lumbar levels. It was revealed that segmental lordosis after surgery at the L4–L5 level was 66 % and 63 % of 15° and 18° cage, respectively; at the L5-S1 – 59 % and 6 7%. Thus, the cage angle must be taken into account, adjusted for its possibility of the final formation of segmental lordosis, when planning a surgical intervention.

Surgical interventions aimed at deformity correction in adults are quite aggressive, since they require a polysegmental impact on the spinal column, in some cases through different approaches. At present, the choice of tactics aimed at observing the minimum sufficiency prin-

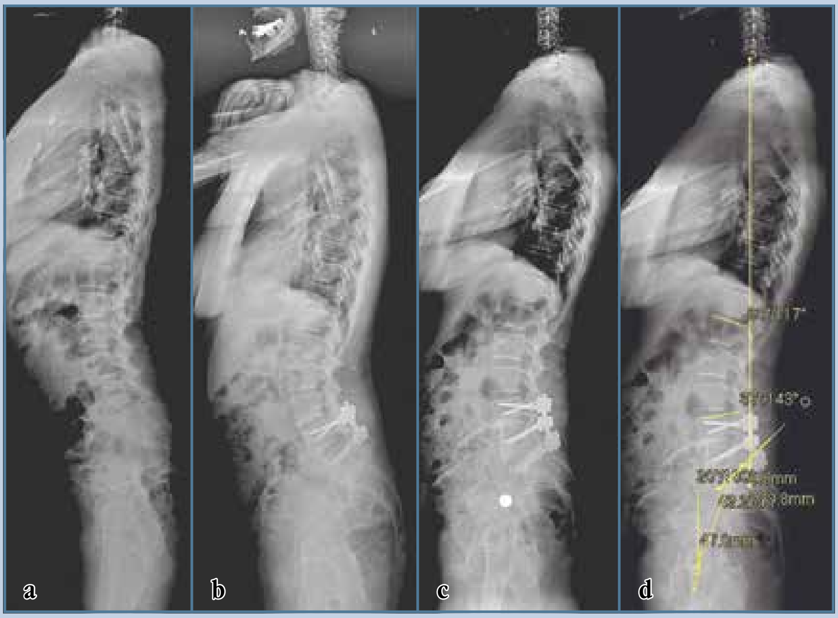

Fig.
X-Ray images of patient T., 55 years old, in step mode in lateral plane: **a** – before the first surgery; **b** – before the second surgery; **c** – after the second surgery; **d** – one year after the second surgery

ciple remains unresolved. The level of complications, negative consequences and related therapeutic and repeated surgical interventions that occur in the treatment of such patients cannot meet the requirements of the modern medicine. Thus, the frequency of general, specific and technical complications can reach 58 % [24]. At the same time, even minimally invasive technologies, divided into stages, cannot significantly reduce their frequency. Mundis et al. [13] found 41.2 % of complications with PSO and 35.3 % with a combination of minimally invasive methods (p = 0.73). Revision surgical interventions, the frequency of which is quite high in patients with spinal deformities, are associated with more number of complications. Gupta et al. [15] found the following in a prospective multicenter study of 421 patients who underwent PSO initially and as a second surgery, with a follow-up period of up to 1 year: motor neurological deficit – 4.2% vs. 9.4 %, intestinal insufficiency – 1.4 % vs. 2.8 %, pseudarthrosis – 1.4 % vs. 2.5 %, repeated surgeries rate – 4.3% vs. 7.4%. Kadam et al. [18] noted 19.4 % of complications after revision surgical intervention with anterior corrective lumbar spine fusion in 36 patients previously instrumented from the posterior approach. Out of these complications, 11.1 % were associated with the anterior approach, 8.3% – with the posterior approach. In a series of patients in the present study, 66.7 % of complications were observed: repeated surgical intervention became necessary in 4 (22.2 %) cases.

Despite all the complications and negative consequences of surgical interventions aimed at correcting spinal deformities, large multicenter studies, systematic reviews and meta-analyses indicate a significant improvement in the quality of life of patients after such surgeries [20, 25, 26]. Schwab et al. [26] determined a significant dependence of the quality of life (ODI, SF-12, SRS-22r) on the sagittal profile parameters (SVA, PT and PI-LL). Based on a literature review that included data from 26 papers, Saigal et al. [20] concluded that corrective surgeries for spinal deformities in adults improves their quality of life significantly (ODI, SF36-PC, SF36-PC). The results of a meta-analysis by Tarawneh et al. [25] strengthened the assertion of previous authors. They showed that the minimum clinically important difference was achieved both in the ODI scale and in SRS-22 or SRS-24. It was based on data from 431 patients who underwent the surgeries with PSO. The present study noted a significant reduction in the intensity of pain syndrome (VAS) and an improvement in the quality of life (ODI).

Study limitations: retrospective monocenteric, small number of patients in a series of clinical cases, absence of a comparison group, heterogeneouss primary surgical interventions, limited follow-up period of 10–19 months. According to the SIGN (Scottish Intercollegiate Guidelines Network) classification, this study has grade 3 evidence, improving which would require comparative studies with more patients and longer follow-up.

Conclusion

Multi-stage surgical correction of residual and aggravated sagittal imbalance with obligatory anterior corrective interbody fusion after instrumental correction of degenerative spine deformity through the posterior approach significantly improves radiological (spinopelvic, global balance) and clinical (VAS, ODI) parameters and enable to restore a harmonious sagittal profile in 61.1 % of cases.

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Address correspondence to:
Baikov Evgeny Sergeyevich
Priorov National Medical Research Center
for Traumatology and Orthopedics,
10 Priorova str., Moscow, 127299, Russia,
Evgen-bajk@mail.ru

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Evgeny Sergeyevich Baikov, MD, PhD, neurosurgeon, Priorov National Medical Research Center for Traumatology and Orthopedics, 10 Priorova str., Moscow, 127299, Russia, ORCID: 0000-0002-4430-700X, Evgen-bajk@mail.ru;

Aleksey Vladimirovich Peleganchuk, MD, PhD, Department of Neurosurgery No. 2, Novosibirsk Research Institute of Traumatology and Orthopaedics n.a. Ya.L. Tsivyan, 17 Frunze str., Novosibirsk, 630091, Russia, ORCID: 0000-0002-4588-428X, APeleganchuk@mail.com;

Abdugafur Jabborovich Sanginov, MD, PhD, Department of Neurosurgery No. 2, Novosibirsk Research Institute of Traumatology and Orthopaedics n.a. Ya.L. Tsivyan, 17 Frunze str., Novosibirsk, 630091, Russia, ORCID: 0000-0002-4744-4077, Dr.sanginov@gmail.com;

Olga Nikolaevna Leonova, PhD, MD, senior researcher, Priorov National Medical Research Center for Traumatology and Orthopedics, 10 Priorova str., Moscow, 127299, Russia, ORCID: 0000-0002-9916-3947, onleonova@gmail.com;

Aleksandr Vladimirovich Krutko, DMSc, neurosurgeon, leading researcher, Priorov National Medical Research Center for Traumatology and Orthopedics, 10 Priorova str., Moscow, 127299, Russia, ORCID 0000-0002-2570-3066, ortho-ped@mail.ru.