NEUROLOGICAL COMPLICATIONS IN SCOLIOSIS SURGERY: A SYSTEMATIC REVIEW OF THE PROBLEM

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The objective of the review is a multi-aspect study of the problem of neurological complications in scoliosis surgery, based on large arrays of literary data (eLibrary, Pubmed). The following aspects of the problem were studied: the incidence of neurological complications in scoliosis surgery, the incidence of neurological complications in scoliosis of various etiologies, the incidence of neurological complications in different age groups, the incidence of neurological complications following various surgical approaches, the frequency of functional recovery after the development of neurological deficit, the causes of neurological complications, risk factors for the development of neurological symptoms, damage to the peripheral nervous system, late development of neurological complications (delayed deficit), and rare complications (casuistry). Neurological complications of surgical interventions for spinal deformities of various etiologies develop relatively infrequently, but this circumstance in no way simplifies the problem, since these complications are sometimes catastrophically severe and require long-term and complex treatment, the success of which is not guaranteed. Surgical treatment of patients with spinal pathology (not just deformities) should be performed in highly specialized centers equipped with the most modern equipment and staffed by highly trained specialists.

Key Words: spinal pathology; scoliosis; surgery; neurological complications.

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The creation of the first effective instrumentation for the correction of spinal deformities in the early 1960s (Paul Randall Harrington) led to an explosive increase in surgical activity worldwide [1]. This, in turn, revealed the risks of specific complications, including (and possibly primarily) from the contents of the spinal canal. There is reason to believe that the first publication dedicated to this problem belongs to MacEwen et al [2]. This article is interesting, among other things, because it does not contain a single reference to other publications, and there is no reference list attached. It is hard to imagine more convincing proof of scientific priority.

In subsequent years, the number of articles on this topic constantly increased, but, as emphasized by Bridwell et al. [3], the true frequency of neurological complications remained undetermined. This indicator varies from 0.3% [4] to 2.0% [5], despite the fact that many publications analyze huge arrays of clinical data – from thousands to tens of thousands of patients [6, 7]. This circumstance prompted us to write this literature review, built on the study of publications based on the analysis of clinical groups of 500 patients and more.

The objective of the review is a multidimensional investigation of the problem of neurological complications in scoliosis surgery, based on large arrays of literature data (eLibrary, PubMed). The studied aspects of the problem are as follows:

- frequency of development of neurological complications in scoliosis surgery;
- frequency of development of neurological complications in scoliosis of various etiologies;
- frequency of development of neurological complications in various age groups;
- frequency of development of neurological complications when using various surgical approaches;
- frequency of functional recovery after the development of a neurological deficit;
- causes of the development of neurological complications;
- risk factors for the development of neurological symptoms;
- lesions of the peripheral nervous system;
- late development of neurological complications (delayed deficit); and
- rare complications (casuistry).

Since a portion of the analyzed cohorts is heterogeneous in terms of etiology (although the majority of deformities were deliberately idiopathic), statistical processing of the obtained data was impossible. Moreover, we dare to assume that there was no particular need for such processing. Surgery for spinal deformities is the domain of the most experienced spine surgeons. For such specialists, it is not so much the figures that are important, but rather the massive collective experience, which allows them to better orient themselves in the problem, and to find the optimal method of treatment or refuse intervention in each specific case.

We considered it necessary not to include in the review the data concerning neurological complications after multiplanar vertebrotomies performed for particularly complex spinal deformities. This is an absolutely specific section of

spine surgery, which is particularly evidenced by the frequency of neurological complications accompanying such operations. These figures fluctuate in the range of 4–7% to 23–27%, which is incomparable with the results of operations for conventional scoliotic deformities [8–12].

Results of the analysis of literature data

The array of literature data we studied is summarized in Table, the content of which, as it seems to us, is quite informative, although all articles were created according to different schemes, therefore their authors emphasized various aspects of the discussed problem.

We considered it appropriate to focus on the following aspects of the problem of neurological complications in patients subjected to surgical correction of scoliotic deformities in children and adults, that is, aged up to 18 and older: the overall frequency of development of neurological symptoms, differences between patients with idiopathic and congenital scoliosis, dependence on the type of surgical approach, and the frequency of functional recovery in the postoperative period.

Frequency of development of neurological complications. The total array, therefore, consists of 121,099 patients. However, regarding three of the 18 cohorts (Reames et al. [5], Patil et al. [16], Winter et al. [4] – the 1985 cohort), we do not possess data allowing us to make the necessary calculations, therefore the total group should be reduced by 26,392 persons and ultimately amounts to 94,707 patients. The frequency of development of neurological complications (taking into account dura mater tears) is 1022 (1.08%) cases.

Frequency of development of neurological complications in scoliosis of various etiologies. Information is contained in only two articles [5, 6]; in these cohorts – 20,733 patients. According to Qui et al. [6], in idiopathic scoliosis, complications were noted in 1.06%, according to Reames et al. [5], in 0.8%, and in congenital deformities – 2.89% and 2.00% respectively.

The frequency of development of neurological complications in various age groups was evaluated in five publications [3, 13–16]. The total number of patients in these cohorts amounted to 17,947. In patients aged up to 18, the complication rate ranges from 0.35 to 0.69%, and in adults – from 0.90 to 1.78%.

Frequency of development of neurological complications when using various surgical approaches was noted in two publications [6, 14] containing information about 7,707 patients. According to Coe et al. [14], the complication was stated when using the anterior approach in 0.26% of cases, posterior approach – in 0.32%, and combined (anteroposterior) approach – in 1.75%. Qui et al. [6] noted the development of neurological symptoms in posterior and combined approaches in 1.24% and 3.43% respectively.

Here we consider it appropriate to provide data regarding the role of ligation of segmental vessels, which accompanies the operation performed through anterior approach. The first mention of the procedure and the possible consequences of ligating and transecting segmental vessels during anterior approach to the thoracic and thoracolumbar vertebrae is contained in the article by Winter et al. [21].

The authors reported on 1197 operations using this technique and stated the complete absence of its negative consequences. They formulated a strict rule: ligate segmental vessels on the convex side of the scoliotic deformity, in the middle of the vertebral body, and do not use hypotensive anesthesia. Ligation near the intervertebral foramen is fraught with damage to small collaterals running into the lumen of the spinal canal and participating in the blood supply to its contents. In 2005, Orchowsky et al. [22] reported on the experience of ligating segmental vessels in 265 adult patients (average age – 40.2 years) operated on using a transthoracic approach. On average, 5.1 arteries were ligated. Two cases of severe neurological deficit were recorded.

The frequency of functional recovery after the development of a neurological deficit. This information is contained in seven works devoted to the treatment of a total of 46,032 patients, in whom 554 complications were noted. Long-term results are not known in all cases. Full recovery at various times after the intervention was noted in 261 (47.1%) patients, partial recovery in 194 (35.0%), and a lack of positive dynamics in 44 (7.9%). Regarding another 36 patients, no data were presented.

Bridwell et al. [3] emphasized in 1998 that the true frequency of neurological complications is undetermined, but the causes of their development are diverse:

- mechanical compression of the spinal cord by hooks, wire, or epidural hematoma;
- protrusion of the ligamentum flavum, posterior longitudinal ligament, or disc tissues into the canal after correction of the spinal deformity;
- stretching of the spinal cord by a distracting instrument;
- purely vascular disorders without a mechanical component with a resulting disruption of the blood supply to the spinal cord; and
- a combination of various mechanisms.

In the 21st century, due to the widespread use of pedicle screw fixation, the first point of this list was supplemented by compression of the dural sac by a suboptimally implanted screw.

Risk factors for the development of neurological symptoms

MacEwen et al. [2], who presented the experience of surgical treatment of 7,885 patients with scoliosis, attributed the following to factors of an increased risk of developing neurological symptoms:

- the presence of a kyphotic component of the deformity;
- congenital scoliosis;
- severe deformities;
- the presence of an initial neurological deficit;
- neurological symptoms after skeletal traction;
- manipulations of increased risk;
- skeletal traction;
- vertebrotomy;

Table
Neurological complications in scoliosis surgery

Publication	Operated patients, *n*	Etiology of deformity, type of instrumentation	Frequency of neurological complications (by etiology and severity of deformity)	Outcomes
MacEwen et al. [2]; Scoliosis Research Society data for years 1965–1971	7885	Idiopathic, congenital, paralytic	87 (0.72%), 13 – injuries to cranial and peripheral nerves. Spinal complications: idiopathic scoliosis – 36, congenital – 21, paralytic – 7, various – 10	Full recovery – 22; partial recovery – 28; no dynamics – 24
Winter et al. [4] (Scoliosis Research Society)	Year 1975 – 3773 Year 1976 – 4334 Year 1981 – 28 000 (over 6 years) Year 1985 (British Scoliosis Society) – 1121 Year 1993 – 2031	459 – Harrington, 339 – Luque	22 (0.6%) 23 (0.5%) 140 (0.5%) Luque – 1.7%. Luque + Harrington – 4.6% 7 (0.3%) – all incomplete	Congenital – more often, 8 – from distraction, 7 – from direct trauma
Bridwell et al. [3]	1030 (863 – children)	–	4 (0.36%): 3 – vascular factor, 1 – vascular + mechanical	2 – full recovery, 1 – partial, 1 – in process
GuiGui et al. [13]	3311 (average age – 27 years)	–	3 (1.78%): 30 – spinal cord injury, 24 – nerve roots, 5 – dura mater	–
Coe et al. [14]	6334	Idiopathic adolescent scoliosis	Anterior approach (1164) – 3 (0.26%); posterior approach (4363) – 14 (0.32%); combined approach – (801) – 14 (1.75%)	Posterior approach: full recovery – 7, incomplete – 2; combined approach: full recovery – 4, incomplete – 4, no dynamics – 1
Diab et al. [15]	1301	Idiopathic adolescent scoliosis	3 (0.23%): 4 spinal cord injuries, 2 – nerve roots, 3 – dura mater	Full recovery in all within 4 months
Patil et al. [16]	5911	Idiopathic adolescent and adult scoliosis	Children – 0.35%, adults – 0.3%	–
Qui et al. [6]	1373: children – 1074, adults – 233	Idiopathic adolescent scoliosis – 756, congenital – 381	6 (1.83%); severe – 0.51%, mild – 1.38%, idiopathic – 1.06%, congenital – 2.83%; combined approach – 3.43%, posterior approach – 1.24%	–
Reames et al. [5], Scoliosis Research Society Morbidity and Mortality database	19 360	Various etiologies	Idiopathic scoliosis – 0.8%, congenital scoliosis – 2.0%, neuromuscular – 1.1%	–
Fu et al. [7], Scoliosis Research Society Morbidity and Mortality database 2004–2007	23 318; average age – 13 years	Various etiologies	324 (1.4%)	Full recovery – 185 (57%), partial – 117 (36%), no dynamics – 16 (5%)

End of Table
Neurological complications in scoliosis surgery

Publication	Operated patients, *n*	Etiology of deformity, type of instrumentation	Frequency of neurological complications (by etiology and severity of deformity)	Outcomes
Sansur et al. [17], Scoliosis Research Society Morbidity and Mortality database	4980	Various etiologies	Dura mater tears – 142 (2.3%); neurological deficit – 30 (1.8%): early – 43, late – 41; epidural hematoma – 12 (0.2%)	Nerve root injury: 23 – full recovery, 33 – partial, 2 – no recovery; spinal cord injury: 6 – full recovery, 5 – partial recovery; cauda equina injury: 1 – full recovery, 3 – partial recovery, 1 – no dynamics
Lykissas et al. [18], review of 27 publications	1136	Idiopathic adolescent scoliosis: Harrington instrumentation – 577, CDI – 305, TPF – 254	2 (0.17%)	–
Gauthier et al. [19]	524	Early onset scoliosis	3 (1.7%): 8 – congenital, 1 – neuromuscular	After 2 years in seven cases full recovery
Skovrlj et al. [20]	5117	Adult scoliosis of various etiologies	35 (0.68%)	–
Total	121 099		1022 (1.08 %)*	

* The total frequency of development of neurological complications was calculated excluding the data presented in the works of Winter et al., Patil et al., Reames et al., since they did not contain all the necessary quantitative indicators. CDI – Cotrel–Dubousset instrumentation; TPF – transpedicular (pedicle screw) fixation of the spine.

• distraction without preliminary traction in congenital scoliosis; and
• traction to achieve additional correction.

Of course, it is necessary to consider these recommendations from today's perspective, since in the 1970s the only method for correcting spinal deformity was distraction according to Harrington (Harrington instrumentation).

Bridwell et al. [3] recorded the development of neurological symptoms in four out of 1090 operated patients, and considered a two-stage intervention on the anterior and posterior segments of the spine performed in one session, revision surgeries, and a kyphotic component of the deformity primarily as risk factors.

Yong Qui et al. [6], having experience in the surgical treatment of 1373 patients, considered interventions for congenital deformities, in the presence of kyphosis of more than 40°, preliminary interventions, and operations for scoliosis of more than 90° to be the most risky in terms of neurological complications.

Skovrlj et al. [20] investigated the influence of operating surgeons' experience on the frequency of complication development. A total of 5117 adults with scoliosis were operated on (all surgeons were members of the Scoliosis Research Society, average age – 52 years), of whom 3,836 (75%) were operated on by active fellows and 1281 (25%) by candidate fellows. A total of 35 (0.68%) neurological complications were noted, of which 21 (0.55%) were after operations performed by more experienced active fellows, and 14 (1.1%) were after operations by candidate fellows. According to the authors of the article, the difference is significant.

Peripheral parts of the nervous system. Neurological complications in spinal deformity surgery are not limited solely to the impairment of functions of the spinal cord and its derivatives. Experience shows that diverse and sometimes extremely severe lesions of other parts of the central nervous system are possible.

In 1997 Myers et al. [23] described 37 cases of vision loss as a complication of spine surgery. The average age of the operated patients was 46.5 years. The average duration of the operation was 410 minutes, the average blood loss amounted to 3500 mL, and intraoperative hypotension was noted. According to the authors, a possible cause is ischemia of the optic nerve, occlusion of the retinal artery, or cerebral ischemia. They recorded 11 cases of bilateral lesions, 15 cases of complete blindness lasting for a minimum of one year. Overall, the prognosis is poor.

In 2002 Mooney et al. [24] quite justifiably characterized this complication as rare, but catastrophic. The diagnosis

is often made on the 2nd–3rd day after surgery; with complete loss of vision, the prognosis is pessimistic. The authors consider two etiologic factors: occlusion of the central retinal artery (probably the result of extraocular pressure and hypotension) and ischemic neuropathy of the optic nerve. Usually, the complication develops in the prone position (lying on the stomach), hence the mention of extraocular pressure on the superciliary arches. An ophthalmologist may reveal a cherry-red macular spot, pathognomonic for the first mechanism. Risk factors in patients with optic nerve ischemia may be giant cell arteritis, hypotension, and older age.

The personal experience of the authors of this review indirectly confirms the negative impact of extraocular pressure on the patient's superciliary arches. We noted two cases of the development of this complication in approximately 2000 operations (in both patients, vision was restored), but after starting to use a special face mask that eliminates undesirable pressure, we have not encountered the described complication in the course of over 3000 interventions performed in the patient's prone position.

Cooper et al. [25] were probably the first to draw attention to the pathology of the *plexus brachialis* developing during spine intervention. The complication is rare, the frequency of plexopathy was 0.02% per 15,000 operations. Pathogenesis — ischemia of intraneural capillaries due to tension and compression of the plexus. Under general anesthesia with relaxation, muscle tone drops, hence the risk of limb malposition and plexus tension. Pre-existing arteriosclerosis, diabetes, and coagulopathy can provoke the formation of a hematoma. Congenital anomalies (cervical ribs, plexus anomalies) and contractures of the shoulder joint can also contribute to plexitis. The prone position with the shoulder abducted and flexed at the elbow joint also increases the risk of developing the complication.

Prielipp et al. [26] recommended supination of the forearm to prevent this complication, which minimizes pressure on the ulnar nerve, and abduction to 30–90°.

Schwartz et al. [27] reported on the possibilities of the method of somatosensory evoked potentials in the aspect of monitoring the peripheral nervous system for identifying and preventing the consequences of prolonged prone positioning on the Relton-Hall spinal frame. The authors operated on 500 patients with scoliosis with intermittent monitoring of the ulnar nerve for early diagnosis of axillary plexitis. A decrease in the amplitude of potentials from the nerve was noted in 18 (3.6%) patients. A change in the position of the arm immediately normalized the amplitude of the potentials; all patients woke up without signs of plexitis.

In 2000 Mirovsky et al. [28] noted that when placing a patient on the Relton-Hall frame during surgery, compression of the lateral femoral cutaneous nerve (*n. cutaneus femoris lateralis*) is possible, and this compression can be bilateral. According to the authors, in 89% of cases, full functional recovery of the nerve is possible within three weeks.

Mooney et al. [24] emphasized that pressure on the upper third of the thigh with damage to the lateral femoral cutaneous nerve (meralgia paresthetica) is the result of using the Relton-Hall frame without additional padding.

These same authors noted that when positioned on the side, the peroneal nerve (*n. peroneus*) may be at risk. They recommend flexion in the hip and knee joints and a pillow under the lower third of the thigh and lower leg. The upper 5 centimeters of the fibula must be free from compression.

Late development of neurological complications (delayed deficit)

Letts and Hollenberg [29] described, probably, the first case of delayed development of paraparesis. A 13-year-old child with scoliosis of 100°, who had previously (when aged 6) undergone surgery without the desired effect, was undergoing removal of a wedge-shaped vertebra. The second intervention was a two-stage anteroposterior procedure, followed by the second stage after three weeks. A year later, displacement of the upper hook was noted, the distractor rod was removed, repeated correction was performed, and after waking up – everything was in order. On the third day, unilateral paresis was noted. The distractor rod was removed, and almost complete recovery was achieved.

In 1986 Johnston et al. [30] published two cases of paraplegia that developed 30 hours and 6 days after the second stage of an operation using Luque instrumentation. The likely cause of the complication is edema following obstruction of the subarachnoid space.

In 1987 Diaz and Lockhart [31] reported the postoperative development of tetraplegia due to syringomyelia of the cervical spine, undiagnosed prior to surgery. The wake-up test conducted during the intervention also did not allow suspecting the development of a catastrophe. The diagnosis was made on the basis of postoperative myelography and cervical laminectomy.

The first case of the formation of an epidural hematoma with progressive paraparesis, which developed 30 hours after surgery, was described by Mineiro and Weinstein in 1997 [32]: a 12-year-old boy with scoliosis of 72° was operated on using Cotrel-Dubousset Instrumentation. The operation went normally, after 30 hours — a complication and re-intervention. The instrumentation was removed, and after 2 months there was almost complete recovery. Chang et al. [33], who described a similar observation, emphasized that re-intervention must be urgent.

Dapunt et al. [34] published a case of tetraparesis that developed on the second day after the operation of posterior spinal fusion of the T3–L4 vertebrae, performed for idiopathic scoliosis. The MRI scan showed signs of ischemia of the spinal cord at the C4–C7 level. According to angiography data, hypervascularization of the T4 body led to the formation of an arteriovenous shunt into the epidural venous plexus. The internal instrumentation was removed, and full regression of the neurological symptoms was stated. The authors emphasized that, in their opinion, a preoperative MRI study would

have helped in the timely diagnosis of the anomaly.

In 1999, Rittmeister et al. [35] described the very rare development of cauda equina syndrome 10 years after an operation for scoliosis due to pressure from a laminar hook at the T12 level.

In 2017, Ferrando et al. [36] presented three cases of late (more than 12 months) development of neurological symptoms after operations for scoliosis: one — cauda equina syndrome, two — posterior compression of the spinal cord due to direct pressure from a supralaminar hook on the concave side of the deformity. After removal of the implants, improvement occurred in all cases.

In 2025 Suggala et al. [37] described a case of the development of a neurological deficit 6 years after surgical correction of idiopathic scoliosis using pedicle screws. One of the screws displaced medially, which caused the appearance of pathological symptoms.

One of the few works in which data on late complications of spinal deformity surgery are analyzed not according to individual observations belongs to the pen of Auerbach et al. [38]. The authors surveyed 352 spine surgeons (members of the Scoliosis Research Society). The frequency of late postoperative neurological deficit is 1 (0.01%) per 9910 interventions. Out of 352 surgeons, 81 (23%) had a minimum of one case of such a complication over the last 10 years (a total of 92 cases). Distribution by diagnoses: scoliosis – 69%, kyphosis – 23%, listhesis – 14%. In 20% of cases, it involved revision operations. In the first 12 hours, neurological symptoms were recorded in 36% of cases, after 13–24 hours – in 27%, after 25–48 hours – in 27%, more than 48 hours – in 10%. Main causes: spinal cord ischemia – 38%, spinal cord compression – 15%. Full recovery was stated in 41% of cases, partial – in 26%, without dynamics – in 33%. Recovery within a week – 21%, 1 month – 38%, the rest – within 6 months.

After spinal cord compression, functional recovery was noted in 86% of cases, after ischemia – in 51%.

Qiao et al. [39] reported an analysis of 5377 operations from the same perspective. They recorded 7 (0.13%) cases of the onset of late neurological symptoms, including in adults – 0.17%, in children – 0.10%. After vertebrotomy, late symptoms were noted in 0.35% of cases, without vertebrotomy – in 0.05%. Somatosensory disorders were identified in one patient, motor disorders – in all seven. Revision was performed in three cases, recovery was noted in six patients.

Rare observations (casuistry)

The main causes of the development of neurological complications in scoliosis surgery are described above. However, a detailed analysis of literature sources allows identifying a number of casuistic, rare mechanisms, knowledge of which can help the surgeon in solving difficult clinical problems, when the cause of the development of a severe complication seems less obvious. These mechanisms are highly diverse and sometimes unexpected.

In 1981, Eismont and Simeone [40] reported on a 17-year-old patient operated on using Harrington instrumentation. Anatomy looked normal, spinal fusion was performed using an autograft from the iliac crest. Two years later, the development of progressive spastic lower paraparesis was noted. Repeat operation – another 2 years later. On preoperative spondylograms, there was a bone block throughout the entire zone of spinal fusion, the internal instrumentation was not displaced. The finding was confirmed myelographically. During the operation, enlargement of the hemilaminae and pedicles of T9 and T10 ertebrae was noted. Bone masses were removed, recovery began rapidly and was almost complete.

Court-Brown and McMaster [41] described a woman aged 59 with lumbar scoliosis (84°) and a pronounced pain syndrome, but without neurological symptoms, operated on using Harrington instrumentation. The operation went typically and without complications. Three years later, acute lumbar pain appeared, weakness in the legs developed, and the patient could not walk. The radiograph showed the broken distraction rod and signs of a pseudarthrosis of the bone block at the level of T12–L1 disc. During surgery, a pseudarthrosis of the block transversely at this level was revealed. The dura mater was compressed by bone and fibrous tissues. Recovery within 3 months.

A similar observation was published by Roy et al. in 1984 [42]. Having 15 (!) years after the corrective operation using Harrington instrumentation, paraplegia developed from the level of the T6 vertebra, the effect of the repeat operation was not achieved.

In 1997, Krodel et al. [43] reported a patient who, 6 years after correction using Harrington instrumentation, developed clinical picture of spinal stenosis and myelopathy due to pressure of the rod on the dural sac. Full recovery.

Takahashi et al. [44] described two observations of patients aged 54 and 58 operated on for degenerative scoliosis: 11 months and 4 years later, respectively, symptoms of radicular pain appeared. During surgery, mobility between elements of the instrumentation, as well as gray granulations compressing the dural sac, which was regarded as intraspinal metallosis, were revealed. Upon removal of the pathological tissues, regression of the pain syndrome was recorded.

Beguiristain et al. [45] presented the results of observation and treatment of a 28-year-old woman with progressive paraparesis developed within 2 months after 14 years after surgery for scoliosis. Examination, including a biopsy, revealed pathological tissues with changes characteristic of metallosis, which had penetrated into the spinal canal with compression of the spinal cord at the T5–T6 vertebrae. The internal instrumentation and altered tissues were removed, and after 6 months full regression of the neurological symptoms was noted. The authors of the article are convinced that implant corrosion occurs more frequently than many assume.

An extremely rare case was described by Vialle et al. [46] A girl aged 16 was operated on for scoliosis. 10 years later – acute pain and paraplegia. During surgery – masses infiltrating the spinal canal, histologically – leiomyosarcoma. The patient died. The extraspinal tumor

rapidly grew into the dural sac, which distorted the clinical picture and delayed the diagnosis and treatment in time.

Gardner [47] described a case of the formation of an intraspinal cyst 22 years after the correction of a scoliotic deformity according to Harrington. The process was accompanied by progressive numbness and weakness in the lower extremities. After removal of the cyst, full recovery was noted. The pseudarthrosis of the bone block did not cause clinical manifestations. Gardner believes that this is the first case where an MRI scan showed compression of the spinal cord by a cyst after surgery for scoliosis.

We believe that the reader should not be misled by the fact that in the majority of described cases, a Harrington distraction rod appeared as the internal instrumentation. Any of the mentioned complications can develop when using modern corrective systems.

Discussion

The development of spine surgery inevitably led to the emergence of a specific section, which some colleagues now call "scoliology". Correction of spinal deformities of various etiologies is accompanied by the development of complications associated with an impairment of the function of elements of the nervous system – both central and peripheral. These special conditions, often being untimely recognized and treated, sometimes lead to the most severe consequences.

Many studies are devoted to the problem of neurological complications in spinal deformity surgery, but we did not find reviews covering all or the majority of its aspects. At the same time, the number of patients operated on for severe scoliotic deformities is truly enormous. For example, during the first 25 years of application of the Cotrel-Dubousset Instrumentation (1983–2008) in the world, about 400,000 patients were operated on with the help of this internal corrector. It can be assumed that to date, 1.5–2 million such interventions have been performed worldwide. There is nothing surprising in the fact that there are publications devoted to the results of surgical treatment of thousands and even tens of thousands of patients of all age groups. And although these cohorts are often very heterogeneous in composition, their analysis allows obtaining complete and convincing information on issues related to neurological complications after operations for spinal deformities.

The frequency of these complications, as it turned out, is slightly more than 1%. Is this a lot or a little? In principle, a complication that has a chance of developing in only one out of 100 operated individuals can hardly be considered frequent. However, neurological complications are a special case, since each of them is fraught with severe invalidization of the patient with small chances of recovery, and the overwhelming majority of these patients are children and adolescents, and the surgery is almost always performed for vital indications.

Only two publications [5, 6] allow comparing the most numerous etiological forms of scoliosis (idiopathic and congenital) by the frequency of development of neurological complications; they accompany operations for congenital spinal deformities more than twice as often. This circumstance is quite explainable: congenital deformities are more rigid, more often have a significant kyphotic component, and are accompanied by intracanal developmental anomalies.

In adults, complications occur more frequently than in patients younger than 18 years, and the difference is more than twofold. This fully fits into our understanding that all types of complications are noted more frequently in adults and are harder to treat.

The inclusion in the complex of surgical treatment of an anterior stage, accompanied by ligation of segmental vessels, can increase the risk of neurological complications by 2–3 times. This is probably due to performing the ligation too close to the intervertebral foramen, which is fraught with a disruption of the blood supply to the contents of the spinal canal.

The restoration of lost functions, regardless of other factors, is noted far from always, which underscores the significance of the problem.

Neurological complications include lesions of the peripheral nervous system, which, often being severe, must be taken into account, and their prevention must be fully ensured.

The mechanisms of development of neurological symptoms vary, but ultimately everything comes down to a disruption of the blood supply to the nervous tissue, which is most sensitive to such changes. Risk factors for the development of neurological complications in patients are numerous and diverse. Underestimating any of them can lead to the most severe consequences, therefore the formulation of indications for surgery must be individual, take into account the maximum possible number of circumstances, and in certain cases the surgeon must find the strength to refuse intervention.

Another serious aspect of the problem is late complications. They develop at highly varied times after surgery (from hours to years) and pose very difficult tasks for the surgeon – both diagnostic and tactical. Very closely adjoined here is the problem of casuistically rare complications in terms of their origin. Collective experience shows that their diversity is immense, the examination of the patient must be as complete as possible, and the "insidiousness" of nature is boundless.

Conclusion

Neurological complications of surgical interventions for spinal deformities of various etiologies develop relatively infrequently, but this circumstance does not in any way simplify the problem, since these complications are sometimes catastrophically severe and require prolonged and complex treatment, the success of which is by no means guaranteed. Surgical treatment of patients with pathology of the spine (in this case, we are talking not only about deformities) should be performed in highly specialized centers equipped with the most modern equipment and staffed by specialists of the highest level of training.

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