SURGICAL CORRECTION OF DEGENERATIVE SAGITTAL IMBALANCE OF THE LUMBAR SPINE

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Objective. To analyze the early clinical and radiological outcomes of lumbar spine fusion in patients with degenerative sagittal imbalance.
Material and Methods. The data of 45 patients who were operated on sequentially using a combination of surgical methods for vertebrogenic pain syndrome and (or) neurological deficit and who had a violation of the sagittal balance of degenerative origin were analyzed. All patients underwent anterior spinal fusion at the L4–L5, L5–S1 levels to correct and restore lower lumbar lordosis. The next stage was decompression through posterior approach, if necessary supplemented by interbody fusion at clinically significant lumbar levels above the L4–L5 segment. In all patients, surgical treatment was completed with screw transpedicular fixation at the levels of interbody fusion. Demographic, clinical and surgical data, and radiological parameters were evaluated.
Results. The study included data from 6 men and 39 women with an average age of 58.9 ± 7.8 years. Duration of hospital stay was 27.1 ± 7.4 days. The primary surgery was performed in 33 (73.3 %) patients, and the reoperation for pain recurrence after previous surgery at the same lumbar level – in 12 (26.7 %) patients. The duration of surgery was 529.8 ± 117.8 min, the blood loss was 1130.4 ± 560.1 ml. Back and leg pain VAS score decreased after surgery from 6.7 ± 0.9 and 4.7 ± 1.4 to 3.3 ± 0.9 and 0.5 ± 0.6, respectively ($p < 0.001$). The ideal sagittal type according the Russoly's classification was restored in 27 (60 %) cases, that below the ideal – in 9 (20 %), and hypercorrection was in 9 (20 %). PT decreased from 26.1° ± 5.7° to 17.4° ± 3.9° ($p < 0.001$) and SVA – from 6.7 ± 3.5 to 2.7 ± 2.3 cm ($p < 0.001$). LL increased from 36.3° ± 18.5° to 55.1° ± 11.8° ($p < 0.001$) and Low LL – from 13.5° ± 9.8° to 37.9° ± 8.2° ($p < 0.001$). According to GAP, the number of patients with severe and moderate imbalance was reduced ($p < 0.001$). Surgical complications were observed in 26 (57.7 %) patients.
Conclusion. The multi-stage surgical treatment of patients with degenerative spinal deformities using corrective fusion in the lumbar spine significantly improves parameters of the spinopelvic and global sagittal balances in the early postoperative period.
Key Words: spinal deformity, degenerative scoliosis, sagittal balance.
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The balance of spinal curvatures is vitally important for proper physiologic functioning, allowing humans to maintain their bodies in an upright position with minimum energy consumption by the muscular system [1]. The lumbar spine is of particular importance, it is the main load-bearing part of the spine. The decrease in lumbar lordosis with the age is directly correlated to intervertebral disc degeneration and development of pain syndrome [2, 3]. It is known that quality of life in aged patients is significantly correlated to changes in the sagittal plane [4, 5]. In recent decades, life expectancy of the population has been increasing, so grows the number of patients requiring surgical assistance for vertebral deformity [6].

There are various surgical methods to correct sagittal imbalance in aged patients with vertebral deformity. Conventional methods are interventions through posterior approaches. Three-column osteotomies (e.g., PSO) give a greater correction of lordosis (ranging up to 35° per osteotomy level) contrary to posterior column osteotomies having a more limited power of correction (in the range of 8–10° per level), which is insufficient in some cases [7]. At the same time, three-column osteotomies are extremely traumatizing and bear a high risk of severe complications [8]. It is not always possible to use this technique in combination with posterior screw fixation in order to improve lumbar lordosis and to restore the ideal type according to the Roussouly's classification and lordosis distribution index, thus resulting in postoperative mechanical complications [9, 10].

Lordosis at the L4–L5, L5–S1 levels makes up approximately 70 % of the total lumbar lordosis and is the main parameter forming the optimal sagittal balance [11]. So, a corrective impact on the lower lumbar spine is one of the key moments in surgical treatment of patients with sagittal imbalance. A combination of approaches involving anterior interbody fusion with hyperlordotic cages at the lower lumbar levels, lateral and/or transforaminal (banana-shaped cage) fusion at the middle and upper lumbar levels, posterior screw fixation, posterior column osteotomies makes it possible to effectively correct multiplanar spinal deformities of degenerative nature with the predominant lesion in the sagittal plane. This approach makes it possible to avoid disadvantages of three-column osteotomies. These methods can be performed through minimally invasive approaches, so there is a possibility to separate these stages and significantly reduce the degree of an instantaneous surgical injury. This aspect is important for treatment of elderly patients.

The objective of the study was to analyze the early clinical and radiological outcomes of lumbar spine fusion in patients with degenerative sagittal imbalance.

The design of the study: a retrospective monocenter study.

Material and Methods

Forty-five medical records of adult inpatients who had been operated on the lumbar spine during the period from January, 2017 to December, 2019 were analyzed. The indications for surgical intervention were vertebrogenic pain syndrome combined with nerve root compression syndrome and/or neurological deficit, neurogenic intermittent claudication syndrome, resistant to conservative treatment. The morphological substrate of clinical manifestations is degenerative spinal stenosis in the lumbar spine combined with sagittal imbalance requiring correction at the lower lumbar level (Low LL) of at least 20°. All the patients had degenerative sagittal imbalance corresponding to at least one of the following parameters: sagittal vertical axis (SVA) > 5 cm, pelvic incidence (PI–LL) > 10°, pelvic tilt (PT) > 20°, lordosis distribution index (LDI) < 40 %. According to SRS-Schwab classification, all the patients had type N curve (scoliotic curve < 30°).

All the patients underwent anterior interbody fusion with hyperlordotic cages at the L4–L5 and/or L5–S1 levels in order to normalize parameters of the sagittal balance. If an additional correction was necessary or in the presence of the morphological substrate of clinical and neurological manifestations, the treatment strategy at the planning stage foresaw the extension of screw fixation and interbody fusion to the L2–L3, L3–L4 levels. In such cases, direct lateral or transforaminal interbody fusion was performed. Decompression was carried out at clinically significant levels. SRS-Schwab Grade 1 or 2 osteotomy was performed at all levels of spinal fusion. Staged surgical treatment had one or several surgical sessions every 7–10 days. This approach is based on the assessment of the patient's physical status in order to reduce surgery duration, volume of instantaneous surgical injury, and related incidence of perioperational complications.

The follow-up period was the entire period of patient's hospitalization. The demographic, clinical and surgical data, as well as radiological parameters were evaluated. The radiological and clinical data were analyzed before the surgical intervention and at the day before the discharge because in this period, there were minimal need in anesthetic agents which impacted the reliability of the findings obtained.

The demographic data included age, sex, body mass index, and length of hospital stay. The clinical data included back and leg pain VAS scores before the surgery and before the discharge, ODI before the surgery. The data related to surgical intervention included type of operation (primary, reoperation), the overall time of the all surgery stages, the overall volume of blood loss, the levels of surgical intervention, intra- and postoperative complications.

Before the surgery, the examination included functional radiography of the lumbar spine (flexion and extension in the lateral projection); radiography of the spine in the upright position in the customary pose, in two standard projections from C0 to the middle one-third of the femoral bones, with hands located on the contralateral collar bones, MRI and MSCT of the lumbar spine. After the surgery, the examination included radiography of the spine in the upright position in the customary pose, in two standard projections from C0 to the middle one-third of the femoral bones, with hands located on the contralateral collar bones, and, if necessary, MSCT and/or MRI of the lumbar spine.

The following radiological parameters were analyzed: PI, PT, SVA, lumbar lordosis (LL), Low LL (Low lumbar lordosis L4–S1), PI–LL, type according to the Roussouly's classification, Global Alignment and Proportion (GAP). Type according to the Roussouly's classification was determined in each patient using the following PI scale: PI < 45° (type I and II), PI 45–60° (type III), and PI > 60° (type IV) [9]. According to Pizones et al. [9], after surgery, types according to the Roussouly's classification were determined as mismatch, match or overcorrection.

The calculations were individualized on the basis of the data of the constant parameter PI. The assessment of the sagittal profile parameters according to GAP [12] is presented in Table 1.

The obtained data were processed using descriptive statistics (for quantitative variables, the mean value M, standard deviation m, results in the form of M ± m; for ordinal variables, there were given frequencies of values and percentage shares relative to the number of valid observations) and by comparison of quantitative and qualitative attributes in the studied groups of patients. Nonparametric methods were used for analysis. Differences between the compared average values of the studied parameters in the groups were evaluated using non-parametric Mann–Whitney U test. The relationship between the qualitative attributes was analyzed using F-test. The interrelation between the two attributes was assessed using Spearman rank correlation analysis. The character of the strength of relationship of the correlation coefficient was taken into account as strong using the following interval scale of values (ρ): 0.70. The relationship between the attributes was considered to be significant at ⩾ 0.3. The threshold statistical significance level (p) was set at ⩽ 0.05. The SPSS 15.0 software package was used for statistical processing.

Results

The cohort consisted of six male and 39 female patients. The average age of the studied patients was 58.9 ± 7.8 years (range, from 41 to 75 years). The average body mass index was 32.2 ± 3.5 kg/m^2 (from 24.7 to 38.3 kg/m^2). The postoperative length of stay was 27.1 ± 7.4 days (from 15 to 43 days).

Thirty-three (73.3 %) patients underwent primary surgical intervention. In 12 (26.7 %) cases, spinal fusion was performed earlier at one of the lower lumbar levels, including TLIF and transpedicular fixation (TPF) at the L4–L5 level (four cases), at the L5–S1 level (two cases); PLIF and TPF at the L4–L5 level (two cases), at the L5–S1 level (two cases); TPF and posterior spinal fusion using autobone graft at the L4–L5 level (one case), and at the L5–S1 level (one case). Unsatisfactory outcomes of previous surgeries were caused by pseudoarthrosis, loss or failed reconstruction of optimal segmental interrelations, or failure of transpedicular fixation devices.

ALIF and TPF at the L4–L5 and/or L5–S1 levels were carried out in 15 (33.3 %) patients; ALIF and TPF supplemented with direct lateral interbody fusion (DLIF) at the L2–L3 and/or L3–L4 levels were performed in 21 (46.7 %) patients; DLIF at the single level, in 15 (33.3%) patients, at two levels, in six (13.3 %) patients; ALIF and TPF supplemented with TLIF at the L3–L4 level only, in nine (20.0 %) patients. All 45 patients underwent TPF. Two-level fixation was performed in 21 (46.7 %) cases; three-level fixation, in 18 (40.0 %); and four-level fixation, in six (13.3 %) cases.

The overall duration of all stages of surgical intervention was 529.8 ± 117.8 min (from 335 to 690 min) per a patient, the average blood loss was 1130.4 ± 560.1 ml (from 550 to 2250 ml). Intra- and postoperative hemotransfusion was performed in four (8.9 %) patients.

After surgery, the clinical parameters according to VAS score were improved sufficiently. Assessment according to ODI was not carried out after surgery because of its non-informative value and non-reproducibility in the given period (Table 2).

Types I and II according to the Roussouly's classification were identified in three (6.7 %) patients; type III, in 27 (60.0 %); and type IV, in 15 (33.3 %) patients. The restoration of the ideal type according to the Roussouly's classification was observed in 27 (60.0 %) cases; type lower than ideal, in nine (20.0 %); and hypercorrection, in nine (20.0 %) cases.

Pre- and postoperative parameters of PT, SVA, LL, Low LL, and GAP were improved significantly after surgical interventions. Data of the statistical analysis are presented in Table 3.

According to the correlation analysis data, a significant relationship was identified between preoperative (back pain VAS score with PI–LL, LDI, GAP; leg pain VAS score with PT and GAP) and postoperative (leg pain VAS score with LDI and GAP) clinical and radiological parameters (Tables 4 and 5).

Twenty-six (57.7 %) patients had intraoperative and early postoperative complications (Table 6). Reoperations were required in six (13.3 %) cases, including three (6.7 %) surgery interventions due to mechanical complications.

A clinical example of a surgical treatment is shown in Figure.

Discussion

The study demonstrates possible combinations of surgical methods in a series of 45 adult patients with violation of sagittal balance of degenerative origin. Anterior interbody spinal fusion with the use of hyperlordotic cages at the lower lumbar levels, in some cases, was supplemented with lateral or transforaminal spinal fusion at the middle and upper lumbar levels. Thus, both radiological (PI,

Table 1

Calculation of the sagittal profile violation according to GAP [12]

Parameters	Categories	Points	Proportionality type
RPV = measured SS – ideal SS; ideal SS = PI 0.59 + 9	<-15 – severe retroversion	3	0–2 – proportional; 3–6 – moderately disproportional; > 7 – severely disproportional;
	15–7.1 – moderate retroversion	2	
	7–5 – aligned	0	
	>5 – anteversion	1	
RLL = measured LL – ideal LL; ideal LL = PI 0.62 + 29	<-25 – severe hypolordosis	3	
	25–14.1 – moderate hypolordosis	2	
	14–11 – aligned	0	
	>11 – hyperlordosis	3	
LDI = L4–S1 LL/L1–S1 LL 100	<40 % – severe hypolordosis	2	
	40–49 % – moderate hypolordosis	1	
	50–80 % – aligned	0	
	>80 % –hyperlordotic maldistribution	3	
RSA = measured GT – ideal GT; ideal Global Tilt = PI 0.48 – 15	>18 – severe positive malalignment	3	
	18–10.1 – moderate positive malalignment	1	
	10–7 – aligned	0	
	<-7.1 – negative malalignment	1	
Age, years	<60 – adult	0	
	>60 – elderly	1	

RPV – relative pelvis position, RLL – relative lumbar lordosis, LDI – lordosis distribution index, RSA – relaive spinopelvic alignment.

PT, SVA, LL, Low LL (L4–S1), PI–LL, and GAP) and clinical parameters (back and leg pain VAS scores) were significantly improved.

The number of aged patients with spinal deformities increases with every passing year with the increase of the knowledge and experience in the spinal surgery and enhancement of anesthetic facilities. These patients undergo decompression, stabilization and deformity correction [5, 6].

Three-column osteotomies (PSO) are the most frequently used techniques to treat patients with spinal deformities, predominantly in the sagittal plane due to their better correction possibilities [7]. At the same time, according to Carreon et al. [13], major surgical complications occurred in 38 % [14, 15], and major repeat surgery was performed in 28% [15] within a five-year follow-up period. Combinations of surgical techniques (anterior, posterior, lateral) at the lumbar spine, including minimally invasive approaches, are as good as PSO in terms of corrective opportunities. They can also significantly reduce instantaneous surgical injury and intraoperative blood loss [16].

It is known that lordosis at the lower lumbar (L4–S1) levels normally constitutes up to 2/3 of the total lumbar lordosis [11]. This level is the lever fulcrum of the spinal column. Even minimal exposure to this very region is able to have a sufficient correction impact on the whole kinematic chain of the spine. In their study, Pizones et al. [9] revealed the interrelation between mechanical complications and recovery of the ideal Roussouly's type based on PI. They found that adult scoliosis patients with postoperative Roussouly's type higher than ideal suffered mechanical complications in 77.4 % of cases, lower than ideal – in 58.3 %, and with the restored ideal type – in 15.1 %. So, the restoration of the harmonic sagittal profile is one of the key tasks for surgical treatment of adult patients with spinal deformities. It is not always possible to adhere to the above mentioned principle using PSO because of the level of its implementation. In some cases, it can be achieved with the use of hyperlordotic cages at the lower lumbar levels or insertion of large lordotic cages at the middle lumbar spine.

The application of hyperlordotic cages was assessed in a series of recent studies. Saville et al. [17] used cages with lordotic angle of 20° and 30° in 41 patients with spinal deformities. The overall mean lumbar lordosis increased from 39° to 59°. The mean sagittal vertical axis (SVA) reduced from 113 mm to 43 mm. In a similar study of Hosseini et al. [18], lumbar lordosis increased from 34.9° to 46.7°, SVA decreased from 79 mm to 34 mm. In the multicenter study of Turner et al. [19], lumbar lordosis increased from 26.7° to 50.8°. The authors assessed the role of posterior column osteotomy in anterior spinal fusion. It increased the segmental angle by 18.7° compared to 12.8° without it. In the literature, there are many works comparing methods of spinal fusion. However, we concentrated our attention to correction interventions (with the necessity to achieve at least 20° of correction) as the most effective technique to restore parameters of sagittal balance. In our study, we assessed parameters in patients who had undergone multistage surgical treatment. The principle component of the surgery was correction of lower lumbar lordosis using spinal fusion at the L4–L5, L5–S1 levels.

Table 2

Clinical data according to VAS score and ODI

Parameters	Before surgery	At the discharge after surgery	P value
VAS score: back pain	6.7 ± 0.9	3.3 ± 0.9	<0.001
VAS score: leg pain	4.7 ± 1.4	0.5 ± 0.6	<0.001
ODI	60.4 ± 8.0	–	–

Table 3

Results of the analysis of the radiological data

Parameters		Before surgery	After surgery	P value
PI		57.3 ± 11.7	–	–
PT		26.1 ± 5.7	17.4 ± 3.9	<0.001
SVA		19.1 ± 4.4	6.7 ± 3.5	<0.001
LL		36.3 ± 18.5	55.1 ± 11.8	<0.001
Low LL (L4–S1)		13.5 ± 9.8	37.9 ± 8.2	<0.001
GAP	proportional	«0–2» – 0	«0–2» – 24	<0.001
	moderately nonproportional	«3–6» – 21	«3–6» – 21	
	severely nonproportional	≥7 – 24	≥7 – 0	

Таблица 4

Correlation data between back pain VAS score and radiological parameters

Parameters	Before surgery	At the discharge after surgery
SVA	0.230	0.025
PT	0.172	-0.199
PI–LL	0.527*	-0.057
LDI	-0.309*	-0.214
GAP	0.339*	0.233

*changes are statistically significant.

This parameter was reliably improved. Low LL (L4–S1) was increased from 13.5° ± 9.8° to 37.9° ± 8.2° ($p < 0.001$). When the morphological substrate of clinical manifestations was not localized at the L4–L5, L5–S1 levels, the surgery was supplemented with the intervention to the superposed levels in some cases. The common lordosis parameter is also important; its optimum values can be achieved when a correction of more than 20° is necessary. It is feasible with the use of three-column osteotomy. In our study, the common lumbar lordosis (LL) increased from 36.3° ± 18.5° to 55.1° ± 11.8° ($p < 0.001$) without PSO. A comparable correction was achieved, and we refer it to a definite advantage of the described surgical treatment. A significant decrease in SVA (as one of the main parameters of the global balance) from 6.7 ± 3.5 to 2.7 ± 3.5 mm ($p < 0.001$) was revealed.

Table 5

Correlation data between leg pain VAS score and radiological parameters

Parameters	Before surgery	At the discharge after surgery
SVA	-0.185	0.085
PT	-0.425*	-0.006
PI–LL	-0.247	0.005
LDI	0.099	-0.777*
GAP	-0.371*	0.528*

*changes are statistically significant.

Table 6

Types of complications and methods of their treatment

Patient	Type of complication	Type of treatment
2nd	Superficial thrombophlebitis of the left forearm	Conservative
	Pulmonary embolism	Conservative
4th	Small bowel eventration	Surgical
5th	Liquorrhea	Conservative
7th	Migration of ventral implant at L4–L5	Surgical
	Iliofemoral vein thrombosis	Conservative
10th	Left iliac vein thrombosis	Conservative
14th	Urological infections	Conservative
15th	Fracture of the craniodorsal angle of the L5 vertebral body	Conservative
16th	Pulmonary embolism	Conservative
17th	Pulmonary embolism	Conservative
19th	Small bowel eventration	Surgical
20th	Liquorrhea	Conservative
22nd	Migration of ventral implant at L5–S1	Surgical
23rd	Weakness of left femoral flexors	Conservative
24th	Weakness of right femoral flexors	Conservative
25th	Left iliac vein thrombosis	Conservative
27th	Iliac vein injury	Surgical
29th	Urological infections	Conservative
32nd	Malpositioned transpedicular screw	Surgical
33rd	Weakness of right femoral flexors	Conservative
34th	Hematoma at the surgical area	Conservative
35th	Liquorrhea	Conservative
37th	Lower paraparesis	Conservative
38th	Urological infections	Conservative
40th	Left iliac vein thrombosis	Conservative
42nd	Pneumonia	Conservative
	Weakness of left femoral flexors	Conservative
44th	Urological infections	Conservative

According to the literature data [20, 21], the use of the direct lateral interbody fusion (DLIF) may increase the segmental lordosis up to 4.9°. In our study, we did not estimate changes in the segmental angle at the levels with this type of spinal fusion because not all the patients had undergone it. It was performed when it was necessary to correct segmental scoliosis at the middle lumbar level and/or in the presence of the morphological substrate of pain or neurological deficit at these levels, as well as to achieve harmonization of the sagittal profile according to the Roussouly's classification. The restoration of the ideal type according to the Roussouly's classification was observed in 27 (60 %) patients, lower than ideal, in nine (20 %), and higher than ideal, in nine (20 %) patients. Harmonization was not achieved in some patients, although it was one of our objectives. Clinical data collection is necessary for understanding reasons of these failures. It is also of interest to understand what Roussouly's types (higher or lower than the ideal) are more significant in clinical manifestations. This is a task for a long-term postoperative period.

In general, the combined multistage approach of treating patients with violation of the sagittal balance can be characterized by longer surgery time, longer length of stay, and greater blood loss. It may have complications specific for anterior and lateral approaches (injuries of intestines, vessels, nerves of the lumbar plexus) [22]. In our study, the overall duration of surgery was 529.8 ± 117.8 min, the blood loss was 1130.4 ± 560.1 ml.

Complications associated with surgery of vertebral deformities with violation

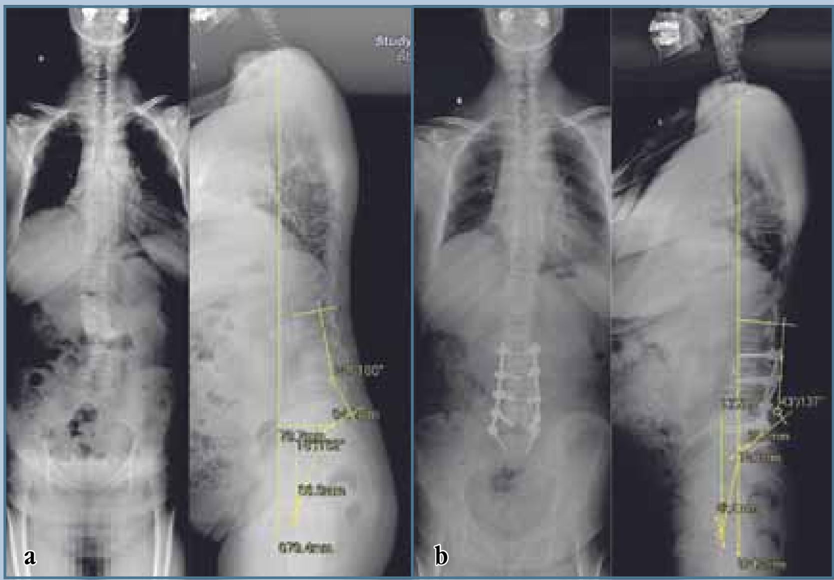

Fig.
A radiograph of a 50-aged female patient with *de novo* lumbar scoliosis manifesting as pronounced pain syndrome in the lumbar spine and neurogenic intermittent claudication: **a** – before surgery, the whole spine and pelvis, from the skull to the proximal femurs, in frontal and lateral projections: PI – 46°, PI–LL – 26°, PT – 18°, SVA – 78 mm, LDI – 96 %, GAP – 7 points, III type according to the Roussouly's classification; **b** – the whole spine and pelvis, from the skull to the proximal femurs, in frontal and lateral projections after ALIF at the L4–L5, L5–S1 levels and after DLIF at the L2–L3, L4–L5 levels: PI – 46°, PI–LL – 3°, PT – 13°, SVA – 13 mm, LDI – 78 %, GAP – 3 points, matched type according to the Roussouly's classification

of the sagittal profile are still an important problem, although new minimally invasive techniques are introduced. Reported complication rates ranged from 18 % to 47 % [23]. Mundis et al. [16] compared data of two groups, each containing 17 patients with PSO and combined minimally invasive anteroposterior approach. No significant difference in the overall major complication rates was found (35.3 % vs. 41.2 %, respectively). In our series, we observed 26 (57.7 %) complications, i.e., 0.6 per a patient. The most common were thromboembolic complications, in seven (15.6 %) patients, despite preventive measures (compression garments, low molecular weight heparins). Among complications specific for ventral and lateral approaches, we observed eventration of small intestine loops in two 2 (4.4 %) cases, injury of iliac vein or lower hollow vein, in one (2.2 %) case, weakness of femoral flexors, in four (8.9 %) cases. No early infection in the surgical area was observed in our series of clinical cases.

Although a high incidence of perioperative complications is observed, the patient's quality of life is significantly improved after surgical interventions. In one of the largest prospective multicenter studies, data of 492 adult patients with spinal deformities were analyzed. Significant correlations were identified between spinopelvic parameters (SVA, PT and PI–LL) and health-related quality of life scores (ODI, SF-12, SRS-22r) [24]. Theologis et al. [22] assessed the outcomes of surgical treatment of patients with vertebral deformities using open posterior instrumented fusion alone or supplemented with LLIF. They marked significant improvement of such parameters as VAS score and ODI not only just after the surgery, but also minimum in two years. Saigal et al. [23] selected 26 articles on the basis of the literature analysis. They came to a conclusion that surgical treatment of adult patients with spinal deformities is an effective therapeutic module reliably increasing quality of life. They marked the improvement after operative interventions basing on the following data: ODI (-19.1 ± 9.0), SF-36 PC (11.2 ± 5.07), and SF-36 PC (9.93 ± 4.96). They also concluded that for the time being, there was no convincing evidence of the effectiveness of nonsurgical treatment because there were not so many observational studies, and with a high level of prejudice. In our study, we revealed significant improvement. Back and leg pain VAS scores decreased after surgery from 6.7 ± 0.9 to 3.3 ± 0.9 ($p < 0.001$) and from 4.7 ± 1.4 to 0.5 ± 0.6 ($p < 0.001$), respectively. The correlation analysis revealed a significant interrelation between back pain VAS score and PI–LL, LDI and GAP ($\rho = 0.53$, $\rho = -0.31$, $\rho = 0.34$, respectively), and leg pain VAS score and PT and GAP ($\rho = -0.43$ and $\rho = -0.37$, respectively).

This study refers to the fourth level of evidence. There are some limitations. The study is an observation of a series of clinical cases. The analysis of clinical parameters (VAS score and ODI) cannot be highly convincing within the frameworks of this work because even at discharge from the hospital some patients required pain management. This fact might impact the real data. The assessment of clinical and radiological parameters is limited by the hospitalization period, it is impossible to analyze any changes at later date. Comparative studies with a prolonged follow-up period are necessary in order to increase the level of evidence.

Conclusion

Multistage surgical treatment of patients with degenerative spinal deformities using corrective fusion in the lumbar spine significantly improves parameters of the spinopelvic and global sagittal balances in the early postoperative period. The multistage surgical treatment using anterior interbody spinal fusion at the L4–L5, L5–S1 levels makes it possible to restore the harmonic sagittal profile in 60 % of cases.

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