THE ROLE OF THE MAIN RISK FACTORS IN THE EARLY ADJACENT SEGMENT DISEASE DEVELOPMENT IN PATIENTS AFTER LUMBAR FUSION

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Object. To identify the importance of main risk factors of early development of degenerative changes in adjacent spinal motion segments after the lumbar fusion.

Material and Methods. The study evaluated the treatment results in 354 patients who underwent fusion in the lumbar spine for degenerative-dystrophic disease. Two groups were compared: Group I included 26 patients with clinically significant adjacent segment disease (ASD) which developed during the first year after surgery, and Group II — 24 patients in whom ASD was identified at a later date.

Results. Significant degenerative changes in the overlying intervertebral disc (Pfirrmann grade 4 and higher) were found preoperatively in 16 (61.5 %) patients in Group I. In Group II, such degenerative changes were observed in 3 (12.5 %) patients. Besides, patients in Group I had higher mean index of the difference between pelvic inclination and lumbar lordosis (PI-LL), than patients in Group II (12.2° and 9.3°, respectively). Nine patients in Group I with Pfirrmann grade 4 to 8 degenerative changes demonstrated sagittal imbalance as Positive in 7 cases and Very Positive in 2 cases, according to Schwab classification.

Conclusion. Decompensation of the pre-existing degenerative changes in the conditions of increased load after fusion is crucial in early development of the adjacent segment disease. Patients with degenerative changes in the adjacent levels of grade 4 and higher according to Pfirrmann, as well as patients with PI-LL index more than 11° have a significantly higher risk of early ASD development.

Key Words: fusion, adjacent segment disease, sagittal balance.

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Currently, the decompression of neurological structures together with rigid fixation with 360° fusion has been a widely accepted procedure for treatment of severe degeneration conditions of the spine [3, 5, 7, 9, 31, 33].

In spite of a successful spinal fusion with instrumented fixation, there is a risk of unsatisfactory long-term outcomes of surgical treatment. Decompensation of the degenerative changes of the adjacent segments to fixed segments as part of the adjacent segment disease (ASD) is crucial [1, 2, 4, 6, 8, 24, 27].

According to several studies [11, 16, 17, 19, 23, 29], spinal fusion alters the normal biomechanics of the spine causing an overload of the adjacent segments due to eliminating mobile segments. Moreover, the lumbar and lumbosacral spine is more subject to changes in the adjacent motion segment biomechanics rather than the cervical spine.

Today, according to many authors [10, 15, 27, 28], rigid fixation of the spine can lead to the development and can accelerate the degeneration of adjacent segments.

The periods of ASD development in the overlying spinal motion segment vary substantially being on average of 26.8 months (range, 3–84 months). This is true for patients operated for degenerative conditions in the lumbar spine by fixation with standard posterior rigid stabilization system [19, 31].

The number of the factors for to the occurrence and progression of degeneration in the adjacent segments to the fixed levels is constantly increasing. They can be separated into two basic categories according the classical studies: patient factors, which are usually do not

depend on the surgeon, and surgical factors, which can directly be modified by the surgeon during the operation [9–11, 16, 19, 21, 22, 26, 29, 31].

The most important patient factors include the female gender, age older than 60 or under 30 years of age, body mass index greater than 30, smoking, concomitant somatic pathology, pre-existing degeneration of adjacent discs, and menopause.

The surgical factors include the long length of fixation, involvement of the L5–S1 segment in fusion, stiffness of the implants, technical fusion execution errors, and sagittal and coronal balance disturbance.

Despite the great numbers of publications regarding ASD development, the early development of the clinically significant ASD has not been established. Degenerative decompensation of the overlying segments during the first year and sometimes during the first months after surgical treatment often requiring repeated surgery has very adverse influence on the quality of life, ability to work, patient trust and psychological status of the patient.

Another issue under discussion and a matter of argument relates to whether ASD includes an iatrogenic component and the way to prevent the disease development by changing the tactics of preoperative evaluation and patient treatment?

The aim of the study was to identify the importance of main risk factors in the early development of degenerative changes in the adjacent spinal motion segments after fusion of the lumbar spine.

Material and Methods

This retrospective study evaluated 354 patients who underwent fusion lumbar surgery from 2006 to 2012 for the treatment of degenerative-dystrophic disease of the lumbar spine. Fusion was performed using transpedicular instrumented fixation with standard rigid systems from a posterior approach.

According to the preliminary assessment of long-term outcomes of treatment, the disease under study was revealed in 50 (14.1 %) of the operated patients.

The following groups of patients were formed based on the long-term follow-up outcomes: group I – 26 patients who developed a clinically significant ASD in the first year after the operation; group II – 24 patients who developed ASD in later dates. The subject population was 62 % female and 38% male. The average age was 56.3 years (range, 24–82 years), the minimum follow-up period was 3 years (range, 3–9 years). MRI evaluation of degenerative changes in the adjacent segments and long cassette standing anteroposterior and lateral radiographs (teleroentgenographs) were performed during the preoperative, postoperative, and follow-up visits. Patients with no preoperative MRIs and patients with signs of preoperative radiographic metal construct instability were excluded from the study.

One to five levels were fused. During the operation, standard open approaches were used and minimally invasive spine surgery was performed through tubular retractors.

Radiographic signs of the segment instability and sagittal and coronal plane alignments were evaluated in all patients. All patients included in the study had no signs of preoperative radiographic instability on the adjacent levels. To detect violations of the global spinal balance and, first of all, the sagittal plane alignment, we studied the preoperative, postoperative, and follow-up teleroentgenographs in two views according to the Schwab classification.

The values of the lumbar lordosis (LL) and pelvic inclination (pelvic incidence, PI) on standing lateral radiographs were assessed using the spine-pelvic ratio indices. Additionally, the difference values of the lumbar lordosis (LL) and pelvic incidence (PI) (PI-LL) were established for all patients.

The adjacent segment degeneration was evaluated by preoperative MRIs and postoperatively scored with an 8-grade modified Pfirrmann classification.

The findings from the measurements were analyzed statistically using simple regression analysis and Student's t-test, and the Mann-Whitney test for small samples. At $P < 0.05$, the differences were defined as statistically significant.

Results

We have identified no statistically significant differences between the compared groups in terms of the most risk factors for ASD. There was no statistically significant evidence on the influence of the fusion length, sagittal balance disturbance, smoking, overweight, certain age or gender association on the early development of clinically significant degenerative changes in the adjacent segment.

Yet, the clinically significant preoperative degenerative changes in the overlying disc at Pfirrmann grade 4 and higher prevailed significantly in the group with the early development of adjacent disc degeneration. Thus, 16 (61.5 %) patients of group I demonstrated these changes of the adjacent intervertebral discs (Figs. 1, 2). Meanwhile, degenerative changes of Pfirrmann grade 4 and higher were found in only 3 (12.5 %) cases of group II.

Alongside this, note that among the 16 patients of group I with degenerative changes of 4 to 8 Pfirrmann grade, nine patients (56.3 %) also had sagittal profile disturbance of the spine, with 7 cases graded as the Positive (+) and 2 cases as the Very Positive (++) by Schwab.

After a more in-depth evaluation of spine-pelvic ratios in patients of both groups, we found certain regularity in the development of early degenerative decompensation of the adjacent segments. For example, the difference between the values of the pelvic incidence and lumbar lordosis (PI-LL) in patients of group I (12.2°) was significantly higher than that of the patients of group II (9.3°).

This study has shown the significant difference between the average values of the PI-LL index in the patients in general with symptomatic ASD and the group of patients without clinical and radiographic findings of degenerative decompensation of the overlying segment (the PI-LL was 10.75° and 6.1°, respectively).

To reliably evaluate the outcomes of the influence of positive sagittal balance is unfortunately impossible due to the small sample size. Nevertheless, this raises the question whether the combination of certain degenerative changes in the intervertebral discs, sagittal imbalance and disturbance of the spine-pelvic ratios as the main risk factors for the adjacent segment degeneration can accelerate the rate of the disease occurrence. This is also indicated by that in the patients with significant pre-existing changes in the adjacent intervertebral disc, sagittal imbalance, and also with the PI-LL value greater than 11°, decompensation of degenerative conditions at the given level occurred in the first 3 months after surgery. Note that all patients with incipient adjacent disc degenerative changes who developed symptomatic ASD in the first postoperative year had disturbed sagittal balance, with 3 (75 %) among these patients were graded as Very Positive (++) by Schwab. Additionally, all the patients of group II with 1–3 Pfirrmann grade degeneration changes had concomitant sagittal profile disturbances graded using Schwab as Positive (+) in 4 cases and Very Positive (++) in 2 cases. Thus, we have identified certain regularity in terms of a probable decompensation at the adjacent segment in the presence of incipient degenerative changes and in adverse biomechanical conditions. These findings have no significant evidence due to the lack of a statistically significant sample.

The results of the comparison of both groups are presented in table.

Discussion

The adjacent segment disease that occurs after spinal fusion has been the subject of broad discussion in the international literature and among more than one generation of surgeons [10, 12–14, 20, 24, 31].

Notably, the major matter of debate states that in the case of surgery for spinal disc degeneration, ASD can be merely the result of the natural course of the disease. An unambiguous answer to this issue is still not possible, particularly given the very distant periods of development and clinical manifestations of this disease. Many authors refer to the study by Schlegel et al. [31] who evaluated the average periods for ASD development in patients who underwent lumbar fusion with the aim of creating a bone block without using metal constructs. The patients were shown to become symptomatic in ASD after an average of 13 years postoperatively. In studies using metal rigid fixation systems the average periods of ASD development, although being inconsistent, are in general shorter than in the paper of Schlegel et al. Based on this, many authors tend to regard the development of ASD as a kind of a sequelae of fusion.

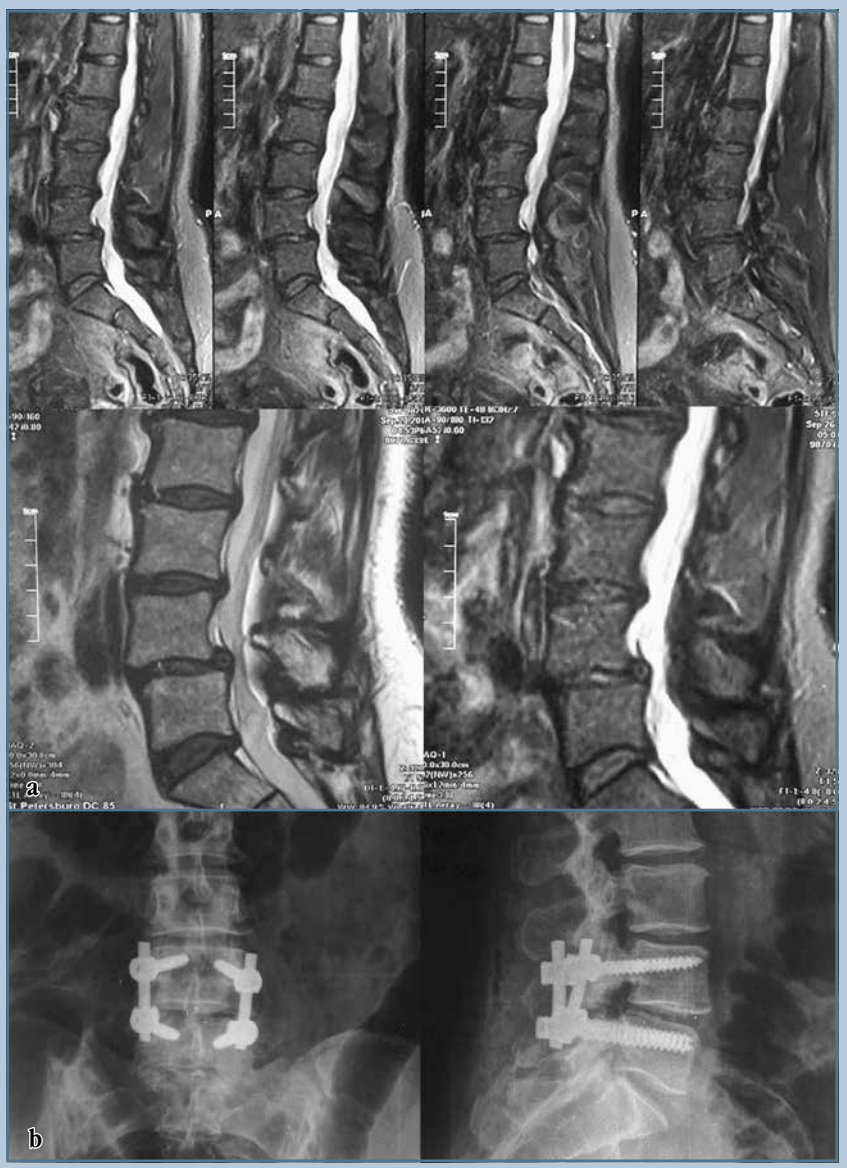

Fig. 1
MRI and radiographs of the patient S., 55 years old, with degenerative-dystrophic disease of the spine, anterior spondylolisthesis L4: **a** – degenerative changes at L3–L4 of grade 4 by Pfirrmann; **b** – transpedicular spondylosynthesis at L4–L5, PLIF at L4–L5

Ekman et al. [18] in a long-term randomized clinical study have recently showed that fusion accelerates degenerative changes at the adjacent level compared with natural history of degenerative-dystrophic spinal disease. Though the early manifestation of adjacent disc degeneration is quite rarely considered independently of the adjacent segment disease and is explained as an individual reaction of the body and limited com-

Fig. 2
MRI and radiographs of the patient S., 55 years, 5 months after surgery: decompensation of degenerative changes at the level of L4–L5 **(a)** with the formation of spinal canal stenosis **(b)** and instability of the spinal motion segment **(c)** under normal global balance **(d)**

pensatory capacities due to an overloading of the adjacent segments.

Thus, Etebar and Cahill in [19] performed an analysis of a large cohort of 125 patients and showed that a total of 18 patients developed symptomatic ASD in an average of 26.8 months after surgery. Furthermore, seven patients (38.9 %) had clinically significant adjacent segment failure in the first postoperative year (3–12 months). Rather sadly, the authors do not comment these cases and consider the patients only in general terms.

In our opinion, the early occurrence of ASD has certain backgrounds and patterns of development.

Previously, we showed a certain tendency to increasing the incidence of clinically significant ASD in the first postoperative year in patients with pre-existing incipient degenerative changes after short fixation. Unluckily, it was impossible to prove statistically the significance of the results at that time due to the small sample of patients and lack of randomized comparison groups [8, 25].

As shown by the results of this study, decompensation of degenerative processes at the adjacent level in the first postoperative year is significantly influenced by pre-existing degenerative changes in the studied segment of a quite high grade. An overloading of the adjacent segments after rigid fixation has been proved by more than one biomechanical study [17, 23]. Apparently, decompensation of pre-existing degenerative changes during an overload after spinal fusion is crucial in the development of early ASD.

The difference of the pelvic incidence and the lumbar lordosis is one of the most important spine-pelvic indices in the development of degenerative conditions in the lumbar spine [30, 32]. Senteler et al. [32] in a biomechanical study show that the spinal-plevic ratios measured as the PI-LL value correlate with loads on facet joints in motion segments at L3–L4 and L4–L5.

In this study, the PI-LL difference has been shown to correlate significantly with both the periods of developing degenerative decompensation and the occurrence of ASD in general.

We have not received statistically significant data on the influence of the sagittal imbalance on the early symptomatic ASD. Meanwhile, certain trends have been identified in cases of a combined sagittal profile imbalance with preopera-

Table

Study patient information

Parameter	Group I (n = 26)	Group II (n = 24)	P value
Gender (m : f), n	8 : 18	7 : 17	>0.05
Age, years	56.1 ± 7.3	58.3 ± 6.7	>0.05
Length of fixation, n (%)			
1 level	12 (46.2)	9 (37.5)	>0.05
2 levels	6 (23.1)	7 (29.2)	>0.05
3 levels	4 (15.4)	3 (12.5)	>0,05
4 levels	3 (11.5)	3 (12.5)	>0.05
5 levels	1 (3.8)	2 (8.3)	>0.05
Underlying disease			
Degenerative spondylolisthesis, n (%)	9 (34.6)	6 (25.0)	>0.05
Spinal canal stenosis, n (%)	7 (26.9)	11 (45.8)	>0.05
Disc herniation, n (%)	10 (38.5)	7 (29.2)	>0.05
ODI (before surgery)	45.2 ± 6.2	43.4 ± 5.8	>0.05
ODI (after surgery)	30.2 ± 5.4	32.2 ± 4.8	>0.05
VAS (before surgery)	6.3 ± 1.2	6.1 ± 1.4	>0.05
VAS (3 months after surgery)	2.2 ± 1.9	2.8 ± 1.7	>0.05
BMI, kg/m2	26.2 ±4.6	27.9 ± 4.8	>0.05
Smoking, n (%)	11 (42.3)	8 (33.3)	>0.05
Sagittal balance disturbance (by Schwab) postoperatively, n (%)			
Positive (+)	8 (30.7)	5 (20.8)	>0.05
Very Positive (++)	5 (19.2)	3 (12.5)	>0.05
Difference between pelvic incidence and lumber lordosis, degrees			
PI-LL	12.2	9,3	<0.05
Pre-existing degenerative changes (Pfirrmann), n (%)			
Grade 1–3	4 (15.4)	6 (25)	>0.05
Grade 4–8	16 (61.5)	3 (12.5)	<0.05
Сроки развития патологии, мес.	6.2 (3–12)	38.4 (17–76)	<0.05

tive degenerative conditions of the adjacent segment and the PI-LL value greater than 11° in the early decompensation of adjacent levels necessitating further study.

The issues that remain open to be discussed are as follows: can the incipient degenerative changes in the intervertebral discs (Pfirrmann 1–3 grades) associated with the sagittal balance disturbances be regarded as a risk factor for ASD and whether there are established threshold values of sagittal imbalance in these cases that are statistically significant for decompensation of adjacent segments.

Nevertheless, based on the findings of our study the early development of ASD in most cases was the result of the wrong choice of tactics of surgical treatment due to underestimating the preoperative intervertebral discs changes and the important spinal-pelvic ratios.

Conclusion

Despite the ongoing discussion on the etiology of ASD and the ambiguity of its development, one cannot deny the significance of the early symptoms of this disease. The early development of ASD in the first postoperative year, in the presence of preoperative degenerative changes in the given segment need consideration within complications of surgical treatment rather than within the versions of the course of the underlying disease.

Considering the risk factors of early ASD development studied in this paper, it is possible to highlight the most important, including pre-existing degenerative changes in the overlying segment at stage 4 and higher of Pfirrmann grade and the PI-LL value greater than 11°. Disturbances of the sagittal profile, based on these findings, should be considered as an unfavorable background promoting the early development of degenerative decompensation of adjacent segments.

To reduce the risk of early development of ASD, a surgeon should avoid fusion ending directly below the compromised intervertebral disc when there are degenerative changes of stage 4 and higher of Pfirrmann grade.

A combination of significant risk factors for developing ASD can accelerate the occurrence of this disease leading to recurrence of pain, which is often hard to treat conservatively.

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