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The Current State of Surgical Treatment of Spondylolisthesis: Modern Approaches to Correction and Stabilization

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Abstract Spondylolisthesis remains a significant clinical problem, often accompanied by chronic pain, neurological deficits, and progressive spinal instability. Advances in surgical techniques have expanded the range of treatment options, focusing on achieving vertebral alignment, decompression of neural structures, and reliable spinal stabilization. This review summarizes current surgical approaches, including open, minimally invasive, and instrumented stabilization methods, as well as interbody fusion and dynamic fixation systems. Comparative analysis indicates that minimally invasive techniques are associated with reduced postoperative pain, shorter rehabilitation periods, and lower complication rates, while traditional open surgeries remain effective in severe deformities and advanced instability. Despite progress in surgical correction, challenges persist regarding optimal implant selection, prevention of adjacent segment disease, and long-term functional outcomes. Continued clinical research and individualized treatment planning are essential for improving surgical results and quality of life in patients with spondylolisthesis.

Keywords Current state of the problem of surgical treatment, Of patients with spondylolisthesis, Various ways of correction and stabilization

1. Introduction

Regarding the problem of surgical treatment of patients with spinal diseases, I would like to consider the treatment of spondylolisthesis separately. The term spondylolisthesis was introduced by H.F. Kilian (1854) to denote the displacement of the body of the overlying vertebra relative to the underlying one in the horizontal plane. According to the direction of displacement, anterolisthesis (anterior displacement), retrolisthesis (posteriorly displacement) and laterolisthesis (lateral displacement) are distinguished. Most often, spondylolisthesis is detected at the level of the lower lumbar (L4-L5) and lumbosacral (L5- S1) vertebral-motor segments, which account for more than 95% of cases of the disease. Classifications of spondylolisthesis are generally recognized, based either on the definition of pathogenetic mechanisms of pathology, or on a quantitative assessment of the degree of "slipping". L.L. Wiltze et al. (1976, 1997) divides spondylolisthesis into the following types: ' Dysplastic (congenital): A - with dysplasia of the L5-S1 joints and their horizontal orientation; B - with sagittal orientation of the intervertebral joints; C - with congenital anomalies of the lumbosacral vertebrae. Isthmic (cervical): A - with spondylolysis; B - with elongation of the interarticular zone, with or without spondylolysis; C - with injury to the interarticular zone. Degenerative, including senile, associated with natural or pathological degeneration of joints [1,3,5,7,9,11,13,15,16].

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2. Results and Analyzes

Traumatic, when the vertebrae are damaged outside the joint area. Pathological, including osteomyelitis or local oncological lesions. Post-surgical (after decompression of the spinal cord, nerve roots, or after laminectomy). According to various authors, 2.2% - 24.2% of the total number of patients examined for lumbar pain have dislocations of the lumbar vertebrae. Degenerative spondylolisthesis is more common in women, accounting for 52.5% - 69.9%. Traumatic spondylolisthesis is more common in men, especially under the age of 30, and accounts for 63%. Some researchers divide degenerative spondylolisthesis into 2 large groups: arthrogenic and discogenic. In turn, each of them is divided into compensated, decompensated and secondary compensated stages. The compensated stage of both types of degenerative spondylolisthesis is characterized by signs of instability with the possibility of vertebral reduction during extension. The presence of a fixed displacement with pathological mobility

of the displaced ends of the arch in the area of spondylolysis or pronounced local arthrosis at the displacement level is typical for the decompensated stage.

The secondarily compensated stage is characterized by the complete settling of the body of the displaced vertebra onto the body of the underlying one with a pattern of neoarthrosis in the zone of spondylolysis, or a decrease in the height of the intervertebral disc is combined with a pattern of apical-arqual neoarthrosis at the displacement level. An analysis of the literature indicates that in recent years, various aspects of spondylolisthesis have been duly reflected in publications by domestic and foreign authors. Of the methods for quantifying spondylolistheses, the simplest is the cranial closure plate of the underlying vertebra is conventionally divided into 4 equal parts, and a perpendicular is lowered from the posterior edge of the upper vertebra to the closure plate of the lower one. More precisely, the value of spondylolisthesis is characterized when determining the percentage of slipping of a vertebra calculated using the Meyerding method using the formula a/b x 100%, where a is the distance from the posterior edge of the lower vertebra to the perpendicular through the posterior edge of the upper vertebra, b is the anterior-posterior size of the upper endplate of the lower vertebra. Thus, the first degree of slippage corresponds to an offset of up to 25%, the second - from 25% to 50%, the third - from 50% to 75%, the fourth - from 75% to 100%. The fifth degree of spondylolisthesis (or spondyloptosis) is characterized not only by the horizontal displacement of the upper vertebra of the spine to the full anteroposterior body size, but also by its additional lateral displacement. According to another classification, spondylolisthesis is divided into stages III. At the compensated stage, the mobility of the vertebra during periods of a step of no more than 2 mm, there is no rotation. With subcompensation, mobility in the sagittal plane is 3-4 mm, in the horizontal plane - 3-4 mm. In the decompensated stage, the mobility exceeds 4 mm (5-10 mm) with a rotation of 5 mm or more. When determining the degree of displacement of the vertebrae in quantitative terms, some suggest dividing, for example, retro-spondylolisthesis into III degrees (I degree - displacement up to 2 mm, II degree - displacement up to 5 mm, III degree - more than 5 mm). Conservative treatment of patients with degenerative spondylitis (dry and underwater stretching, massage, X-ray therapy, corsets, etc.) rarely gives good results. 37.1%-48.8% of patients with spondylolisthesis require surgical treatment. He considers it necessary to stabilize the anterior sections in the compensated and secondarily compensated stage of the discogenic type of degenerative spondylolisthesis [2,4,6,8,10,12,14,16].

The compensated stage is based on neurological syndromes, mainly associated with segment instability at the displacement level. The secondarily compensated stage is characterized by irreversible changes in the peripheral nervous system with the phenomena of compensatory-adaptive segment rearrangements in new conditions. The same authors consider the presence of a decompensated stage of the discogenic type of degenerative spondylolisthesis to be an indication for open reduction of displaced vertebrae from anterior access. The clinical picture of the disease in patients of this group is dominated by compression radicular syndromes associated with a violation of the anatomical relationships of vertebral structures at the displacement level. In patients with arthrogenic type of degenerative spondylolisthesis, open correction and stabilization can be performed from the anterior approach in the absence of spinal canal stenosis in the clinic, high risk of postoperative stabilization of segments and satisfactory condition of the patient's somatic status.

Posterior access surgery is indicated for patients with arthrogenic type of degenerative spondylolisthesis with predominant localization of the degenerative-dystrophic process in the arched joints and musculoskeletal system. According to the indications, these operations can be used either as independent interventions in the form of stabilizing or distraction-correcting fusion, or as auxiliary operations for additional fixation of segments after anterior interbody fusion in order to activate patients early in the postoperative period. Posterior stabilization can be performed in patients with compensated and secondarily compensated stages of spondylolisthesis, whose orthopedic and neurological status are dominated by signs of arthrogenic instability. Sometimes this is a necessary measure, in particular, in the older age group with a burdened medical history, or with a significant prevalence of the degenerative-dystrophic process.

He believes that the indications for surgery in patients with spondylolisthesis are not related to the degree of vertebral displacement. The main thing is the clinic of the disease and the prognosis. It divides readings into absolute and relative ones. The absolute indications in children and adolescents are as follows: Progressive displacement of the L5 vertebra, when stage II is already occurring. Surgeries at the age of 11-12 are more justified. In stages III-IV, surgical interventions are possible at an earlier age. Severe secondary lumbosacral radicular syndrome. Antalgic scoliosis in spondylolisthesis. The combination of the progression of scoliosis with the progression of spondylogenesis. Progressive L51 grade spondylolisthesis in the presence of non-healing of the arch or aplasia of the posterior sacrum. Traumatic spondylolisthesis. This author considers the following to be relative indications for surgery in children and adolescents: Significant biomechanical changes with deepening of lumbar lordosis or intensification of thoracic kyphosis with ineffectiveness of conservative therapy. Stable form of displacement of the L5 vertebra in adolescents (TII-TV stage). I.M. Mitbrey refers to the absolute indications for surgery in adults: Spondylolisthesis of L4, L5 vertebrae of any degree with pronounced instability in case of ineffectiveness of conservative therapy. Lower paraparesis and pelvic organ dysfunction.

Frequently occurring disco-radicular syndrome. Secondary gross pathology of the spinal cord membranes, impaired cerebrospinal fluid dynamics, arachnoid cysts, compression of the "horse tail". Severe instability, aggravated by laminectomy. Pathology of intervertebral discs. Spondylolisthesis with

antalgic scoliosis. Traumatic spondylolisthesis. Spinal canal stenosis. The author considers relative indications in adults to be: Spondylolisthesis in middle-aged people who are not engaged in physical labor, with significant remissions, when the exacerbation of pain interferes with self-care. Spondylolisthesis in the elderly, which greatly reduces their activity. To operate on patients who have symptoms associated with dislocation of the vertebra, and if the patient does not respond to conservative treatment, or a sharp deterioration occurs. Surgery is indicated even in cases where there is a fairly substantial risk of deterioration, but the symptoms of the disease may not appear.

V.V. Zaretkov defines the indications for surgery as follows: Spondylolysis and spondylolisthesis with persistent pain syndrome that does not respond to conservative therapy for 6-12 months. Signs of a clear progression of vertebral displacement. Spondylolisthesis with progressive neurological disorders. Progression of scoliosis in spondylolisthesis. Displacement of the vertebra due to elongation of the arch. In degenerative spondylolisthesis, they are indicated only in 2 cases: when there is persistent lumbargia and radicular syndrome, or compression of the roots by osteophytes, the body of a displaced vertebra, a herniated disc, a fibrously altered longitudinal ligament and epidural tissue. According to other researchers, the indications for surgery for spondylolisthesis are: Spondylolisthesis exceeding grade I in children and adolescents. With higher degrees of displacement, severe pain syndrome, and neurological deficits, surgery is indicated at any age. Displacement of the vertebra of any degree in the presence of instability. Combination of spondylolisthesis with abnormalities of the lumbosacral spine. Combination of spondylolisthesis with scoliotic disease. As can be seen from the above, each author interprets the indications for surgery based on his classification and his personal experience of surgical treatment of this category of patients. Surgical treatment of spondylolisthesis is still a widely discussed issue, both in Russian and foreign literature.

A wide variety of surgical methods for the treatment of spondylolisthesis has been proposed, while there is no single treatment strategy. For a better understanding of the problem, it is necessary to consider the methods of spinal fusion and osteosynthesis devices used to treat spondylolisthesis. I would also like to note that, despite the large number of devices and stabilization methods, the problem of treating spondylolisthesis still remains unresolved. Spondylolisthesis surgery is developing through the introduction of various types of spinal fusion. For a long period, until the 1950s, in the treatment of spondylolisthesis, grafts were installed exclusively from behind without opening the spinal canal using two types of techniques: Albee sG and Hibbs SG. Nervous structures of the spinal canal in spondylolisthesis. James and Nisbet, Adkins, Gill, Manning, and White performed laminectomy of the mobile arch during spondylolisthesis and decompression without fusion. Their ideas, sometimes controversial, have revolutionized the surgery of spondylolisthesis. At the same time, the direction of anterior interbody fusion was developing, which theoretically seemed better than posterior fusion.

The first operations were performed in 1923 for tuberculous spondylodiscitis. R. Sarpegg in 1932 put forward the idea of using anterior interbody fusion for the treatment of spondylolisthesis, and in 1933 F. Bums implemented it by performing interbody fusion transabsom. This complex and risky surgical technique began to be used, and by 1953 M. Ingebridsen counted 63 cases of its implementation. Interbody fusion surgery has developed in two main directions: the first, which progressed rapidly in the 50s and especially in the 60s, is anterior interbody fusion, performed transabdominally or retroperitoneal; the second, less fashionable, based on the principles of low injury, is posterior interbody fusion, which simultaneously solves two problems. The main tasks are decompression and stabilization. The trend in recent years has been a combination of anterior and posterior types of spinal fusion, enhanced spinal fusion and reduction of the displaced vertebra using additional osteosynthesis. V.D. Chaklin is a pioneer of surgical interventions on the bodies of the lumbar vertebrae and the author of the operation of anterior spinal fusion with extraperitoneal access for spondylolisthesis in our country and abroad. In 1931, he performed the first anterior fusion surgery with left-sided extraperitoneal access for spondylolisthesis. Since the 60s, Russian authors have proposed several methods of anterior fusion surgery in relation to the treatment of lumbar osteochondrosis. The operation allows total or subtotal (with some modifications) removal of the degenerated lumbar disc and, thus, to eliminate the root cause of neurological complications of osteochondrosis. Methods of anterior cantilever fusion in patients with severe forms (grade II-IV) of spondylolisthesis, methods of open vertebral reduction and interbody fusion with allografts from the anterior approach were proposed. Anterior stabilization of a dislocated vertebra by interbody fusion is traumatic, accompanied by large blood loss, and cases of migration and lysis of grafts are not uncommon. According to some authors, in 6.6-15.5% of cases after interbody fusion, repeated operations for pseudoarthrosis are necessary. Moreover, after repeated operations, fusion is achieved only in 88% of cases at the L5-SI level and in 83% at the L4-5 level. Patients feel absolutely healthy in 47-85% of cases. Radicular pain was relieved after surgery in only 75% of patients, pain in the lumbar spine in 16.6-40% of patients. The anterior isolated graft is exposed to significant impacts due to the small size of the contact areas between it and the vertebral body.

In the last decade, ventral minimally traumatic interventions have been actively developed, and two types of accesses to the lower parts of the vertebral bodies using minimally invasive technology have been introduced. On the one hand, surgeons have developed laparoscopic techniques. On the other hand, the traditional ventral access was reduced in size and supplemented with microsurgical techniques, as a result of which this access acquired all the advantages of a minimally invasive method known as mini - ALIF (Anterior lumbar interbody fusion). The advantages of this method are

to reduce the likelihood of technical errors, minimal tissue injury, low blood loss, and a short duration of surgery with a small number of complications. A number of researchers have successfully used combined anterior-non-posterior access in spondylolisthesis. This technique is effective in severe vertebral dislocations, as well as in unsuccessful stabilizing operations performed from the posterior approach. Nevertheless, despite such impressive prospects for minimally invasive anterior fusion methods, the percentage of serious complications with their use remains quite high (13.5%): iliac vein injury, peritoneal injury, dural sac injury during decompression, sympathetic disorders [14,16].

The technique of percutaneous posterolateral access. Since then, the method of percutaneous nucleotomy began to develop. In 1988, in addition to the standard equipment for percutaneous endoscopic nucleotomy, he developed an abrasive cutter for processing endplates and began performing percutaneous interbody fusion. Moreover, according to the author, this type of spinal fusion is optimal in combination with external transpedicular fixation, in cases where segmental reduction, distraction and (or) correction of lordosis are required. The use of B-TWIN system implants for percutaneous interbody fusion was reported. These small implants are inserted into the interbody space percutaneously from the posterolateral access. According to the authors, additional fixation of the operated spinal segment is not required. To date, more than 800 such operations have been performed. I would like to note that performing interbody fusion should simultaneously solve several tasks: restoring the height of the interbody gap, the axis of the spine, keeping the vertebra in the position of eliminated anterior slipping, and eliminating instability in the affected vertebral motor segment. Unfortunately, the small-sized implants used do not meet these requirements. The problem of vertebral reposition in spondylolisthesis has been attracting increasing attention from researchers over the past 10-15 years. To reposition the vertebra, as well as to achieve anterior decompression of the roots of the "horse tail", a total corporectomy with interbody fusion was performed, but later this technique was abandoned, since without reliable stabilization, secondary displacement occurred. The use of various methods of posterior osteosynthesis (metal immersion fixators in the form of plates, wires, rods) was the next stage in the development of spondylolisthesis surgery. Additional stabilization made it possible to reduce secondary vertebral displacement in a large number of cases. Nevertheless, correction of the deformation remained impossible. For the first time, transpedicular fixation was proposed, which proved to be more reliable than other methods. However, after a certain time, the internal transpedicular clamps deform due to metal fatigue, and there may be fractures of rods, plates, and suppuration. In addition, repeated operations are required to remove them. The complication rate ranges from 9 to 25%. It can be considered proven that the reliability of transpedicular fixation without restoring interbody support is very low, but it significantly increases if transpedicular fixation is combined with interbody fusion. According to some researchers, neurological complications due to spinal distraction itself in order to correct a dislocated vertebra, as well as spinal fusion using internal fixators and screws, occur in 30-50% of patients. These authors insist on slow distraction, subsequent decompression, correction and fixation of the spine. Neurological complications associated with surgical repositioning and spinal fusion in spondylolisthesis have been observed by many researchers. There is a correlation between the frequency of such complications and the magnitude of intraoperative reduction. One of the causes of postrepositional neurological complications may be nerve tension during simultaneous vertebral reduction. Correction of lumbosacral kyphosis significantly reduces the tension of the root, that is, the elimination of kyphosis can have a protective effect. Some researchers performed a gradual reposition with additional intraoperative monitoring of the state of the neuromuscular apparatus using the Wake-up test. Despite the intraoperative diagnosis, in the postoperative period in 25% of cases they received a loss of fixation due to unscrewing of screws and in 25% - a neurological deficit, and in 12.5% of patients it turned out to be persistent. I would like to focus separately on the problem of the need for complete or partial reduction of dislocated vertebrae during operations for spondylolisthesis. Some authors consider it necessary to correct the dislocated vertebra before stabilization. But some of them do not insist on a complete one hundred percent reduction.

An original device for correcting vertebral dislocations has been proposed and put into practice, with the help of which it is possible to eliminate vertebral dislocation during spondylolisthesis simultaneously or gradually in the postoperative period under the control of the neurological status of the patient. We are talking about an external transpedicular fixation device, which allows not only to eliminate the displacement of the vertebra in a prolonged manner, but also to fix it securely until a block is formed in the affected segment of the spine. In the course of scientific research, it was proved that with gradual reduction of a displaced vertebra under the control of the patient's neurological status, maximum correction can be achieved without worsening neurological symptoms. Various techniques were used to form the spinal cord, depending on the type of spondylolysis.

3. Conclusions

Thus, in the presence of spondylolysis, laminectomy of the dislocated vertebra was performed, followed by discotomy and interbody fusion with an autoclave, an implant made of porous titanium nickelide from the posterior lobe. In other types of spondylolisthesis, transperitoneal and extraperitoneal open accesses to the interested area of the spine were used to perform interbody fusion. Auto-hardness and porous titanium nickelide were also used as a material for fusion. When using an external transpedicular fixation device in the treatment of spondylolisthesis of varying degrees of complexity, it was possible to achieve complete

reduction of the displaced vertebra in 46% of cases. At the same time, there was no aggravation of neurological deficit in any case. Thus, the problem of treating spondylolisthesis remains unresolved. We see its solution in reducing the surgical aggression of surgical intervention by introducing minimally invasive methods of spinal fusion and osteosynthesis while improving treatment outcomes, both orthopedic and neurological.

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