SINGLE- AND MULTISTAGE SURGICAL TREATMENT OF PATIENTS WITH DEGENERATIVE SAGITTAL IMBALANCE

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

Objective. To analyze the nearest clinical and radiological results of simultaneous and staged surgical treatment of patients with degenerative sagittal imbalance.

Material and Methods. Retrospective monocentric cohort study included analysis of data from 54 patients who underwent simultaneous combination of surgical methods with obligatory corrective anterior fusion at the L4–L5 or at L4–L5 and L5–S1 levels (Group I, n = 27) or similar surgical intervention though divided into stages with an interval of 5 days or more (Group II, n = 27). A comparison of clinical, radiological, and operational data during inpatient treatment was carried out.

Results. The duration of surgery was 410.93 ± 76.34 minutes in Group I and 594.63 ± 102.61 minutes in Group II (p = 0.000001); the blood loss was 926.67 ± 378.63 ml versus 1345.19 ± 522.97 ml, respectively (p = 0.001575). Postoperative clinical and radiological parameters did not differ between groups: VAS back (p = 0.248647), VAS leg (p = 0.196140), PT (p = 0.115965), SVA (p = 0.208449), LL (p = 0.023654), LDI (p = 0.931646), PI-LL (p = 0.693045), GAP (p = 0.823504), and restoration of the ideal Russoly type (p = 0.111476). The incidence of perioperative complications in groups was comparable: 17 (62.96 %) in Group I and 15 (55.56 %) in Group II (p = 0.583171). Patients with a high Charlson comorbidity index had a significantly higher incidence of complications (p = 0.023471). The index of surgical invasiveness in Group I had a significant correlation with the total number of complications (ρ = 0.421332).

Conclusion. Clinical and radiological results and the incidence of complications are comparable between single- and multistage approaches to correct sagittal balance disorders. In staged treatment, the total duration of surgery and the volume of blood loss are significantly higher. With a high Charlson comorbidity index and Mirza surgical invasiveness index, a multistage approach to the treatment of patients with sagittal imbalance is preferred.

Key Words: degenerative scoliosis, sagittal balance, spinal deformities.

Please cite this paper as: *Baikov ES, Peleganchuk AV, Sanginov AJ, Leonova ON, Krutko AV. Single- and multistage surgical treatment of patients with degenerative sagittal imbalance. Hir. Pozvonoc. 2021;18(2):44–53. In Russian.*

DOI: http://dx.doi.org/10.14531/ss2021.2.44-53.

Year after year, the number of age-related patients suffering from spinal deformities is steadily increasing. The reason for this is an extended life and increased requirements for its quality. The majority of patients with spinal deformities are managed conservatively. Nevertheless, with the development of clinical implications, a surgery can significantly improve the patients' life quality [1–5]. It has several aims: decompression, correction and stabilization. The extended thoracolumbar instrumentation, which may include interbody fusion, is used to achieve the correction. In case of three-plane deformities (frontal, sagittal, axial), the surgical treatment is quite aggressive. It is associated with a high frequency of reoperations until the desired clinical and radiological result is achieved [6, 7]. The complication rate in the treatment of spinal deformities can vary from 40 to 80 %. Meanwhile, the share of severe complications (surgical site infections, neurological deficit, PE, myocardial infarction, etc.) is 17–49 % [8, 9]. Therefore, the current trend in spinal surgery is to find ways to reduce the frequency of such complications by knowledge improvement, the use of minimally invasive techniques, the use of the emergent approaches in anesthesiology and aftercare [10].

The high degree of physiological stress in the patient during corrective surgeries is associated with continuous anesthesia, major blood loss, and a decline in the nutritional parameters [11, 12]. It is believed that performance of several minor surgeries instead of a single-stage surgical treatment (the stages are performed in one surgical session) is easier for the patient in terms of reducing the degree of one-time physiological stress [13, 14]. Significant reasons in favor of multistage surgeries (the stages are performed in several surgical sessions) are the following: less workload on the surgical team, repeated X-rays with the possibility of treatment strategy correction before the next stage. Nevertheless, there are studies indicating the absence of advantages of the stage approach over the single methods. This relates to increased risks of complications, higher economic costs due to a long admission [13]. Currently, the literature suggests that there is no robust evidence of the advantages of one or another treatment strategy of patients with spinal deformities. The Russian researchers challenged themselves to develop criteria, surgical procedures classification, and their effectiveness in the treatment of this kind of patients [15]. A better understanding of the positive and negative aspects of one (single) or another (multistage) approach will enable both the doctor and the patient to make a more reasonable decision in surgical planning.

The aim of the study is to analyze the nearest clinical and radiological results of simultaneous and staged surgical treatment of patients with degenerative sagittal imbalance.

Material and Methods

Study design: a retrospective multicenter cohort study. From January 2017 to September 2020, the data of 54 adult patients who underwent surgery were revised. The surgical alternatives were the following: pain syndrome in the lumbar spine in combination with nerve compression syndrome and/or neurological deficit, neurogenic claudication syndrome, resistant to chronic (more than 3 months) conservative therapy. The morphological substrate of clinical evidence was degenerative stenosis of the lumbar spinal canal with a sagittal balance disorder.

Study inclusion criteria:

– Patients over 18;

– anterior lumbar interbody fusion and posterior screw fixation;

– sagittal imbalance (compliance with one or more of the criteria: sagittal vertical axis (SVA) – more than 5 cm, the difference between pelvic incidence (PI) and lumbar lordosis (LL) – more than 10°, pelvic tilt (PT) - more than 20°, lordosis distribution index (LDI) – less than 40 %);

– type N according to SRS-Schwab (front plane deformity is less than 30°).

Exclusion criteria:

– traumatic, tumor, and inflammatory injuries of the spine;

– types L, D, T according to SRS-Schwab, only posterior corrective decompression and stabilization surgeries;

– conditions that prevent or represent a significant risk during anterior lumbar interbody fusion (previously performed surgeries on the pelvic organs, abdominal cavity, and retroperitoneal space);

– osteoporosis;

– the formed artificial bone block according to the Bridwell grading system (1st grade) at the level of L4–L5 and/or L5–S1;

– vertebral end plates destruction, preventing the correct insertion of interbody cages at the level of L4–L5 and/or L5–S1.

The surgery consisted of two obligatory and one optional stages:

– obligatory (posterior decompression + transpedicular fixation (TPF): decompression at clinically significant levels, SRS-Sshwab osteotomy of grades 1 or 2 and posterior transpedicular screw fixation were performed at all levels where interbody fusion was performed;

– obligatory (ALIF): anterior lumbar interbody fusion by hyperlordotic cages (the lordotic angle 15° or 18°) at the lower lumbar levels (L4–L5 or L4–L5 and L5–S1);

optional (LLIF): lateral lumbar interbody fusion (LLIF) at the level L3–L4 or L2–L3 и L3–L4 (if additional correction is necessary or if there is a morphological substrate of clinical and neurological manifestations, found at the planning stage).

The sequence of surgical stages was defined by clinical and morphological changes (intensity of stenosis, mobility of segments, presence of implants after previous surgeries, etc.). This arrangement could be the following: LLIF – ALIF – posterior decompression – TPF, ALIF – posterior decompression – TPF, posterior decompression – ALIF – TPF. If surgical treatment involved performing LLIF, then this type of spinal fusion was constantly carried out as a priority.

If the surgery was performed as a revision one and the patient had a transpedicular instrumentation system in the proposed correction area, then certain peculiarities were considered: the primary posterior stage (instrumentation removal, posterior decompression, osteotomies and insertion of transpedicular screws at all necessary levels). The next stage was performed on the anterior column support (with the removal of previously inserted interbody implants, if there were any). The final posterior stage: placement of the transpedicular system).

In the treatment of patients with this abnormality, we followed the surgical guidelines developed by European spine surgeons [16, 17], indicating the need for a balanced recovery of LL. It should be calculated on the basis of PI, and the lower lumbar LL should be 2/3 of LL).

According to the surgical approach, the patients were divided into 2 groups: Group I – all stages of surgical intervention in one surgical session (one-stage); and Group II – 2–3 stages of surgery with an interval of 5 or more days (multistage).

The follow-up period consisted of the entire hospital stay length. Demographic, clinical, operational, and radiological indicators were assessed. Radiological and clinical data were reviewed before the surgery as well as a day before discharge. During this period there is a minimal need for anesthetic management caused by a surgical trauma, which reduces their impact on the accuracy of the results obtained.

The demographic data consisted of age, gender, body mass index, and hospital stay length. Clinical data: VAS (back and leg pain before surgery and before discharge), ODI before the surgery. The Charlson index was used to evaluate the comorbidity status: low: 0–2 points, moderate: 3–6 points, high: 7–9 points, and very high: more than 9 points [17]. The data related to surgical intervention was given: Mirza surgical invasiveness index [18], the type of surgery (original, repeated), the surgery duration (for multistage approach – the total of all stages), the total volume of blood loss (for multistage approach – the total of all stages), the levels of surgery, intra – and postoperative complications, the period between the surgery stages, and reoperations during the hospital stay.

Preoperative scope of the examination: stress radiography of the lumbar spine (flexion and extension in the lateral projection); radiography of the spine upright in the usual position, in two standard projections from C0 up to the middle third of the femurs, the position of the hands is opposite collarbones; MRI and MSCT of the lumbar spine. Postoperative scope of the examination: radiography of the spine upright in the usual position, in two standard projections from C0 up to the middle third of the femurs, the position of the hands is opposite collarbones; MSCT and/or MRI of the lumbar spine if necessary.

The studied radiological parameters: PI, pelvic tilt to the vertical (PT), SVA, LL, lower lumbar LL (L4–S1), PI-LL, Russoly type [17], Global Alignment and Proportion (GAP) [18].

The Russoly type in each patient was identified by PI: types I and II < 45°, type III – 45–60°, type IV > 60° [19]. After surgery, the Russoly type was determined as uncorrected, corrected, or hypercorrected.

The obtained research results were processed using the descriptive statistics calculation (for quantitative variables, the average value is M, the standard deviation is m, the results were presented in the form M ± m; for ordinal variables, the frequencies of values and percentages relative to the number of valid observations were given. Also, the comparison of quantitative and qualitative signs in the studied groups of patients was performed. Distribution-free methods were used for the analysis. The differences between the compared average values of the studied parameters in the groups were assessed using the nonparametric Mann – Whitney U-test. Fisher's criterion was used to correlate the qualitative characteristics with each other. The relationship between the two features was measured using Spearman's correlation coefficient. The strength of the correlation coefficient relationships was considered by its interval scale (ρ): less than 0.19 – very weak connection, 0.20–0.29 – weak connection, 0.30–0.49 – moderate connection, 0.50–0.69 – average connection, more than 0.70 – strong connection level. The strength of relationship between the signs at least 0.3 was considered significant. The threshold level of statistical significance (p) was considered to be less than or equal to 0.05. The SPSS 15.0 software was used for statistical data processing.

Results

In Group I, there were 6 (22.22 %) men and 21 (77.78 %) women. The average age of the studied patients was 59.29 ± 8.69 (from 41 to 75). The average body mass index was 33.13 ± 3.39 (from 24.70 to 38.30) kg/m^2.

Group II included 1 (3.70 %) male and 26 (96.30 %) female patients. The average age was 59.63 ± 6.48 (from 41 to 73). Body mass index was 31.71 ± 3.39 (from 25.64 to 37.32) kg/m^2.

In Group I, 7 (25.93 %) patients underwent earlier surgery for degenerative discs disease, in Group II – -6 (22.22 %; p = 0.752506). Initially, monosegmental fusion was carried out at one of the lumbar levels (TPF in combination with or without interbody fusion). A repeated surgery was necessary due to the adverse outcome: pseudoarthrosis, loss of correction at the operative level, failure of instrumented fixation, aggravation of abnormal changes at adjacent levels.

The hospital stay from the day of surgery to the moment of discharge in Group I was 25.52 ± 8.60 (from 14 to 43) days versus 28.41 ± 6.48 (from 15 to 43) days in Group II (p = 0.063826).

The interval between the stages in Group II was in the range from 5 to 14 days (8.71 ± 2.76).

The complications happened in three patients between the surgery stages. These complications were a counterindication for the next stage during the period of their relief. Thus, they were not included in the calculation of the average inter-stage period. The next surgery stage was performed after 3 months. The surgery duration in Group I was 410.93 ± 76.34 min and was less than the total of all stages in Group II, in which this value was in the range of 594.63 ± 102.61 min (p = 0,000001). The average blood loss in Group I was 926.67 ± 378.63 ml, which is significantly less than the total volume in all surgery stages of Group II – 1345.19 ± 522.97 ml (p = 0.001575).

The levels and types of spinal fusion and screw fixation in patients of both groups are given in Table 1. The data given in the table shows that in the group of multistage surgical treatment more frequently required the involvement of a larger number of levels for screw and interbody (because of LLIF) stabilization.

The statistical analysis of clinical and radiological characteristics in the groups is given in Tables 2 and 3. The analysis data show a honestly significant improvement in all the assessed indicators in both groups.

There was no significant difference in the level of VAS pain in the back and leg at the end of surgical treatment before the patients were discharged from the hospital (p = 0.248647 and p = 0.196140, respectively). This fact was determined by the intergroup analysis. In comparison of the results of changes in radiological parameters, there were also no significant differences (p > 0.05), except for LL, which was significantly higher in the group of a single surgical treatment (p = 0.023654).

In the group of a single surgical treatment, types I and II according to Russoly were observed in 0 (0.00 %) cases, type III – in 18 (66.67 %), and type IV – in 9 (33.33 %). In the group of multistage surgical treatment, Russoly types I and II were found in 4 (14.81 %) patients, type III – in 14 (51.85 %) patients, and type IV - in 9 (33.33 %) patients. The restoration of the ideal Russoly type in Group I was reached in 19 (70.37 %) cases; in Group II – in 13 (48.15 %) cases. These data are comparable (p = 0.111476).

The reported complications were divided into 5 types: mechanical, infectious (surgical site infections), neurological, thromboembolic, etc (Table 4). The other complications included pneumonia, urinary tract infection, injury of large vessels, eventration of bowel loops, liquorrhea, and renal disease. There was no significant intergroup difference (p = 0.583171).

The number of reoperations in Group I was 5 (18.52 %). They were caused by SSI in 2 (7.41 %) patients and by migration of anterior interbody cages in 3 (11.11%) patients. In Group II, there were 3 (11.11 %) reoperations. There was only one case of small bowel loop eventration (3.70 %), and 2 cases (7.41 %) of anterior interbody implant migration. The inter-group comparison did not identify any significant differences on the basis of “reoperation due to a complication” (p = 0.447851).

In Group II, 3 (11.11 %) patients had complications which postponed the following surgery stages: two individuals (7.41 %) had PE, and in one patient (3.70 %) there was a thrombosis of the left iliac vein, which caused the second stage of the surgery to be performed after 3 months.

The patients’ distribution in groups according to the Charlson comorbidity index was as follows: low index – 8 (29.63 %) people in Group I versus one (3.70 %) in Group II (p = 0.011333); moderate – 12 (44.44 %) vs 20 (74.07 %), respectively (p = 0.028162); high – 7 (25.93 %) vs 6 (22.22 %), respectively (p = 0.516621).). After a comparative analysis of complications depending on the Charlson comorbidity level, it was determined that in patients with a high index in the group of one-stage surgical treatment, the complication rate was 100 % (a complication in each of 7 patients), in the group of multistage treatment – 40 % (p = 0.023471). In the correlation analysis, there was a significant relationship between the high Charlson comorbidity index and the total number of complications in the patients of the group of one-stage surgical treatment (Table 5). According to Mirza et al. [18], the value of the surgical invasiveness index is graded from 0 and higher at a pitch of 5. In the patients of the present study, it was in the range from 11 to 22 points. In groups I and II, 20 (74.07 %) patients and 5 patients ranked 11–15 points (18.52 %; p = 0.000050), respectively; 16–20 points – 6 (22.22 %) and 15 (55.56 %; p = 0.012813) individuals, respectively; 21–25 points - 1 (3.70 %) and 7 (25.93 %; p = 0.022786) patients, respectively. It is not possible to conduct a comparative inter-group analysis of the frequency of complications depending on the rank of the invasiveness index due to the small number and inconsistency of statistical material in the groups. Nevertheless, this dependence was found within the same group with a single surgical treatment (Table 5).

Discussion

Surgical treatment of adult patients with spinal deformities is characterized by the duration, high frequency of serious complications, and the need to use a combination of surgical techniques [13]. Regardless of the aggressiveness of such treatment, the life quality of patients significantly improves in comparison with conservative therapy [20–22]. Surgeries for spinal deformities are aimed at the reduction of pain syndrome and neurological manifestations [23]. Generally, this issue affects elderly and old senile patients who have a compromised comorbid status [10]. Thus, most surgeons, when it is necessary to use a combination of techniques, prefer to divide the treatment into stages carried out in different time periods. The reason for this technique is the reduction of simultaneous surgical injury, blood loss, and the risks of long-term anesthesia. Meanwhile, it is proven that the surgery duration is an independent risk factor for perioperative complications [24]. Nevertheless, the papers of recent years point to the inconsistency of the superiority of the single surgical treatment over the multistage one [11, 12, 25, 26]. The aim of this paper is to increase the contribution to the treatment issue of adult patients with spinal deformities. The comparative initial data and applied surgical techniques were reviewed, but performed either in a single or multistage surgical treatment.

There are various surgical techniques and approaches in the treatment of patients suffering from spinal deformities. Everything depends on many factors: the patient’s age, his comorbid status, the severity of deformity in one plane or another and the surgeon’s convictions. The aged patient’s appointment to a spine surgeon is associated with a significant pain syndrome or neurological manifestations. Despite the spinal deformities are always three-plane, as a rule, the main role in clinical manifestations development belongs to sagittal plane changes, which occur and worsen with the degenerative changes’ progression in the lumbar spine [27, 28]. Therefore, the key treatment of patients with this pathology is the restoration of a harmonious sagittal profile of the lumbar spine: LL is calculated based on the values of PI, and the lower – lumbar LL should be 2/3 of LL [10, 16, 29]. This method was used in the treatment of patients in the study. It was obtained by anterior lumbar interbody fusion at two lower lumbar levels (if necessary, it was combined with the direct lateral interbody fusion in the superjacent department of the spine), vertebrotomies of the posterior support elements, and TPF.

There are few papers concerning the comparative results of correction of spinal deformities in adults with a single and multistage techniques [6, 25, 30, 31]. Passias et al. [25] in their retrospective analysis of 142 patients ‘ data, the baseline of which was compared using the PSM method, found no difference

Table 1

Distributiont of patients of the studied groups by the number of levels and types of spinal fusion, n (%)

Characteristics	Group I (n = 27)	GroupII (n = 27)
Transpedicular fixation		
two levels	19 (70.37)	5 (18.52)
three levels	7 (25.93)	15 (55.56)
four levels	1 (3.70)	7 (25.93)
ALIF L4–L5, L5–S1	15 (55.56)	4 (14.81)
ALIF L4–L5 + LLIF L3–L4	4 (14.81)	1 (3.70)
ALIF L4–L5, L5–S1 + LLIF L3–L4	7 (25.93)	15 (55.56)
ALIF L4–L5, L5–S1 + LLIF L2–L3, L3–L4	1 (3.70)	7 (25.93)

Table 2

Clinical data analysis of patients of groups I and II

Groups	Characteristics	Before the surgery, points	After the surgery, points	p-level
I (n = 27)	VAS (back), points	6.44 ± 0.89	3.11 ± 0.97	0.00006*
	VAS (leg), points	4.59 ± 1.67	0.44 ± 0.69	0.00005*
	ODI, %	58.0 ± 8.78	–	–
II (n = 27)	VAS (back), points	6.89 ± 0.85	3.41 ± 0.89	0.00006*
	VAS (leg), points	4.78 ± 1.22	0.63 ± 0.56	0.000032*
	ODI, %	63.04 ± 6.55	–	–

* The changes are statistically significant.

between the groups in the six estimated indicators of sagittal balance after 6, 12 and 24 months. In the paper by Arzeno et al. [6], a large correction of the imbalance was found in the group of multistage treatment. The authors attributed this fact to a large number of performed osteotomies in these patients. While using a single surgical treatment, it was possible to achieve a greater correction of the deformity than with a multistage one. This data was provided from the earlier studies [30, 31]. Such contradictory data can be explained by the diversity of the studied patients and the use of different surgical techniques. In our study, there was no significant difference in the characteristics of the spinal-pelvic and global balance after surgical treatment in both groups: PT (p = 0.115965), SVA (p = 0.208449), LDI (p = 0.931646), PI-LL (p = 0.693045), GAP (p = 0.823504). The recovery rate of the ideal Russoli typeis also comparable between the groups (p = 0.111476).

High-evidence studies (level I and II) show that the life quality of operated patients with spinal deformities is significantly improved, despite the fact that it is associated with a high risk of serious complications [3, 4]. In one of the largest prospective multicenter studies, the authors identified a significant relationship between a number of indicators of the spino-pelvic and global balance (SVA, PT and PI-LL) and the patient life quality (ODI, SF-12, SRS-22r) [3]. The comparable data was found by Tarawneh et al. [4] in a meta-analysis. The evaluation of the treatment outcomes of more than 400 patients with adult scoliosis defined the achievement of a minimum clinically significant difference on the ODI and SRS scales. In the work of the above-mentioned group of authors [6], comparing the outcomes of multi- and one-stage surgical treatment, a significant and similar improvement in the life quality was observed between the groups. Also, there was an increase in the degree of functional adaptation of patients after 24 months. The evaluation was performed by the following scales: ODI, SF - 36 PCS, SF-36 MCS and SRS Total scores ($p > 0.05$). Our study was limited by the length of hospital stay, and at the time of discharge, a number of patients needed pain management what could affect the true values of the data. That is why it would be incorrect to present an analysis to assess the life quality. However, according to the VAS scale (back and leg pain), there was a significant improvement in the groups after surgery (Group I: p = 0.00006 and p = 0.00005, respectively; Group II: p = 0.00006 and p = 0.000032, respectively).

A high-quality research paper is characterized by a study based on comparable preoperative clinical and radiological indicators. This approach to research minimizes the risks of bias and systematic errors [25]. The authors, who study the surgery treatment of patients with spinal deformities and conduct studies of

Table 3

Assessment of changes in the sagittal balance characteristics in patients of groups I and II

Characteristics	Group I (n = 27)			Group II (n = 27)			Groups I and II after the surgery, p-level
	Before the surgery	After the surgery	p-level	Before the surgery	After the surgery	p-level	
PI, deg.	60.81 ± 9.58	–	–	53.04 ± 12.11	–	–	–
PT, deg.	26.22 ± 6.20	18.19 ± 3.84	0.00006*	25.89 ± 5.40	16.67 ± 4.04	0.00006*	0.115965
SVA, sm	5.73 ± 3.57	2.45 ± 2.46	0.00004*	7.69 ± 3.57	3.17 ± 2.20	0.00047*	0.208449
LL, deg.	41.70 ± 17.05	58.04 ± 11.60	0.00056*	29.59 ± 18.53	51.33 ± 11.12	0.00036*	0.023654*
LDI, %	43.52 ± 14.79	68.07 ± 11.81	0.00011*	30.22 ± 23.45	69.0 ± 10.05	0.00047*	0.931646
PI-LL, deg.	19.11 ± 15.32	2.78 ± 9.88	0.00003*	23.44 ± 12.87	1.70 ± 7.96	0.00003*	0.693045
GAP							
0–2 points	0 (0.00 %)	13 (48.15 %)		–	14 (51.85 %)		
3–6 points	17 (62.96 %)	14 (51.85 %)	0.000062*	8 (29.63 %)	13 (48.15 %)	0.000003*	0.823504
More than 7 points	10 (37.04 %)	0 (0.00 %)		19 (70.37 %)	–		

* The changes are statistically significant.

Table 4

Types of complications in patients from groups I and II, n (%)

Complications	Group I (n = 27)	Group II (n = 27)	p-level
Mechanical	4 (14.81)	2 (7.41)	0.390910
Infectious	2 (7.41)	0 (0.00)	0.153366
Neurological	2 (7.41)	5 (18.52)	0.228553
Thromboembolic	5 (18.52)	3 (11.11)	0.447851
Other	5 (18.52)	7 (25.93)	0.516621
Number of patients with complications	17 (62.96)	15 (55.56)	0.583171

The changes are statistically significant.

a design similar to ours, focus on the following peculiarities: perioperative complications, intraoperative blood loss, the surgery duration, and the length of hospital stay.

Maddox et al. [26] assessed the surgical findings of two cohorts of patients with staged (n = 52) and non-staged (n = 90) treatment operated only from the dorsal approach. The authors revealed a greater blood loss (4269 ml vs. 3405 ml) and, in this regard, a more frequent need for hemotransfusion in the group of multistage treatment. Moreover, they indicated a longer stay in the ICU (3.1 vs. 2.2 days.). However, the total number of perioperative complications and the length of hospital stay did not differ significantly between the groups. Passias et al. [25] noted a long duration of the operation (679.8 minutes vs. 378.0 minutes; $p < 0.001$) and the length of hospital stay (19.0 days vs. 7.2 days; $p < 0.001$) in the group of multi - stage surgery. There were no differences in intraoperative blood loss and the frequency of major and minor complications in the groups. However, in assessing the frequency of perioperative complications, depending on the interval between stages (1–3 days vs. 4–30 days), a greater number of them were revealed during the 2nd stage of the surgery later than 4 days (44 % vs. 17 %; $p = 0.011$). Arzeno et al. [6] performed a study similar to the above, except that the interval between the stages in the multistage treatment group was less than three days, compared with the results of the group in which the surgery was single. Following a regression analysis, the authors did not reveal a significant increase in the postoperative bed day, the total number of complications and reoperations in the multistage surgery group ($p > 0.05$). Nevertheless, the total duration of the surgery and blood loss were significantly higher in this group ($p < 0.05$).

In this study, a greater total blood loss ($p = 0.001575$) and the surgery duration ($p = 0.000001$) were found in the multistage treatment group). While the length of hospital stay was higher in the multistage surgery group, it was not statistically different ($p = 0.063826$). The total number of complications and reoperations in the group of single surgical treatment was higher (by 7.40 % and 7.47%, respectively), but there was no statistically significant difference ($p = 0.583171$ and $p=0.447851$, respectively). The analysis of the complication dependence on the Charlson comorbidity level showed a significantly higher number of them with a high index in the group of a single surgical treatment ($p = 0.023471$). There was a significant correlation between the Mirza invasiveness index and the total number of complications in the same group. One of the disadvantages of the multistage approach is the probability of complications which can significantly enhance the period between surgeries or cause a reoperation. Three patients in our study suffered from thromboembolic complications (PE, iliac vein thrombosis). For this reason, the next surgical stage was performed after 3 months. The greatest number of reoperations is due to the anterior migration of the cages at the ALIF level, which was associated with the compression of large vessels or the loss of achieved correction. We can conclude that the following factors were the starting point of the complication: the hyperlodotic shape of cage (the maximum determinants for its squeezing from the

Table 5

Correlation of the total number of complications with the Charlson comorbidity index and the Mirza invasiveness index in patient groups

Characteristics	Total number of complications	
	Group I: n = 17 (62,96 %)	Group II: n = 15 (55,56 %)
Invasiveness index		
11–15 points	0.421332*; 15 (55.56 %)	0.234521; 4 (14.81 %)
16–20 points	-0.327968*; 2 (7.41 %)	-0.200000; 7 (25.93 %)
21–25 points	-0.255704; 0 (0.00 %)	0.018898; 4 (14.81 %)
Charlson Comorbidity Index		
Low	-0.174185; 4 (14.81 %)	0.175412; 1 (3.70 %)
Moderate	-0.240098; 6 (22.22 %)	-0.018898; 11 (40.74 %)
High	0.453743*; 7 (25.93 %)	-0.149241; 3 (7.41 %)

* The changes are statistically significant.

interbody space, especially at the lower lumbar levels); relatively poor natural adhesion of the cage to the bone tissue of the vertebrae (the PEEK implant material, the contact surface of the cage is weakly eroded to adhere to the end plate of the vertebral body); the lack of conditions preventing the cage displacement (the implant design did not provide the fixing elements in the form of perforated plates or screws, as well as anterior fixing plates were not used).

The limitations of our work include the following: a retrospective non-randomized monocenter study, the lack of comparison of groups by the PSM method due to the limited amount of clinical material, and the period of observation of patients (the length of hospital stay). The evidence level of this study according to SIGN (the Scottish Intercollegiate Organization for the Development of Clinical Recommendations) is 2-.

Conclusion

The combined corrective surgeries with obligatory anterior spinal fusion with hyperlordotic cages at the lower lumbar levels in patients with sagittal imbalance of degenerative genesis are associated with a high frequency of perioperative complications. Nevertheless, they can significantly improve the indicators of the spino-pelvic and global balance in the early postoperative period.

One- and multistage techniques for the sagittal balance correction are similar according to the clinical and radiological results in the early postoperative period and the total number of perioperative complications. The total duration of surgery and the intraoperative volume of blood loss are significantly higher with a multi-stage treatment option.

The multistage approach to the treatment of patients with sagittal imbalance is advantageous when the Charlson comorbidity index, as well as the Mirza surgical invasiveness index are high.

We believe that further highly-proven studies are necessary to specify the indications for single-and multistage techniques in the treatment of patients with sagittal imbalance of degenerative etiology.

The study had no sponsorship. The authors declare no conflict of interest.

References

1. **Vasilyev AI.** Degenerative scoliosis: literature review. Hir. Pozvonoc. 2016;13(4):56–65. In Russian.
2. **Saigal R, Mundis GM Jr, Eastlack R, Uribe JS, Phillips FM, Akbarnia BA.** Anterior Column Realignment (ACR) in adult sagittal deformity correction: technique and review of the literature. Spine. 2016;41(Suppl 8):S66–S73. DOI: 10.1097/BRS.0000000000001483.
3. **Schwab FJ, Blondel B, Bess S, Hostin R, Shaffrey CI, Smith JS, Boachie-Adjei O, Burton DC, Akbarnia BA, Mundis GM, Ames CP, Kebaish K, Hart RA, Farcy JP, Lafage V.** Radiographical spinopelvic parameters and disability in the setting of adult spinal deformity: a prospective multicenter analysis. Spine. 2013;38:E803–E812. DOI: 10.1097/BRS.0b013e318292b7b9.
4. **Tarawneh AM, Venkatesan M, Pasku D, Singh J, Quraishi NA.** Impact of pedicle subtraction osteotomy on health-related quality of life (HRQOL) measures in patients undergoing surgery for adult spinal deformity: a systematic review and meta-analysis. Eur Spine J. 2020;29:2953–2959. DOI: 10.1007/s00586-020-06439-y.
5. **Wang G, Hu J, Liu X, Cao Y.** Surgical treatments for degenerative lumbar scoliosis: a meta analysis. Eur Spine J. 2015;24:1792–1799. DOI: 10.1007/s00586-015-3942-x.
6. **Arzeno AH, Koltsov J, Alamin TF, Cheng I, Wood KB, Hu SS.** Short-term outcomes of staged versus same-day surgery for adult spinal deformity correction. Spine Deform. 2019;7:796–803.e1. DOI: 10.1016/j.jspd.2018.12.008.
7. **Cheng I, Stienen MN, Medress ZA, Varshneya K, Ho AL, Ratliff JK, Veeravagu A.** Single- versus dual-attending strategy for spinal deformity surgery: 2-year experience and systematic review of the literature. J Neurosurg Spine. 2020;33:560–571. DOI: 10.3171/2020.3.SPINE2016.
8. **Scheer JK, Tang JA, Smith JS, Klineberg E, Hart RA, Mundis GM Jr, Burton DC, Hostin R, O'Brien MF, Bess S, Kebaish KM, Deviren V, Lafage V, Schwab F, Shaffrey CI, Ames CP.** Reoperation rates and impact on outcome in a large, prospective, multicenter, adult spinal deformity database: clinical article. J Neurosurg Spine. 2013;19:464–470. DOI: 10.3171/2013.7.SPINE12901.
9. **Soroceanu A, Burton DC, Diebo BG, Smith JS, Hostin R, Shaffrey CI, Boachie-Adjei O, Mundis GM Jr, Ames C, Errico TJ, Bess S, Gupta MC, Hart RA, Schwab FJ, Lafage V.** Impact of obesity on complications, infection, and patient-reported outcomes in adult spinal deformity surgery. J Neurosurg Spine. 2015;23:656–664. DOI: 10.3171/2015.3.SPINE14743.
10. **Klimov VS, Vasilenko II, Evsyukov AV, Khalepa RV, Amelina EV, Ryabykh SO, Rzaev DA.** The use of LLIF technology in adult patients with degenerative scoliosis: retrospective cohort analysis and literature review. Genij Ortopedii. 2018;24(3):393–403. In Russian. DOI: 10.18019/1028-4427-2018-24-3-393-403.
11. **Passias PG, Klineberg EO, Jalai CM, Worley N, Poorman GW, Line B, Oh C, Burton DC, Kim HJ, Sciubba DM, Hamilton DK, Ames CP, Smith JS, Shaffrey CI, Lafage V, Bess S.** Hospital readmission within 2 years following adult thoracolumbar spinal deformity surgery: prevalence, predictors, and effect on patient-derived outcome measures. Spine. 2016;41:1355–1364. DOI: 10.1097/BRS.0000000000001552.
12. **Schwab FJ, Hawkinson N, Lafage V, Smith JS, Hart R, Mundis G, Burton DC, Line B, Akbarnia B, Boachie-Adjei O, Hostin R, Shaffrey CI, Arlet V, Wood K, Gupta M, Bess S.** Risk factors for major peri-operative complications in adult spinal deformity surgery: a multi-center review of 953 consecutive patients. Eur Spine J. 2012;21:2603–2610. DOI: 10.1007/s00586-012-2370-4.
13. **Passias PG, Ma Y, Chiu YL, Mazumdar M, Girardi FP, Memtsoudis SG.** Comparative safety of simultaneous and staged anterior and posterior spinal surgery. Spine. 2012;37:247–255. DOI: 10.1097/BRS.0b013e31821350d0.
14. **Rhee JM, Bridwell KH, Lenke LG, Baldus C, Blanke K, Edwards C, Berra A.** Staged posterior surgery for severe adult spinal deformity. Spine. 2003;28:2116–2121. DOI: 10.1097/01.BRS.0000090890.02906.A4.
15. **Byvaltsev VA, Kalinin AA, Ryabykh SO, Burtsev AV, Shepelev VV, Ochkal SV, Polkin RA, Biryuchkov MYu.** Simultaneous surgical interventions in spinal neurosurgery: a systematic review. Genij Ortopedii. 2020;20(2):275–281. In Russian]. DOI: 10.18019/1028-4427-2020-26-2-275-281.
16. **Le Huec JC, Hasegawa K.** Normative values for the spine shape parameters using 3D standing analysis from a database of 268 asymptomatic Caucasian and Japanese subjects. Eur Spine J. 2016;25:3630–3637. DOI: 10.1007/s00586-016-4485-5.
17. **Roussouly P, Pinheiro-Franco JL.** Biomechanical analysis of the spino-pelvic organization and adaptation in pathology. Eur Spine J. 2011;20 Suppl 5:609–618. DOI: 10.1007/s00586-011-1928-x.
18. **Mirza SK, Deyo RA, Heagerty PJ, Konodi MA, Lee LA, Turner JA, Goodkin R.** Development of an index to characterize the "invasiveness" of spine surgery: validation by comparison to blood loss and operative time. Spine. 2008;33:2651–2662. DOI: 10.1097/BRS.0b013e31818dad07.
19. **Pizones J, Moreno-Manzanaro L, Sanchez Perez-Grueso FJ, Vila-Casademunt A, Yilgor C, Obeid I, Alanay A, Kleinstuck F, Acaroglu ER, Pellise F.** Restoring the ideal Roussouly sagittal profile in adult scoliosis surgery decreases the risk of mechanical complications. Eur Spine J. 2020;29:54–62. DOI: 10.1007/s00586-019-06176-x.
20. **Teles AR, Mattei TA, Righesso O, Falavigna A.** Effectiveness of operative and nonoperative care for adult spinal deformity: systematic review of the literature. Global Spine J. 2017;7:170–178. DOI: 10.1177/2192568217699182.
21. **Scheer JK, Smith JS, Clark AJ, Lafage V, Kim HJ, Rolston JD, Eastlack R, Hart RA, Protopsaltis TS, Kelly MP, Kebaish K, Gupta M, Klineberg E, Hostin R, Shaffrey CI, Schwab F, Ames CP.** Comprehensive study of back and leg pain improvements after adult spinal deformity surgery: analysis of 421 patients with 2-year follow-up and of the impact of the surgery on treatment satisfaction. J Neurosurg Spine. 2015;22:540–553. DOI: 10.3171/2014.10.SPINE14475.
22. **Mikhaylov DA, Ptashnikov DA, Usikov VD, Masevnin SV, Hao Meng.** Topical issues of treatment of degenerate scoliosis at the present stage (review). Traumatology and orthopedics of Russia. 2014;(4):127–134. In Russian.
23. **Shishkova VN.** Comorbidity and polypharmacy: focus on cytoprotection. Consilium Medicum. 2016;18(12):73–79. In Russian.
24. **Kim BD, Hsu WK, De Oliveira GS, Saha S, Kim JYS.** Operative duration as an independent risk factor for postoperative complications in single-level lumbar fusion. Spine. 2014;39:510–520. DOI: 10.1097/BRS.0000000000000163.
25. **Passias PG, Poorman GW, Jalai CM, Line B, Diebo B, Park P, Hart R, Burton D, Schwab F, Lafage V, Bess S, Errico T.** Outcomes of open staged corrective surgery in the setting of adult spinal deformity. Spine J. 2017;17:1091–1099. DOI: 10.1016/j.spinee.2017.03.012.
26. **Maddox JJ, Pruitt DR, Agel J, Bransford RJ.** Unstaged versus staged posterior-only thoracolumbar fusions in deformity: a retrospective comparison of perioperative complications. Spine J. 2014;14:1159–1165. DOI: 10.1016/j.spinee.2013.07.485.
27. **Gelb DE, Lenke LG, Bridwell KH, Blanke K, McEnery KW.** An analysis of sagittal spinal alignment in 100 asymptomatic middle and older aged volunteers. Spine. 1995;20:1351–1358.
28. **Korovessis P, Stamatakis M, Baikousis A.** Segmental roentgenographic analysis of vertebral inclination on sagittal plane in asymptomatic versus chronic low back pain patients. J Spinal Disord. 1999;12:131–137.

29. **Yilgor C, Sogunmez N, Boissiere L, Yavuz Y, Obeid I, Kleinstuck F, Perez-Grueso FJS, Acaroglu E, Haddad S, Mannion AF, Pellise F, Alanay A.** Global Alignment and Proportion (GAP) score: development and validation of a new method of analyzing spinopelvic alignment to predict mechanical complications after adult spinal deformity surgery. J Bone Joint Surg Am. 2017;99:1661–1672. DOI: 10.2106/JBJS.16.01594.
30. **Dick J, Boachie-Adjei O, Wilson M.** One-stage versus two-stage anterior and posterior spinal reconstruction in adults. Comparison of outcomes including nutritional status, complication rates, hospital costs, and other factors. Spine. 1992;17(8 Suppl):310–316. DOI: 10.1097/00007632-199208001-00017.
31. **Shufflebarger HL, Grimm JO, Bui V, Thomson JD.** Anterior and posterior spinal fusion. Staged versus same-day surgery. Spine. 1991;16:930–933. DOI: 10.1097/00007632-199108000-00011.

Address correspondence to:
Baikov Evgeny Sergeyevich
Novosibirsk Research Institute of Traumatology and Orthopaedics n.a. Ya.L. Tsivyan,
17 Frunze str., Novosibirsk, 630091, Russia,
Evgen-bajk@mail.ru

Received 24.11.2020
Review completed 31.03.2021
Passed for printing 07.04.2021

Evgeny Sergeyevich Baikov, MD, PhD, Head of the Neurosurgical Department No. 2, Novosibirsk Research Institute of Traumatology and Orthopaedics n.a. Ya.L. Tsivyan, 17 Frunze str., Novosibirsk, 630091, Russia, ORCID: 0000-0002-4430-700X, Evgen-bajk@mail.ru;
Aleksey Vladimirovich Peleganchuk, MD, PhD, trauma orthopaedist, Neurosurgical Department No. 2, Novisibirsk Research Institute of Traumatology and Orthopaedics n.a. Ya.L. Tsivyan, 17 Frunze str., Novosibirsk, 630091, Russia, ORCID: 0000-0002-4588-428X, APeleganchuk@mail.ru;
Abdugafur Jabborovich Sanginov, MD, PhD, neurosurgeon, Neurosurgical Department 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 Nikolayevna Leonova, MD, PhD, researcher, Novosibirsk Research Institute of Traumatology and Orthopaedics n.a. Ya.L. Tsivyan, 17 Frunze str., Novosibirsk, 630091, Russia, ORCID: 0000-0002-9916-3947, onleonova@gmail.com;
Aleksandr Vladimirovich Krutko, DMSc, 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.