SURGICAL TREATMENT OF LOW GRADE SPONDYLOLISTHESIS: THE MODERN STATE OF THE PROBLEM

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The paper presents a literature review on contemporary problems of surgical treatment of low grade spondylolisthesis. The results of various surgical techniques including modern minimally invasive methods of treatment are provided. The importance of selecting a method of surgical intervention depending on the type of spondylolisthesis, sacro-pelvic balance, and global sagittal balance is indicated, as well as their influence on the quality of life of patients. Complications and causes of pseudoarthrosis development depending on different methods of interbody fusion are discussed. The choice of optimal treatment tactic is the main problem in surgery of low grade spondylolisthesis.
Key Words: spondylolisthesis, low grade spondylolisthesis, pseudoarthrosis, global sagittal balance.

Please cite this paper as: *Bulatov AV, Klimov VS, Evsyukov AV. Surgical treatment of low grade spondylolisthesis: the modern state of the problem. Hir. Pozvonoc. 2016;13(3):68–77. In Russian.*
DOI: http://dx.doi.org/10.14531/ss2016.3.68-77.

Spondylolisthesis is a pathologic condition, in which one vertebra is displaced in relation to the other, occurring either asymptomatically or symptomatically. The history of studies on spondylolisthesis covers 19th century, the period before roentgenology developed, and the 20th century up to the beginning of the 21st century, the era of roentgen diagnostics.

Spondylolisthesis was first described in 1782 by the Belgian obstetrician Herbinaux, which reported a bony prominence that obstructed the delivery. The term “spondylolisthesis” was coined in 1854 by Kilian (from the Greek spondylos “vertebra” and olysthesis “a slip”), which marked the start of the problem’s study [8].

Origins theory

Since the beginning of the 19th century, there have been many opinions on nature and mechanisms of spondylolisthesis. The literature counts theories on the inherent and the acquired character of the condition. In 1836, Rokitansky described two anatomical specimens of the L5 anterior displacement into the cavity of the lesser pelvis (spondyloptosis). The author considered one case as an inherent slippage, while the other he attributed to the lumbosacral disc disorder.

Kiwisch (1851) and Seyffert (1853) reported two cases of the disc slippage and agreed with Rokitansky on the inherent character of the disease. In 1853, Kilian thoroughly analyzed four specimens provided by Rokitansky, Kiwisch, and Seyffert and assumed one displacement to be inherent, whereas other three to be caused by tuberculosis. Later, in 1858, D.F. Lyambl revealed poor ossification of the vertebral arch in a patient with spondylolisthesis and named the defect “spondylolysis”. In 1865, having noticed that the spinous process remains in an initial position after vertebral body slippage, Hartmann suggested that splitting of the arch could be the reason of such slippage. F.L. Neugenbauer (1881, 1890) described vertebral body slippage without arch splitting. The author believed that the slippage occurred because of the sagittal expanding of the vertebra and its bending, mainly in the pars interarticularis [9].

In 1888, F.L. Neugenbauer introduced the theory of inherent spondylolysis. Contrary to his opinion, Lane (1893) was stating that spondylolysis develops in the lifetime. The latter considered the cause to be either a fracture or a separation of the pars interarticularis by the articular processes of the superior and the inferior vertebrae in a scissors-like way.

A genuine interest to spondylolisthesis appeared with the creation of radiological methods. In 1908, Codivill first described spondylolisthesis based on an X-ray image [8]. Now, radiological visualization is the basic method of diagnostics of spondylolisthesis and identification of its nature.

Epidemiology

Spondylolisthesis occurs at a rate of 2–4 %. In patients with lower-back pain, this value reaches 7–10 %. In 89 % of cases, such patients belong to the working-age population (35 to 60 years old) [10].

The frequency of occurrence of spondylolisthesis is clearly gender- and race-specific. Among young patients, men are seen the most often, while among the elderly patients – women [32]. In women, spondylolisthesis occurs with a frequency of 6 % in Taiwan [19], 8 % – in Denmark [35], and up to 20–25 % – in the USA [23, 63]. In men, the incidence comprises 3–4 % in Taiwan and Denmark, 4–31 % – in the USA [19, 23, 32, 35, and 63]. The Afro-American women are diagnosed with spondylolisthesis thrice as often as the Caucasian women [23, 32].

About 20–22 % of patients are 7 to 20 years old [8]. Spondylolytic spondylolisthesis observed in men is often of grades I and III, in women – of grades II and IV–V. In up to 86 % of cases, spondylolytic spondylolisthesis is localized at the L5–S1 level, 10 % – at the L4–L5 level and about 4 % – at the L3–L4 level [37].

In patients with degenerative spondylolisthesis (DS), the offset value does not exceed 45–50 % of the vertebral body. Up to 80 % of DS cases are revealed at the L4–L5 level, 20 % – at the levels L3–L4 and L5–S1. Degenerative spondylolisthesis, observed most often in patients aged over 40, is associated with osteoporosis in 39 % of cases [14].

Classification

Considering the variety of spondylolisthetic types, many classifications have been suggested. Most of them assess the degree of the vertebral body offset [8, 11, 29, 36, and 50].

Based on the percentage of the vertebral body displacement, a commonly adopted Meyerding grading system [50] offers four grades. In 1956, Junge and Kuhl [36] adjusted this classification by adding grade V to show the complete offset of the vertebral body in relation to the inferior vertebral body anteriorly.

I.M. Mitbreit [7] introduced the spondylolisthesis grading system that assesses the slip angle of the overhanging vertebra (the angle between the vertical and the centerline coming through vertebral bodies). He proposed the terms of stable and unstable spondylolisthesis and provided scientific credence to those. In patients with unstable spondylolisthesis, the interaction between the overhanging and the inferior vertebra changes with the posture change, which does not occur with the stable form of the disease. Providing an understanding of the degree of the vertebra's displacement, this classification does not, however, give information on the nature and the character of the pathologic process.

Wiltse et al. [66] developed spondylolysis grading system and thoroughly described the causes and symptoms of each variant. Now, it is the most commonly adopted and widely used classification.

In 2005, Spinal Deformity Study Group (SDSG) initiated a study of the spinopelvic sagittal balance associated with degenerative spinal deformities. In 2006, Roussouly et al. [56] examined 133 patients diagnosed with spondylolisthesis and revealed two subtypes of sacropelvic ralationship, the balanced pelvis and the retroverted pelvis (a compensatory mechanism of the sagittal balance). This work provided a substantiation for two mechanisms of the spondylolisthesis formation. In a case of the balanced pelvis, the superior vertebral body slips off, while in a case of the retroverted pelvis a nutcracker type of compression (from above) takes place. See Fig. 1.

Based on the collected data, Labelle et al. [42] offered new classification of spondylolisthesis by three key parameters that can be distinguished in the sagittal X-ray view of the spine and the pelvis: 1) grade of the vertebral body displacement (low-grade or high-grade);

2) pelvic incidence, PI (low, normal or high);

3) spinopelvic balance (balanced or imbalanced).

By eliminating the assessment of displasia, authors made classification easier.

This system distinguishes two grades: low-grade slippage with up to 50 % of the vertebral body hanging over and high-grade slippage with more than 50 % of the vertebral body hanging over. The system employs following parameters to assess the spinopelvic relationship: the pelvic incidence (PI), the sacral slope (SS), the pelvic tilt (PT) and the sagittal vertical axis (SVA).

There are three types of the sacropelvic balance described for low-grade spondylolisthesis. The first is low PI balance (<45°) contributing to the nutcracker type spondylolisthesis. In the second case, PI is within 45–60°, so listhesis develops either because of the nutcracker-like mechanism or because of the slippage. In the third case, PI is high (>60°), so spondylolisthesis develops because of the slippage (Fig. 2). Depending on each parameter and type of the sacropelvic balance, the surgeon assesses the extent of surgical intervention and adjust the character of the sagittal balance correction. SDSG continue their study upon today.

Development of surgical approaches

From a vast amount approaches, described over a 100-year history of the surgical treatment of degenerative-dystrophic disorders in the lumbosacral spine, many are only of historical interest now. First attempts of the operative stabilization in patients with spondylolisthesis were made using the posterior spinal fusion. In 1915, Ryerson [58] performed spinal fixation in the patient with spondylolisthesis by introducing a tibial graft between spinous processes.

In 1930, R.R. Vreden [3] suggested a fibular graft, located perpendicular to the spinal axis, with its extremities abutting iliac bones so that the weight of the upper body part would be partly distributed over the pelvic bones.

Gibson [27] used H-shape tibial graft placed between spinous processes as separating element in the posterior spinal fusion.

Later in 1946, Watson-Jones used metal plates to fix spinous processes. The search of more reliable stabilization means allowed medical society to improve the posterior spinal fusion [9].

Cleveland et al. [45] fixed the spinal column using bone autografts arranged along the spinous processes' bases.

In the approach employed by Meyerding [50], two tibial grafts were laid down both sides along spinous processes (from L5 to S1). Space between them was filled with fragments of cancellous bone.

The next step in the spondylolisthesis treatment was vertebral fusion using bone interbody grafts.

In 1931, V.D. Chaklin [13] first developed and applied anterior lumbar interbody fusion (ALIF). The method consisted of the anterior extraperitoneal approach to vertebral bodies, partial wedge resection of the two adjacent vertebral bodies together with intervertebral disc and interbody fusion using an autograft. Thus, surgeons obtained a new operative approach to treating patients with spine disorders and traumas by pathogenetically substantiated means. The approach was widely accepted and further modified.

In 1966, Ya.L. Tsivyan [12] reported a technique of anterior interbody fusion which consisted of formation of the space between the anterior part of the slipped superior vertebra and the inferior vertebra and filling of this space with cortical/spongious bone graft (preserved allograft or autograft).

The anterior approach has several points to consider, among which are the risk of damaging major vessels, the limited ability of the full reduction and intervention via spinal nerve roots. In the first place, the anterior interbody fusion entails the risk to the patient's life, which requires high qualification from a surgeon. Despite a common tendency to lowering the risks of the anterior interbody fusion, complications persist. According to Brau [16], this approach entails such complications as damage of blood vessels (1.6 %), retrograded ejaculation (0.1 %), bowel obstruction over 3 days (0.6 %), and superficial wound infection (0.4 %).

In the meantime, the posterior interbody infusion appeared. Lee and Briggs [44] introduced the method of filling the interbody space with bone chips to form a bone block after laminectomy.

To achieve interbody fusion, Cloward [21] abraded intervertebral disc via the posterior approach and then introduced iliac crest harvest bone grafts to the interbody space. This approach is known as the posterior lumbar interbody fusion (PLIF). Over the time, the approach was modified and became commonly accepted among spine surgeons. The introduction of the implant-mediated interbody stabilization system via the posterior approach was expected to resolve the problem of the spinal canal decompression and that of stabilization of the pathologically unstable region. However, the posterior interbody fusion is a complicated and traumatizing intervention for spinal nerve roots.

Interbody implants became a new trend in the spine surgery. Bagby, the USA orthopedist, initially used cylindrical threaded steel interbody cages in spinal fusion to treat cervical myelopathy in horses. In 1977, Bagby and Kuslich [41] developed and reported the use of hollow cylindrical implants (cages) in the interbody fusion. Those were first generation devices made in form of hollow titanium cylinders that could be introduced via both the anterior and the posterior approaches. The main problem was

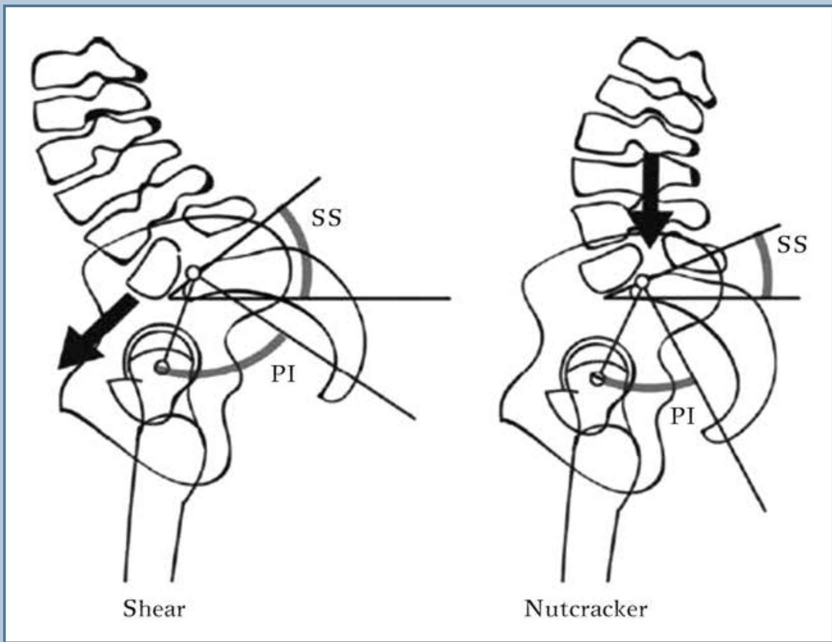

Fig. 1
Types of spondylolisthesis formation suggested by Roussouly [53]

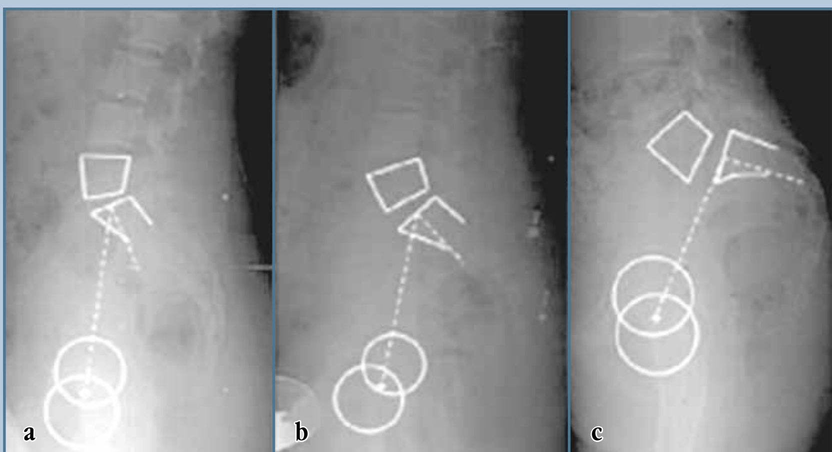

Fig. 2
Types of sacro-pelvic balance according to Labelle [36]: **a** – type I; **b** – type II; **c** – type III

to make the interbody space larger and ensure the fusion stability. Cages essentially need being installed using the supporting technology [9].

Ido and Urushidani [34] reported data obtained in the X-ray examination of patients in the long-term period after the installation of biopolymer ceramic cages via the posterior approach. Authors note on the biological inertness and fine acceptability of such implants in the interbody space.

McAfee [48] described long-term results of the posterior interbody fusion using Bagby and Ray cylindrical cage. The positive outcome was observed in 27 (93 %) out of 29 patients.

In 1982, Harms and Rollinger [31] developed a technique of the transforaminal lumbar interbody fusion (TLIF) as an alternative to PLIF to treat various lumbar spine disorders requiring the interbody fusion, including spondylolisthesis. In recent decades, TLIF, performed via the unilateral posterior approach, have been widely accepted [6]. Unilateral TLIF has several advantages compared to PLIF. As the approach goes more laterally, the risk of traction of the spinal nerve root and the dural sac is lower, same as the risk of damaging nervous structures [26]. Meanwhile, PLIF, practically always requiring the spinal nerve root traction, often entails neurological complications (49.2 %) [4]. With a wider approach and more delicate maneuvers on nervous structures, there is no necessity in an extensive surgical release of the nerve roots, which usually leads to cicatricial affection [6]. In the surgical treatment of spondylolisthesis, reduction of the vertebra is one of the matters of debate. Having a deep history, this problem has not been solved yet [2, 4, 8, 9].

There were many attempts to perform the reduction of the slipped vertebra using different traction systems [11]. The successful correction was achieved in an insignificant number of the operated patients (21–43 %), but only a few of them managed to keep the result. While trying to calculate the optimal degree, surgeons used both full reduction and fixation of the slipped vertebral body with different outcomes [2, 8]. The results of incomplete reduction were more positive compared with those obtained in the course of "at-any-costs reduction". Thus, medical society realized the necessity of graded approach to the use of reduction in spondylolisthesis treatment [9].

Many authors have different opinions on the necessity of the slipped vertebra reduction. The low-grade spondylolisthesis (I–II) requires the reduction of the vertebra to the most extent [9, 24]. The high-grade spondylolisthesis (III–IV) demands vertebra reduction not to exceed the grade II; however, the full reduction is also allowable on condition that there is no risk of neurological complications [24, 39]. Today, no common opinion on the degree of reduction is accepted.

In 1944, King reported the technique of transarticular fixation of joints with short screws. Roy-Camille and Demeulenarer [57] used the posterior spinal fixation with plates that were secured with screws introduced via the back portions of the vertebral arch. With this method authors were able to do primary stabilization via the posterior approach safely.

In 1982, Cotrel and Dubousset [22] suggested the system of posterior instrumentation for the spine correction and fixation. In 1983, Dubousset first operated a patient using the CDI stabilizing system (with rod bending and derotation maneuver). By 1988, there were enough observations to make first conclusions. Cotrel et al. [22] reported a new universal segmental system of devices for the spine surgery that allowed tri-axial correction of deformities by segment-selective distraction and compression with derotation maneuver to ensure rigid fixation without external means of immobilization in the postoperative period. This stabilization system was a prototype of the modern transpedicular systems.

While approaches used in decompression and reduction, technical means and respective instrumentation reached a high level, the advantages of the reduction of the slipped vertebra are still open to discussion. There have been elaborated devices to perform the reduction (screws for transpedicular fixation).

In 1993, in the scope of the international symposium Acta Scandinavia, Blumenthal and Gill [15] reported the results of the operative treatment of the spondylolisthesis using a combination of posterolateral spondylosyndesis and transpedicular screw fixation. The positive outcome was observed in 96 % of cases. Authors noted on rigid fixation and stable regression of the radicular compression syndrome.

Medical society gradually realized that formation of the artificial bone block and elimination of the neurovascular compression are the key factors of the successful surgical treatment [8]. Meanwhile, failures still took place despite the achievement of successful interbody fusion [28, 42, 46].

Modern ways of the operative treatment of low-grade spondylolisthesis resulted from the evolution of high-tech methods and their implementation [6]. One of the main surgical principles is to perform the maximally effective operation of the same scope as the open surgery with minimal iatrogenic injury by means of less aggressive approaches. The minimally invasive surgery, MIS, allows one to avoid soft tissues injuries, minimize the wound surface, prevent blood loss, ease postoperative pain and reduce the length of hospital stay with the same effectiveness and scope of the treatment [6, 24, 26, 53, 55].

Foley and Gupta [26] first described the posterior subcutaneous fixation. Authors reviewed the subcutaneous technique of the transpedicular system installation in 12 patients with low-grade listhesis (10 with the degenerative form, 2 – with the isthmic). In all cases, good results of the operative treatment were observed. To perform surgical invasion authors used a set of instruments comprised by a system of tubular retractors, a lighting system, and other surgical instrumentation. In the discussed technique, paravertebral muscles are not cut but expanded with different-sized tubular retractors.

Describing the subcutaneous installation of transpedicular screws, Fassett and Brodke [24] suggested that method was used in patients with low-grade spondylolisthesis (grades I–II according to Meyerding).

Phillips and Mather [55] detailed the performance technique of MIS TLIF. They recommend that this method is used for low-grade spondylolisthesis (grades I–II) and in patients with obesity.

Comparing open PLIF and MIS PLIF performed in 32 patients with low-grade spondylolisthesis, Park and Ha [53] noted on the lesser blood loss, less intensive lumbar pain, faster recovery, and a shorter hospital stay associated with the minimally invasive technique despite the similarity of the clinical and X-ray examination results.

The implementation of microsurgical technique and various retractor systems allowed surgeons to minimize and modify the standard ventral approach (MIS ALIF) [63]. MIS techniques are effective for posterior stabilization in up to 87 % of cases [53, 55] and for low-grade spondylolisthesis in up to 91 % of cases [24] when combined with anterior spondylosyndesis via the mini-approach (MIS ALIF).

According to many authors [28, 40, 42, 46], consistent postoperative limits of the sagittal balance significantly improve the treatment results.

In 1979, Marnay demonstrated the important role of the pelvis as the anatomical segment in the sagittal balance of the spinopelvic stability. He coined the term “couple charniere” and defined the spinopelvic stability. In their work dated 1983, Vidal and Marnay [62] described the morphology and sagittal balance of the body in patients with spondylolisthesis and differentiated four fundamental characteristics of this condition: vertebral slippage, pelvic retroversion, vertically oriented sacrum, hip-joint anteroversion. These factors lead to a digression of the normal spine orientation from the vertical axis, as well as that of lumbosacral joint and femoral heads.

Schwab and Lafage [43] revealed a dependency between the values of spinopelvic parameters, pain syndrome intensity and improvement of the quality of life.

Stabilization of the lumbar spine can lead to degradation of the global lumbar lordosis (GLL) and activation of compensatory mechanisms such as decrease in the sacral slope angle, the pelvic tilt increase and the decrease in the thoracic kyphosis grade. This produces postoperative vertebral pain, a higher risk of degeneration of the adjacent segment and development of degenerative spondylolisthesis.

Kim et al. [40] reported the results of treatment of low-grade listhesis taking into account the parameters of sagittal balance. The quality of life was higher in the group of patients that underwent GLL recovery compared to the group for which GLL was not considered.

Similar data can be found in the work of Ould-Slimane et al. [52] based on the assessment of the treatment outcomes for 45 patients with low-grade listhesis. The authors revealed direct correlation between duration of the bone block formation and GLL recovery.

Treatment results and complications

A failed formation of the bone block around the interbody fusion (pseudoarthrosis) is the main reason of those defining persistent pain in the lumbar spine. The evolution of the bone block is assessed from spondylograms using Bridwell scale [46].

Usually, the quality of the performed fusion is assessed by computed tomography. The density of bone structures can be differentiated using Hounsfield intensity scale (displayed on the screen as white-and-black range). The Hounsfield units (densitometric values) correspond to the degree of attenuation of the roentgen radiation by the bone tissue. The zero point of the Hounsfield scale (0 HU) is water density. Average densitometric values of the bone density comprise +400 HU and more [14, 54].

Many authors report the violation of the interbody fusion procedure as one of the reasons of pseudoarthrosis [9, 20, 29, 30, 48, 51, 59, 60].

In the USA and European clinics, a large amount of the interbody fusion operations is made using small-diameter cages. Implants themselves are heavier than the bone graft inside. These conditions allow one to minimize the contact area between the vertebral end plates and the bone graft [60].

McAfee [48] reported five patients with pseudoarthrosis diagnosed during the repeated operation. Stress radiography revealed instability of less than 5°, which FDA classifies as ankylosis.

Hanley et al. [30] described seven patients in which CT used to diagnose pseudoarthrosis revealed neither transparency zones, nor fractures around the implant, nor other X-ray translucency indications later found in the surgical intervention.

Pseudoarthrosis may develop after the posterior cage implantation because of incomplete or inadequate discectomy or insufficient preparation of the respective vertebral end plates. According to Santos et al. [59], putting cages into the interbody space without resection of the vertebral end plates leads to pseudoarthrosis in 21 % of cases.

Ming-Fu et al. [20] experimentally proved that one implant introduced into the interbody space at an angle is enough to ensure support of the adjacent vertebral bodies and formation of the bone block, in contrast to standard PLIF, which necessarily requires bilateral fusion. Failure to perform bilateral fusion makes implant lose its supportability in the frontal plane and increases the risk of pseudoarthrosis. These data are confirmed by Fogel et al. [25], which provided the results of operative treatment in 26 patients using PLIF with one interbody implant. According to their data, pseudoarthrosis developed in 11.5 % of cases.

According to Haggart et al. [29], pseudoarthrosis is observed in 60 % of cases.

It is very important to choose the correct size of the interbody cage. The analysis performed by Hongli et al. [64] in 1570 patients clearly demonstrates that the level L5–S1 requires small-height implants (not more than 13 mm); whereas for upper levels the size is variable but should not be less than 10 mm.

The incorrect choice of an implant with smaller proportions may entail the risk of introducing the cage not in parallel to the vertebral end plates so that block will not form because bone surfaces do not match and the cage migrates. If the implant is of a larger size, there is a risk of traumatization and breakage of the vertebral end plates and that of the pseudoarthrosis development.

Some authors [47] note that migration of the screw cages occurs in 1.7 to 10.0 % of cases. In 1999, Okuyama and Elias [51] reported long-term results of PLIF operations. In 20 % of patients, the previously operated segment was found unstable. The X-ray examination revealed instability of the implant in 6–7 % of patients, cage rotation – in 6 % of patients, and lateral migration – in 5–7 % of patients.

The vertebral end plates are often damaged while space for the implant is prepared. Usually, it happens in surgeons grasping the technique or in patients with marked osteoporosis [6]. Osteoporosis remains an important problem in the elderly patients with degenerative low-grade spondylolisthesis. Andersen [14] pointed 39 % incidence of osteoporosis among patients operated for low-grade listhesis. Based on the results of X-ray examination, Dambacher and Broll [18] described indications of osteoporosis which included glomerular bone pattern, thinning of the bone cortical layer, emphasized margins of the cortical layer.

Recently, the use of various osteoinductive materials has been widely discussed. Paul et al. [54] reported the use of bone morphogenetic protein-2 (BMP) in the fusion operations. With the BMP use, pseudoarthrosis developed in 5.0 % of cases, while in patients with autografts – in 33.9 %.

The recovery of the intervertebral disc height and that of the global lumbar lordosis (GLL) are equally important aspects of the spondylolisthesis treatment. Disc height can be restored by means of the interbody cage. However, it is a debatable question whether all types of interbody implants are equally effective in restoration of the disc height and GLL. The study performed by Patrick et al. [33] statistically proved that ALIF surpasses TLIF in its ability to restore the size of the intervertebral foramen, the segmental angle, and GLL in low-grade listhesis. ALIF technique allowed for 18.5 % increase in the intervertebral foramen size, whereas with TLIF the size reduced by 0.4 %. Moreover, ALIF ensured 8.3° increase of the segmental angle and 6.2° increase of GLL, while with TLIF the segmental angle decreased to 0.1° and GLL increased by 2.1°. Analogous results were given by Watkins et al. [65]. According to their analysis, the largest increase of GLL was observed after ALIF and XLIF and comprised 4.5° and 2.2° respectively, while after TLIF the increase of GLL amounted to 0.8° only. Restored disc height after ALIF comprised 2.2 mm, after XLIF (eXtreme Lumbar Interbody Fusion) – 2.0 mm and after TLIF – 0.5 mm. In all compared groups, the grade of spondylolisthesis became considerably lower.

With a vast amount of surgical methods used for the treatment of low-grade spondylolisthesis, it is necessary to consider the respective complications. All complications can be differentiated into three groups: general surgical complications, neurological complications, and those related to the use of stabilizing systems. Depending on the time of manifestation, there are also early and delayed complications.

General surgical complications include festering, damaged abdominal cavity organs, injured major vessels, thrombosis, fractures of bone structures (vertebral wings), suture failures (wound dehiscence, postoperative ventral hernia), surgical site hematoma, intestinal paralysis, acute urinary retention, sensitization, hemodynamically significant blood loss.

Neurological complications include aggravation of neurologic impairment caused by inadequate decompression, hyper-traction, incomplete or complete traumatization of the spinal nerve roots, excessively high limits of electrical coagulation, wounds of the dura mater (influx of liquor during the surgery, liquor cyst, liquorrhea).

The complications related to stabilizing systems may include malposition of the transpedicular screw, interbody cage migration, bone resorption around the implant or screws, fractures of metal constructions, metallosis.

In general, listed complications occur in up to 20 % of all surgical interventions on the lumbar spine [1, 38, 61]. According to the data of Russian and foreign authors [1, 17, 38], general surgical complications make up 3.0–14.7 % of the total, neurological – 7.80–29.18 % (because of intraoperative liquor influx) [4, 38], complications, related to implantation of stabilizing systems – 5.7–47.5 % (mainly because of pseudoarthrosis and malposition of transpedicular screws) [5, 6].

Scoliosis Research Society Morbidity and Mortality Committee analyzed 108419 cases of surgical treatment of degenerative spinal disorders. Superficial infections were revealed in 0.8 % of cases, deep infections – in 1.3 %. The postoperative neurological impairment was observed in 12 % of cases [17].

Bridwell [17] studied 430 cases of low-grade listhesis and revealed complications in 7.4 % of patients. Postoperative neurological impairment occurred in 12 % of cases, of which 80 % corresponded to the stable impairment. The incidence of wound infection reached 5 %.

In 2011, A.N. Rott [9] published the results of treatment of low-grade listhesis in 80 patients. Complications rate comprised 11.25 %, deep wound infections – 3.75 %, liquorrhea – 1.25 %, aggravation of neurological impairment – 3.75 %, deep venous thrombosis – 1.25 %.

A.A. Afaunov et al. [1] reported on 308 patients operated for degenerative spinal disorders. Repeated surgical interventions were performed in 8.17 % of cases. Mainly, revision surgery in the early postoperative period was caused by technical errors during decompression (2.26 %), liquorrhea (2.59 %) and defects related to implantation of the stabilizing systems (3.32 %). Terence et al. [61] analyzed the interbody fusion results in 1498 patients. According to their results, complications were observed in 7.68 % of cases, intraoperative liquorrhea – in 29.18 % of cases, blood loss, requiring transfusion – in 13.11 % of cases, trauma of the spinal nerve roots – in 9.83 % of cases, deep venous thrombosis – in 4.91 % of cases, gastrointestinal and urogenital systems' complications – in 6.01 %, thromboembolia of the pulmonary artery – in 4.91 % of cases.

Kalakoti et al. [38] analyzed 126044 patients operated in all the USA hospitals in 2015 for degenerative lumbar spine disorders using stabilizing systems. Among them, 2.06 % of patients experienced neurological complications (including liquorrhea, traumatic injuries of the spinal nerve roots), 2.35 % – deep venous thrombosis, 1.72 % – thromboembolia of the pulmonary artery, 2,40 % – superficial wound infection, 1.59 % – deep wound infection, 1.23 % – gastrointestinal complications.

Evolution of MIS technologies allowed medical society to carry out stabilizing operations in patients before considered inoperable because of a high risk of complications and lethal outcome. Calculations made to design a treatment of low-grade listhesis considered factors that influence the quality of life such as age, gender, body-mass index (BMI), comorbidity and bone density [14, 39, 49, 53].

McClendon et al. [49] studied 112 patients and demonstrated that BMI higher than 30 kg/m^2 increases the risk of complications thrice and cuts the Oswestry Disability Index twice compared to normal BMI.

Park and Ha [53] noted that the elderly patients are subject to deep wound infections more often than the patients with serious coexisting disorders.

Presently, a number of questions concerning the treatment of low-grade listhesis require further studying: evolution of pseudoarthrosis, grade, and rate of the bone block formation, the improvement of the quality of life in the postoperative period. It is unclear how the sagittal balance influences the quality of life of the patients operated for low-grade listhesis. Russian publications have no data on the problem, which indicates its importance and necessity of further studies.

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Received 25.03.2016

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