SCOLIOSIS AND SPONDYLOLISTHESIS: LITERATURE REVIEW

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At present, there are no reliable prognostic factors indicating the progressive nature of spondylolisthesis in children and adolescents. Often the main complaint is a pain syndrome, which is well arrested by conservative therapy, while the quality of life of patients without surgery is not significantly impaired. The presented review of the literature shows that it is better to correct scoliotic deformity at a younger age when indications arise. Isthmic spondylolisthesis and scoliosis should be considered as different pathologies. In the absence of convincing evidence that spondylolisthesis has caused the scoliosis development, indications for surgical treatment should be considered as those for individual pathologies. Isolated correction of scoliotic deformity does not lead to a progression of scoliosis. Papers of Russian and foreign authors from e-Library, Medline and PubMed databases were reviewed. The evidence level in majority of papers is III(C), and in part of papers – II(B).
Key Words: spondylolisthesis, scoliosis, correction of spinal deformity.

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The problem of choosing a surgical approach for treatment of various spine deformities remains to be one of the most acute issues. In each particular case, the surgeon strives to achieve the maximum correction with minimal complication risks, eliminate the need for repeated interventions while minimizing the area of the spinal fusion and invasiveness of the intervention. As for individual pathologies, such as scoliosis and spondylolisthesis, there is a sufficient number of publications regarding these diseases that can be found in the literature. While the authors approaches described in such papers may somehow vary, the main principles are often similar.

The combination of scoliosis and isthmic spondylolisthesis in a patient is always an exclusive case, which requires special attention and approach. To date, there is no consensus on the optimal approach for treating such patients. For this reason, a vast number of individual clinical cases can be found in the literature [41, 50, 61].

Incidence

The incidence of a combination of these pathologies varies widely. This is due to the absence of a clear distinction between causation of these diseases. Some authors report that scoliosis occurs in 47–48 % of spondylolisthesis cases. Moreover, all deformities of more than 15° as well as deformities of mainly lumbar and thoracolumbar localization comprise this group [43]. In these cases, it is appropriate to treat scoliosis as a consequence of spondylolisthesis, and scoliotic curve may develop due to the pain syndrome or asymmetric displacement of L5. Therefore, reduction in the scoliotic curve can be expected in the surgical treatment of spondylolisthesis.

In the general population, spondylolisthesis occurs in 2.4–6.0 % of cases [7, 30, 38].

Researchers from the University of Virginia (USA) analyzed the data of adolescents of 10–19 years of age who sought medical assistance for the back pain during the period of 2007–2010. In more than 80 % of the cases, no accurate diagnosis has not been determined within a year. Distortion of the musculoskeletal system (muscle spasm, 8.9 %), scoliosis (4.7 %), degenerative lesions of the lumbar spine (1.7 %), and lumbar disc herniation (1.3 %) were the most frequent diagnoses. The incidence of other diagnoses, including spondylolysis, spondylolisthesis, infection, tumor, and fracture comprised less than 1 % [60].

According to Gennari et al. [31], the pain in the back is due to scoliosis in 31 %, spondylolysis in 13 % and spondylolisthesis in 5 % of the cases.

Spondylolisthesis associated with scoliosis occurs in 1.2 % of the cases [49].

McPhee et al. [43] noted the fact that the incidence of scoliosis is higher in case if vertebra displacement is more than 25 %. The lowest incidence rate of scoliosis is observed in isthmic spondylolisthesis.

According to the presented data, one can conclude that the incidence of spondylolisthesis in scoliotic deformities is the same as for the general population. Furthermore, lumbar and thoracolumbar scoliosis can develop as a result of asymmetric vertebra slipping.

Comorbidities

Association of scoliosis and spondylolisthesis is an often case in patients with Marfan syndrome, neurofibromatosis, and *spina bifida* of L5 [12, 22, 54, 61]. However, one cannot claim that any pathology, including one accompanied

by systemic dysplasia of the connective tissue, can cause spondylolisthesis.

Some researchers associate scoliosis and spondylolisthesis with flatfoot deformity considering them as a risk factor for feet pathology [13]. Yet failure of the connective tissue is more likely to be one of the important factors.

The most common symptom that allows spondylolisthesis detection is back pain. Pain develops as a result of trauma in more than half of the cases [12, 49].

Ramirez et al. [49] report that back pain in children and adolescents with scoliosis occurs in 32 % of cases. The pain intensifies with age and maturation of bone tissue as well as in the presence of traumas in the past medical history. The pain is temporary and arrested by conservative therapy in more than half of the cases.

Risk factors for spondylolisthesis progression

There are almost no cases of spondylolisthesis in children under 1 year of age while it reaches 5 % by the age of 5–7 years, then the incidence increases insignificantly and reaches 6 % by the age of 18. In most cases, the disease is asymptomatic. This fact can confirm the role of vertical loads on the L5 vertebral arch resulting in its fatigue damage. Spondylolisthesis that appears in childhood and adolescence rarely progresses reaching grade III–IV (varies from 1 to 22 % according to various authors) and stops progressing at all after adolescence. The incidence is almost the same in boys and girls [7]. However, more severe degrees of displacement are observed in female patients [7].

A.I. Prodan et al. [7] consider the following factors as risk factors for the progression of spondylolisthesis: 1) sagittal vertebral-pelvic imbalance; 2) dysplasia of the lumbosacral spine (*spina bifida*, hypoplasia of the articular and transverse processes associated with dysplasia of *lig. iliolumbales*, hypoplasia of L5 and S1 vertebral arches, high position of L5 in relation to the bispinal line, and etc.); 3) trapezoidal deformity of L5 body and domed deformity of the upper surface of the sacrum; 4) spasm of growth in children and adolescents; 5) incomplete morphogenesis of the axial skeleton; 6) instability of the lumbosacral segment; 7) development and progression of degenerative changes in the intervertebral disc at the level of displacement [29].

Other authors report that spondylolisthesis develops three times more often in boys than in girls [12].

The risk factor for progression of spondylolisthesis most discussed in the literature is lumbopelvic imbalance observed both in children and adults [44, 51].

In addition to spondylolisthesis, the balance is affected by the size of the thoracic scoliotic curve. In addition, lumbar lordosis is decreased in patients with degenerative lumbar scoliosis [35].

The Scoliosis Research Society (SRS) conducted an analysis of childhood and adolescent spondylolisthesis. It has been proved that there is a high risk of spondylolisthesis progression up to the grade I–II (from 43 to 74 %) in bilateral defect of the interarticular part of the arch. The chances of spontaneous block formation are high in case of unilateral defects and early detection. There is no reliable evidence for the factors of further progression. However, the risk of low back pain in the near future and adulthood, including a higher risk of indications for surgical treatment, significantly increases in spondylolisthesis. The conducted multicenter study lacks reliable evidence to predict the course of spondylolisthesis for early surgical interventions [26].

Some researchers report attempts to evaluate the progression of spondylolisthesis based on the signs detected by MRI. Algorithms for analysis of the intensity of the MR signal from intervertebral discs have been developed, and an unfavorable prognosis for their degeneration has been proved [32, 45].

In order to assess the quality of life of patients with spondylolisthesis, the SRS-22 questionnaire has been proposed [34].

Conservative treatment

SRS conducted an analysis of papers on child and adolescent spondylolisthesis. A large number of studies with a low level of evidence have been revealed during literature study. Of the reports corresponding to a high level of evidence, the data has been obtained that a positive effect of conservative treatment of spondylolisthesis is achieved in 80 % of cases and in 85 % of cases of surgical treatment. At the same time, there are no adequate groups for comparing patients, no terms for the conservative treatment to be considered ineffective. Patients who underwent surgical treatment often did not receive conservative therapy. It turned out to be impossible to evaluate the efficiency of an individual approach of conservative therapy as well as compare the effects of different types of surgical treatment due to the different degree of invasiveness of the methods. As a result, the researchers came to the conclusion that this problem requires further detailed consideration [27].

The main goal of conservative therapy is pain management. Compression of nervous structures is extremely rare in children and adolescents in early grade spondylolisthesis. Thus, the conservative treatment results in a positive effect in the overwhelming majority of cases [2, 9, 49].

Surgical treatment for back pain is required in extremely rare cases: when conservative therapy is inefficient, in case of compression of nervous structures and when deformity progression is evidenced during follow-up [31].

The literature often reports no significant difference in the progression of listhesis, quality of life and pain sensation in the groups of pediatric and adult patients with spondylolisthesis after surgery and without it [24, 59].

For instance, Lundine et al. [42] present evidence for the absence of differences in complaints and quality of life in patients who underwent surgery for spondylolisthesis and in children and adolescents receiving conservative therapy. Moreover, the risk of adverse outcome is higher in initially higher grade of spondylolisthesis in both groups. Often, there is no indication for emergency surgical treatment when the disease is asymptomatic or with minor manifestations. Surgery at an older age provides more effective results with lower risk of complications. In the absence of conser-

vative treatment, sensations are subjectively worse. Data were evaluated using the SRS-30 questionnaire.

No differences in progression of listhesis, quality of life and pain sensation were noted in the groups of patients who were and were not subjected to spondylolisthesis in the study conducted by Xue et al. [59].

In contrast to the abovementioned data, there are studies in the literature providing evidence for higher efficiency of surgical treatment compared to the conservative one. However, there is still no significant progression of spondylolisthesis in children and adolescents without surgery within the two-year observation period [25].

Some authors report successful brace therapy in spondylolisthesis. However, there are no reliable radiographic data confirming the effect of treatment, and the main attention is paid to significant reduction in pain [23].

A successful case of conservative treatment of high degree spondylolisthesis in a girl with thoracic scoliosis and a symptom of neurogenic lameness with the help of a brace is reported. The degree of spondylolisthesis remained the same, but neurologic symptoms partially regressed [57].

Surgical treatment

Despite the fact that the history of surgical treatment of spondylolisthesis extends for more than a decade, there is still no single method of selecting a surgical approach. There are no unambiguous and clear signs of progression, there are completely different indications for surgical treatment as well as different methods of treatment. Literature data of the recent years report cases of more successful treatment with significantly fewer complications.

There are numerous studies with a high degree of reliability on the effectiveness of conservative therapy for spondylolisthesis in children and adolescents, in most cases the non-progressive course of the disease with a sufficiently high quality of life. However, there are more and more reports on the positive outcomes of surgical treatment for grade I–II spondylolisthesis in children and adolescents.

Only a few articles describe clear indications for the surgical treatment. For example, Pink et al. [47] believe that patients with incurable pain during conservative therapy, patients with spinal instability or confirmed progression of displacement are to be subjected to the surgical treatment.

Compression of nervous structures, which can occur even in low-grade spondylolisthesis, is undoubtedly an indication for surgical treatment [16, 30].

Recently, more and more attention is paid to the lumbopelvic balance, the disruption of which can worsen the disease prognosis. These indicators are also paid attention to during the preoperational planning phase [3, 4, 7].

A.I. Prodan et. al. [8] came to the conclusion that surgical treatment of grade I–II spondylolisthesis is not difficult. Therefore, only posterior transpedicular fixation with vertebral reduction is sufficient. In cases of the treatment of higher-grade spondylolisthesis, 360° spinal fusion with various variants of vertebrotomy and neuromonitoring is mandatory.

Audat et al. [21] compare the results of surgical treatment of low-grade spondylolisthesis by decompression of the neural structures with those achieved by vertebral body reduction, both performed under conditions of transpedicular fixation. However, there was no significant difference in the results of the treatment in both groups.

Other researchers [5, 10, 36] tend to consider 360° spinal fusion as the optimal method of treatment for different age groups. It is especially necessary in case if spondylolisthesis is accompanied by congenital anomalies in L5 development [22].

Comparison of the results of surgical treatment for grade I–III spondylolisthesis using the method of anterior decompression and stabilization and posterolateral spinal fusion with transpedicular fixation showed no significant differences in the treatment outcome [11]. In case of isolated anterior spinal fusion, the incidence of an adverse outcome can reach 25.5 % [17].

Most authors believe that complete reduction of the displaced vertebra in grade III or higher spondylolisthesis provides an increased risk of neurological complications [4, 10]. In this case, the correction should be performed under conditions of intraoperative neuromonitoring [14].

A.P. Shein et al. [19] concluded that one-stage reduction of the vertebra over 90 % relative to the value of the initial displacement slightly worsens the prognosis for the subsequent recovery of EMG characteristics of the functional state of the sensorimotor structures of the lower limbs in case of a positive clinical effect.

The multicenter study performed by SRS revealed that about 50 % of patients with spondylolisthesis had compression of the nervous structures. The overall complication rate after surgery was 10.4 %. The worsened neurological deficit was noted in 31.5 % of the cases, dural sac rupture and infection were observed in 8.13 % and 12.2 % cases, respectively [30].

Waddell et al. [56] concluded that posterolateral interbody fusion in degenerative scoliosis and spondylolisthesis results in stable fixation and formation of a solid block in 88–96 % of cases. The treatment is significantly more successful when the method is supplemented by posterior transpedicular fixation. Pain radiating to the lower limbs and weakness in the legs, which were cured within six months, were noted in more than 50 % of cases. The following complications were observed after transpedicular fixation: 2 cases of junctional kyphosis formation, 1 case of instrumentation failure.

In order to reduce the risk of intraoperative complications, which are quite high for one-stage reduction, the method of gradual management of L5 displacement with the help of the external fixation device has been proposed [1, 18]. It is beyond doubt that this method has a number of advantages. However, it cannot be considered to be optimal due to the long-term presence of the external metal structure, which can cause considerable discomfort during a long period of time.

In addition, the external fixation device can be used in the treatment of traumatic spondylolisthesis with high

efficiency and the possibility of the three-plane correction [6].

Some specialists mention high effectiveness of epidural adhesion in combination with kinesitherapy in patients with lumbar spondylolisthesis [15].

The analysis of complications in the surgical treatment of high-grade spondylolisthesis in children and adults does not show a significant difference between the two groups. Complications reach a total of 24.8 %. The most frequent complication is an increase in the neurological deficit (up to 11.9 % of cases). Among these cases, the developed neurological deficit regresses within the next six months in 90 % of cases [39].

As for the surgery of scoliotic deformities, there is evidence that a surgery performed in childhood does not lead to pronounced degenerative changes in adjacent segments and, in most cases, does not require surgical treatment. A timely performed spinal fusion for scoliotic deformities, even in childhood, is more effective than delayed surgery in adulthood. The observation period is up to the age of 51 [58].

There is an experience of comparison of the quality of life of patients with scoliosis and patients with spondylolisthesis who underwent surgery in adolescence. Patients show higher satisfaction with treatment and have a longer-term stable effect after correction of scoliosis, while patients with spondylolisthesis, most likely due to the severe pain, had lower rates. In addition, pain regression is quite often observed, in up to 6 % of cases, after surgical treatment of spondylolisthesis. The average follow-up period was 14.8 years for patients with spondylolisthesis, and 17 years for patients with scoliosis [37].

As for the scoliosis in adults, the question often arises whether surgical treatment is necessary, especially taking into account the extremely rare progression of scoliosis by the end of active bone growth. The answer to this question is the report that a significant reduction in pain and improvement in the quality of life is noted in adults after surgical treatment of scoliosis compared to the patients who received only conservative therapy [52].

Association of scoliosis and spondylolisthesis

The opinion prevailing in the world literature is that scoliosis, especially with low degree of severity, develops due to spondylolisthesis. Hence, the chances of spontaneous correction of the scoliotic curve are high in case of adequate correction of spondylolisthesis.

For example, Peterson et al. [46] established that mild asymmetric spondylolisthesis is the cause of lumbar scoliosis in children and adolescents. With the introduction of 3D CT into practice, it became easier to prove the relationship between lumbar scoliosis and spondylolisthesis. Pneumaticos et al. [48] present several cases of decrease in the scoliotic curve.

There are papers where authors consider scoliosis and spondylolisthesis to be different pathologies [33].

The article by Crostelli and Mazza [28] has caused many objections. The authors expressed their opinion that scoliosis developed due to spondylolisthesis is usually characterized by a lumbar curve of no more than 15 °Cobb angle. Furthermore, spondylolisthesis as a concomitant pathology can lead to a greater progression of scoliotic deformity. When selecting a treatment approach, one must focus his attention on those indications for surgery that are applicable for individual pathologies, and treat separately one of the pathologies that is the most crucial according to its clinical manifestations. In response to this report, an article [62] was published, which describes the case of self-correction of 50° thoracic scoliosis after 88 % correction of only L5–S1 spondylolisthesis in a 12 year-old girl. The patient was followed up on spine deformity for two years, she had no complaints about back pain and neurological deficit. Scoliosis was almost completely corrected in the supine position, i.e., it was mobile. A similar case is described in another article. A 12-year-old patient with L5 radiculopathy and persistent scoliosis underwent surgery for spondylolisthesis. The scoliotic curve remained without changes immediately after surgery. The deformity correction was noted one year after surgery. In addition, pain was arrested, and neurological symptoms regressed [53].

There are reports on the development of spondylolisthesis in neurofibromatosis. A patient with neurofibromatosis, dural ectasia and spondylolisthesis with mild scoliosis suffered from pain in the lumbar region. Fixation with transpedicular structure combined with L1–S1 spinal fusion with iliac crest bone autograft was performed, and the pain was arrested. Scoliosis remained without changes [61].

A peculiar clinical case is described in an article by Roberts, Tsirikos [50]. A patient with mucopolysaccharidosis, scoliosis, and bilateral spondylolysis of L5 without spondylolisthesis has been presented. An anteroposterior fusion of T9–L4 was performed. After surgery, grade I–II spondylolisthesis of L4 was developed, which did not progress for 3.5 years and was not clinically manifested. The initial kyphosis of the thoracolumbar region comprised 60°, it was corrected to 4°, initial scoliosis angle was 42°, it was corrected to 4°. Apparently, the correction of kyphosis turned out to be insufficient in this case, since the lumbar region should be normally lordosed. Another possible reason is an inadequate correction of the global sagittal balance, since the upper instrumented vertebra is located at the T9 level, which is often the apex of physiological kyphosis and, for this reason, an unfavorable fixation point due to a high risk of torso imbalance and formation of junctional kyphosis.

In another study [55] of 34 patients with spondylolisthesis, 10 patients had scoliosis that required further surgical correction. According to the authors, scoliosis was associated with listhesis in 8 cases and regarded as idiopathic scoliosis in 2 cases. Spinal fusion between the transverse processes of L5 and the sacral wings was performed using iliac crest bone autografts without decompression and instrumentation. Despite spondylolysis in a number of patients, a stable result was obtained, which allowed a total of 28 patients to return to professional sport. Idiopathic scoliosis and scoliosis associated with spondylolisthesis are clearly

distinguished in this report. The need for surgical correction was quite high even in case of the prevalence of secondary scoliosis.

Arlet et al. [20] consider scoliosis and spondylolisthesis as different diseases. There are rare cases when scoliosis develops due to asymmetric spondylolisthesis, while surgical treatment of spondylolisthesis can reduce or almost completely eliminate the scoliotic curve. Surgical treatment is necessary only in case of strict indications for each individual pathology. Scoliosis correction in spondylolisthesis does not adversely affect the state of the displaced vertebra.

Some authors [38] tend to believe that correction of scoliotic deformity alone neither lead to the progression of spondylolisthesis nor worsen the quality of life in comparison with patients who have only scoliosis but not spondylolisthesis. The observation period is 4 years. In this case, the guarantee of a positive result is preservation of at least three free levels from the lower instrumented vertebra to the L5 level.

Other authors [40] present evidence that surgical treatment of idiopathic adolescent scoliosis does not lead to a significant increase in degeneration of the underlying intervertebral discs (the observation period is 9 years).

Conclusion

Having analyzed the literature data, one can conclude that spondylolisthesis of the lumbar vertebrae can cause scoliotic deformities of the spine in 48 % of cases. These are mainly lumbar and thoracolumbar types of grade I–III scoliosis. These types of scoliosis rarely require surgical treatment, they usually present *de novo* scoliosis and manifest themselves in the progression of degenerative spinal lesions. There is a high chance of self-correction of the scoliotic curve in case of the properly selected approach to the surgical treatment of spondylolisthesis, correction of the lumbosacral and pelvic sagittal balances of the spine. There are exceptional cases that describe self-correction of the grade IV thoracic scoliosis after surgery for spondylolisthesis.

To date, there are no reliable signs of spondylolisthesis progression in children and adolescents. In most cases, the grade of spondylolisthesis does not usually exceed I–II. The main complaint of this group of patients is pain, which is successfully cured by conservative therapy. Surgical treatment of grade I–II spondylolisthesis is recommended only in exceptional cases when conservative therapy yields no positive results, and patients suffer from severe pain, in case of persistent neurologic deficit or confirmed progression of spondylolisthesis. Conservative therapy and dynamic observation are possible in grade III and higher spondylolisthesis, in case of relatively asymptomatic disease, absence of neurological deficit and pain. The risk of postoperative complications is quite high even in low-grade spondylolisthesis. The quality of life is not affected in non-surgical treatment of spondylolisthesis, while a delayed surgery has a greater effect and provides lower risk of complications.

The situation is different in case of the surgery of scoliotic deformities. Surgical treatment in adolescence is most effective, since it prevents a scoliotic curve from reaching its critical values, which can lead to impaired function of internal organs, irreversible degenerative changes in the spine and a severe cosmetic defect. Correction of scoliotic deformity in adolescence does not lead to an increase in degenerative changes in adjacent segments of the spine.

Structural scoliosis, especially of thoracic localization, and spondylolisthesis should be considered as separate diseases, which can complicate each other. Indications for surgical treatment should be determined for each pathology separately. Surgical correction of the scoliotic curve does not adversely affect the state of the un instrumented lumbar spine and does not lead to spondylolisthesis progression

Any surgery on the spine should be accompanied by restoration of the global and lumbopelvic balance.

Assessment of the quality of life of patients can be carried out using the SRS-22, 24, 30 questionnaires with a high degree of credibility.

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