# TETHERED SPINAL CORD SYNDROME ASSOCIATED WITH SPINA BIFIDA: CLINICAL AND RADIOLOGICAL CHARACTERISTICS AND INDICATIONS FOR SURGERY (SYSTEMATIC REVIEW OF THE LITERATURE)

***S.O. Ryabykh[1, 2], S.A. Gorchakov[3], A.A. Kalashnikov[1, 3]***
[1]*Veltishchev Research and Clinical Institute for Pediatrics and Pediatric Surgery, Moscow, Russia*
[2]*St. Petersburg State University, St. Petersburg, Russia*
[3]*Speransky Children's City Clinical Hospital No. 9, Moscow, Russia*

**Objective.** To analyze literature data on clinical and radiation characteristics of the tethered spinal cord syndrome in *spina bifida* and to define criteria for indications for surgical treatment.
**Material and Methods.** A search for prospective cohort clinical studies evaluating the clinical and radiation picture and indications for surgical correction of the tethered spinal cord syndrome associated with *spina bifida*, published in 2005—2023 was performed in the Pubmed, EMBASE, eLibrary and the Cochrane Library databases. The literature search was carried out by one researcher. The study was carried out in accordance with the international recommendations for writing systematic reviews and meta-analyses PRISMA. The levels of evidence for reliability and grades of the strength of recommendations were evaluated according to the ASCO Guidelines.
**Results.** A total of 394 literature sources were found in the databases. Duplicate materials (n = 81) have been removed. When non-full-text articles were excluded, only 28 out of 251 remained studies met the inclusion criteria and were analyzed. According to the level of evidence, 18 of them were classified as B level, and 10 — as C level.
**Conclusion.** The components of the tethered spinal cord syndrome are a dystopic spinal cord cone, a shortened fixed filum terminale, and the presence of a lumbosacral lipoma. At the same time, there are currently no clear criteria for the integral assessment of the clinical and morphofunctional state of patients, and the available scales are not specific. The described MRI criteria are limited by the level of evidence, but despite this, they reflect a high level of consensus among experts, including that on the defining indications for surgical spinal cord untethering. The lack of clear indications for surgical intervention and the debatability of performing preventive untethering of the spinal cord require further study of the problem with an emphasis on analyzing the criteria for tethered spinal cord syndrome.
**Key Words:** children, *spina bifida*, spinal cord, spinal cord malformations, tethered spinal cord syndrome.
Please cite this paper as: *Ryabykh SO, Gorchakov SA, Kalashnikov AA. Tethered spinal cord syndrome associated with spina bifida: clinical and radiological characteristics and indications for surgery (systematic review of the literature). Russian Journal of Spine Surgery (Khirurgiya Pozvonochnika). 2024;21(1):27–34. In Russian.*
*DOI: http://dx.doi.org/10.14531/ss2024.1.27-34.*

*Spina bifida* is a congenital abnormality based on the splitting of the spine due to a defect in the neural tube closure at the 4th week of embryonic development. The incidence averages about one case per 1,000 newborns and, according to most authors, is directly correlated with genetic risk factors. The level of spinal column lesion determines the severity of clinical manifestations, in particular the degree of neurological disorders and pelvic organ dysfunction [2]. Meningomyelocele is often associated with severe neurological deficit or other congenital defects such as hydrocephalus and Chiari malformation [3].

One of the most frequent manifestations of *spina bifida* is primary or secondary tethered spinal cord syndrome (TSCS). The cause of the development of primary TSCS is the low (caudal to the L1–L2 level) position of the terminal end of the spinal cord due to the attachment of the placode to the surrounding tissues, which results in tension of the spinal cord and is often associated with the presence of a thick filum terminale. The secondary syndrome develops as a result of surgical treatment for meningomyelocele.

TSCS unites a number of abnormalities that are heterogeneous in etiology, but similar in pathogenesis. Their manifestations are the consequence of the loss of functions of the caudal spinal cord and its roots, including progressive neurological, orthopedic and urological symptoms such as weakness and pain in the lower extremities, reduced mobility, clubfoot, impaired pelvic organ function, recurrent urinary tract infections, and impaired sensory functions [3].

Despite the common views on the development of TSCS (etiopathogenesis) and the clinical and diagnostic picture, it can be stated that there are no uniform indications for the untethering of the spinal cord and its elements. The lack of clear indications for surgical treatment, including the ambiguity of the concept of preventive untethering, requires further study of the problem and clarification of indications for surgery, which defined the article's objective.

The objective is to analyze literature data on clinical and radiation characteristics of the tethered spinal cord syndrome in *spina bifida* and to define criteria for indications for surgical treatment.

## Material and Methods

A search for prospective cohort clinical studies assessing MRI semiotics, clinical symptoms, indications for surgical correction of the tethered spinal cord syndrome associated with *spina bifida*, published in 2005–2023, was performed in the Pubmed, EMBASE, eLibrary and the Cochrane Library databases. The search was performed by one researcher, the study was performed in accordance with the international PRISMA protocol (Table 1).

At the first stage, within the PRISMA protocol, literature sources were searched using the keywords "tethered spinal cord syndrome", "*spina bifida*", "tethered cord syndrome", "meningomyelocele" and "post-MMC syndrome". The search depth was 18 years. At the second stage, articles that did not meet the research criteria were excluded; at the third stage, the full texts of selected articles were reviewed for compliance with the inclusion criteria and the list of references for relevant studies (Table 1, Fig. 1).

In addition, the search for issue-related sources was done by keywords using search queries in the GPT-Chat (Table 2, Fig. 2).

The articles were ranked according to the confidence level of evidence (from I to V) and the levels of gradation of the strength of recommendations (from A to D) using the protocol of the American Society of Clinical Oncology (ASCO) [4, 5], also used in the preparation of clinical guidelines in the Russian Federation, with the choice of the most cited issue-related papers.

## Results

A total of 394 literature sources were found in databases (Fig. 3). Duplicate materials (n = 81) were excluded. 251 articles remained after excluding non-full-text articles, but only 28 of them were analysed because they met the inclusion criteria (Table 3). The level of evidence of 18 studied papers was B, of 10 – C.

Two of the most cited studies were identified. The first was a prospective multicenter randomized clinical study by Copp et al. [7], dedicated to the clinical and radiation picture of TSCS (225 citations). The second was a prospective multicenter randomized clinical study by Yamada et al. [8] dedicated to the pathogenesis and clinical picture of the TSCS (148 citations).

To analyse the content of the articles in the "Discussion" section, the latter were ranked to answer the main questions of the study:

- What are the components of the tethered spinal cord syndrome, depending on the level of *spina bifida*?
- What is the MRI semiotics of the tethered spinal cord syndrome?
- What is the indication for surgical untethering of the spinal cord?

## Discussion

### *Components of spinal cord tethering depending on the level of spina bifida*

According to the principles of biomechanics, it can be stated that the caudal part of the spinal cord is a damping system represented in the upper parts by denticulate ligaments located at the level of T12–L1 segments, and in the lower parts of the spinal cord by a filum terminale. Yamada et al. [8] found out that this system prevents spinal cord tension above the level of T12–L1 vertebrae. If the elastic properties of the filum terminale are impaired, its damping properties and the balance of the spinal cord as a whole reduce.

The main causes of spinal cord tethering are lipomeningomyelocele and diastematomyelia. Complex caudal malfor-

**Table 1**
Criteria for inclusion/exclusion and selection of publications in accordance with PRISMA principles

| PRISMA elements | Inclusion | Exclusion |
|---|---|---|
| Participants | Children under 18 years of age who have undergone surgery for tethered spinal cord syndrome | Patients over 18 years of age and those who have not been treated for tethered spinal cord syndrome |
| Interventions | Surgical treatment of tethered spinal cord syndrome in patients with *spina bifida* | Surgical treatment of tethered spinal cord syndrome not associated with *spina bifida* |
| Comparison | Study groups in selected articles | |
| Outcome | MRI semiotics, clinical picture, indications for surgery | |
| Design | Non-randomized, retrospective, prospective | Randomized, clinical cases, case series |
| Publications | In Russian, English, full text | In any other languages, without access to the full text |

mations, anterior meningocele, neurenteric cysts, sacral meningeal diverticula with a fatty filum terminale, terminal syringomyelia and caudal regression syndrome are less frequent. In conditions of acquired pathology, the source of tethering and possible traction of the spinal cord is intradural postoperative scar tissue.

The pathogenetic basis of TSCS is the mechanical tension of the caudal spinal cord, resulting in local ischemia, impaired electrobiological activity of the spinal cord, and, at the molecular level, inhibition of oxidative phosphorylation and axonal degeneration [10]. Revascularization of the spinal cord after surgical untethering explains the reversible origin of neurological disorders. These abnormalities tend to progress during the period of active growth of a child, resulting in an aggravation of the clinical picture and in the formation of a persistent neurological deficit [11–13].

*MRI semiotics of tethered spinal cord syndrome*

Diagnostic measures for secondary TSCS are reduced to a comparison of the clinical and radiation picture and electrophysiological criteria with consideration to the changes in the patient's condition. The main neurological manifestations of spinal cord tethering and tension are gait changes, pelvic organ dysfunction, including persistent urinary tract infections. The semiotics of orthopedic disorders involves deformity of the spinal axis (more often scoliosis and lordoscoliosis), hip instability, knee contractures and foot deformity. Meanwhile, there are no clear criteria for the integral assessment of the clinical as well as morphological and functional state of patients, and the available scales (Ashworth, Modified Tardieu Scale, mJOA, SBNS) are not specific [29, 30].

All the patients who underwent surgery for TSCS have MRI signs of spinal cord tethering [11]. Meanwhile, symptomatic options for TSCS are found only in 30% of patients. The formation of tethering, as a rule, occurs at the level of the previous surgical treatment. In this case, adhesions form between the spinal cord and its membranes, and occasionally with scar tissues. Frequently, spinal cord tethering is formed at the level of L4–S3 vertebrae [14, 15]. According to Yamada and Won [16], the risk of a symptomatic form of secondary tethered spinal cord syndrome increases with spinal cord cone dystopia caudal to the S1 level of the vertebra.

Consequently, MRI is the gold standard of diagnosis, and the main MRI criteria for spinal cord tethering are substantiated by Horrion et al. in 2014 [19]:

1) dystopic spinal cord cone below the level of the L1–L2 vertebrae;

2) syringomyelia is an intramedullary cystic formation; small cysts have a tubular shape, while large cysts seem to be beads or sacculated cavities separated by barriers;

3) myelopathy with the development of tethering in the cervical and thoracic levels; visually: spindle-shaped thickening of the spinal cord; local amplification (T2-WI) or decrease (T1-WI) of the signal intensity of the spinal cord;

4) the filum terminale lipoma is a hyperintense (T1-WI) intradural space-occupying lesion closely connected with the filum terminale;

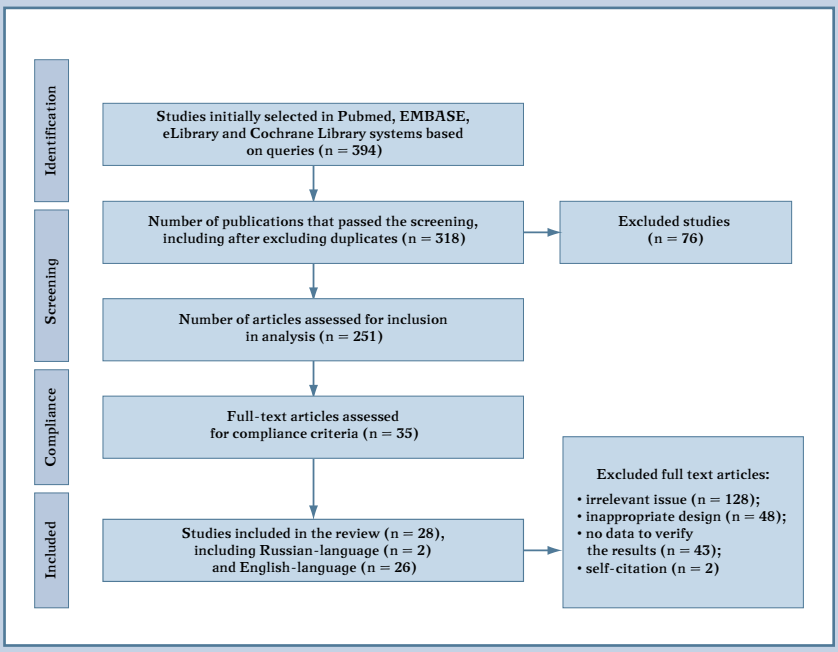


**Fig. 1**
Schematic algorithm for selecting issue-related publications in accordance with PRISMA criteria

**Table 2**
Comparison of staged search for issue-related publications in accordance with PRISMA criteria and using the GPT-Chat

| Parameters | Independent search in literature | GPT-Chat |
|---|---|---|
| Identification | 394 | 420 |
| Screening | 251 | 273 |
| Compliance | 36 | 51 |
| Inclusion | 28 | 38; 8 of them are relevant |

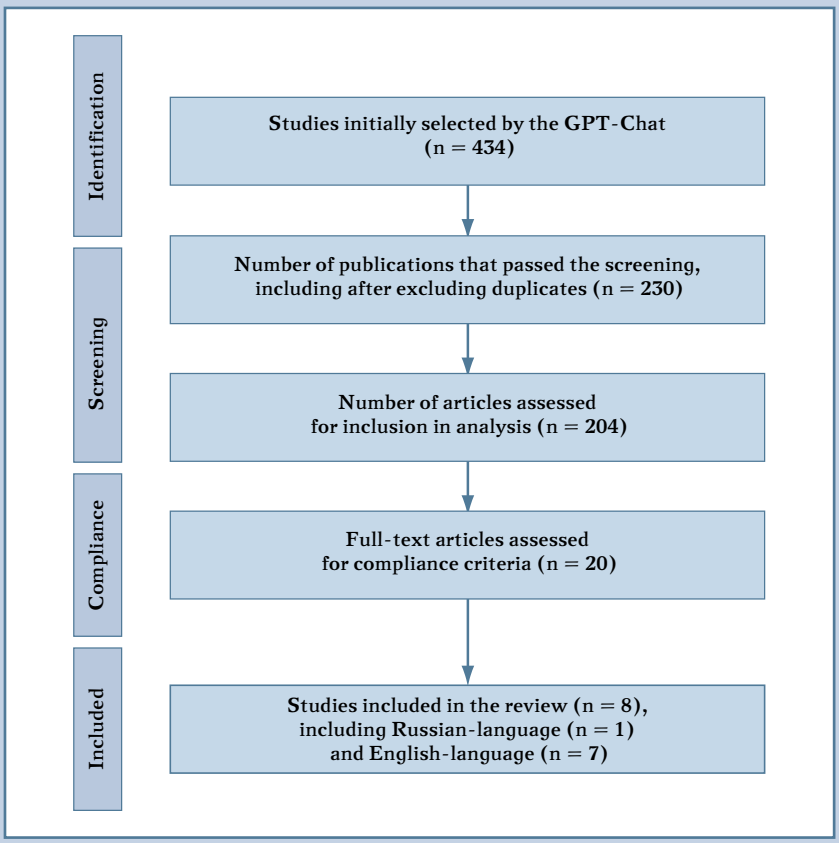


**Fig. 2**
Schematic algorithm for selecting issue-related publications in the GPT-Chat

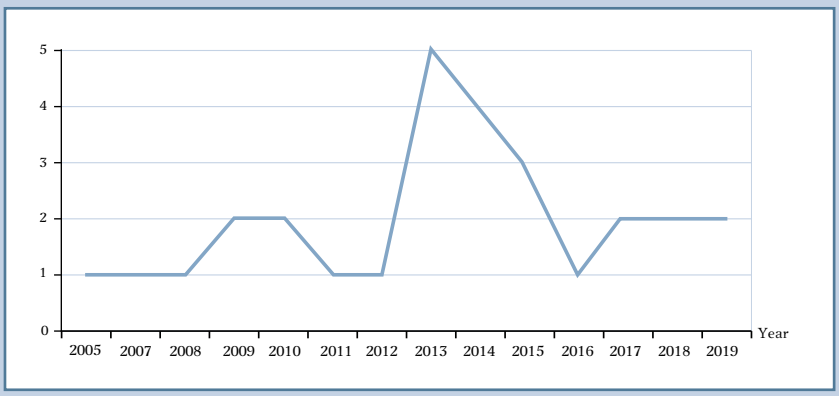


**Fig. 3**
Graph of the number of published issue-related papers included in the review

5) thickening of the filum terminale of 2 mm or more.

*Indications for spinal cord untethering*

One of the factors for the unreasonable extension of indications for surgical treatment is the multifactorial ethiology of the TSCS. Accordingly, it is proposed to consider as an indication for surgical treatment a combination of MRI signs, the clinical picture of the secondary tethered spinal cord syndrome and the progression of neurological symptoms [1, 5, 9] that, in fact, reflects the clinical and neuroimaging picture of the spinal cord tension. Concurrently, most researchers [21–23] point out the predominantly transient nature of the initial neurological symptoms in the early correction of TSCS. In rare cases, there are pronounced positive changes after untethering in patients with long-term symptoms.

The evolution of anesthetic support techniques, microsurgical dissection methods, and intraoperative control of the surgeon's actions (primarily intraoperative neurophysiologic monitoring) defined the overall success of surgical treatment in all age groups immediately after clinical and instrumental verification of pathology, even in cases where the disease progressed asymptomatically [24–26]. This has resulted in the conception of preventive elimination of tethering before the manifestation of clinical symptoms, aimed at preventing possible irreversible injury to the spinal cord [27, 28].

Another urgent matter is the elimination of tethering in adolescents before the onset of a period of accelerated growth [26]. Nowadays, however, this strategy is severely criticized due to the increase in postoperative neurological and urodynamic deficits, as well as the incidence and progression of orthopedic complications [7, 10].

## Conclusion

The components of the TSCS are a dystopic spinal cord cone, a shortened filum terminale and a lumbosacral lipoma. Meanwhile, there are currently no clear criteria for the integral assessment of the clinical and morphofunctional condition of patients, and the available scales are not specific. The described MRI signs are limited by the evidence level, but they reflect a high level of consensus among experts, including that on the defining indications for surgical spinal cord untethering.

The absence of clear indications for surgical treatment and the controvertible nature of performing preventive unteth-

Table 3
General characteristics of studies included in the systematic review

| Study | Year | Country | Study type | Patients, n | LE | GR |
|---|---|---|---|---|---|---|
| Kurtser M.A. et al. [2] | 2018 | Russia | RCS | 7 | IV | C |
| Khachatryan V.A. et al. [17] | 2009 | Russia | RCS | 34 | IV | C |
| Copp et al. [7] | 2015 | Great Britain | RCS/RCT | 22 | II | B |
| Hudgins, Gilreath [6] | 2004 | USA | RCS | 12 | II | B |
| Horrion et al. [19] | 2014 | Belgium | RCS | 20 | II | B |
| Furtado et al. [31] | 2020 | USA/Germany | RCS/RCT | 26 | II | B |
| Hertzler et al. [18] | 2010 | USA | RCS | 47 | III | C |
| Caldarelli et al. [9] | 2013 | Italy/USA | RCS | 22 | III | C |
| Mazzola et al.[10] | 2019 | Italy | RCS | 18 | II | B |
| Blount et al. [27] | 2007 | USA | RCS | 30 | III | C |
| Henderson et al. [29] | 2005 | USA | RCS | 38 | II | B |
| Danzer et al.[20] | 2016 | USA | RCS/RCT | 27 | II | B |
| Hsieh et al. [21] | 2010 | USA | RCS | 26 | II | B |
| Hoving et al. [22] | 2011 | Great Britain | RCS | 65 | II | B |
| Hsieh et al. [23] | 2006 | USA | RCS | 24 | II | C |
| McCarthy et al. [24] | 2019 | USA | RCS | 27 | III | C |
| Barley et al. [25] | 2010 | USA | RCS | 19 | II | B |
| Ogiwara et al. [13] | 2011 | Japan/USA | RCS | 16 | II | B |
| Filippi et al. [14] | 2010 | Australia | RCS | 13 | II | B |
| Massimi et al. [15] | 2011 | Italy | RCS/RCT | 18 | II | B |
| Yamada, Won [16] | 2007 | Japan | RCT | 37 | II | B |
| Yamada et al. [8] | 2007 | Japan | RCT | 34 | III | C |
| Lew, Kothbauer [1] | 2007 | USA | RCS | 41 | III | C |
| Adzick et al. [11] | 2011 | Great Britain | RCT | 14 | II | B |
| Verbeek et al. [12] | 2012 | USA/Netherlands/Germany | RCT | 21 | III | C |
| Sharma et al. [30] | 2006 | India | RCT | 22 | III | C |
| Bloria et al. [3] | 2020 | India | RCS | 19 | II | B |
| Shobeiri et al. [26] | 2021 | Iran | RCS | 21 | III | C |

PCS – prospective cohort study; RCT – randomized clinical trial; LE – level of evidence according to the American Society of Clinical Oncology (ASCO) [32]; GR – gradation of recommendations according to the ASCO.

ering of the spinal cord require further study of the problem, with an emphasis on definition of the term "tethered spinal cord syndrome" and analysing its clinical and neuroimaging criteria.

*Limitations of the study.* Firstly, the authors sought to limit the study to secondary tethered spinal cord syndrome with an analysis of the criteria for tethered spinal cord syndrome and indications for surgical untethering. Secondly, the study intentionally does not include papers analysing the efficacy of prenatal procedures. Thirdly, there is a clear deficit of studies with a high level of evidence, as well as intra- and inter-expert consensus, which affects the results of the review.

*The study had no sponsors. The authors declare that they have no conflict of interest.*
*The study was approved by the local ethics committees of the institutions. All authors contributed significantly to the research and preparation of the article, read and approved the final version before publication.*

## References


1. **Lew SM, Kothbauer KF.** Tethered cord syndrome: an updated review. Pediatr Neurosurg. 2007;43:236–248. DOI: 10.1159/000098836.
2. **Kurtser MA, Prityko AG, Spiridonova EI, Zvereva AV, Sokolovskaya YuV, Petraki VL, Asadov RN, Polyakova OV, Abolits MA, Kutakova YuYu.** Open fetal surgery for *spina bifida*. Obstetrics and genecology. News, opinions and training. 2018;6(4): 38–44. DOI: 10.24411/2303-9698-2018-14004.
3. **Bloria SD, Chauhan R, Luthra A, Mahajan C.** Management of a patient with meningomyelocele. In: Problem Based Learning Discussions in Neuroanesthesia and Neurocritical Care, ed. by Prabhakar H., Rajan S, Kapoor I, Mahajan C. Springer Nature eBook, 2020;163–178.
4. **Bubnova MG, Butina EK, Vygodin VA, Koltunov IE, Kukushkin SK, Kutishenko NP, Lukina YuV, Martsevich SYu, Oganov RG, Poddubskaya EA, Shalnova SA.** Fundamentals of evidence-based medicine: textbook. Moscow, 2010.
5. **Somerfield MR, Padberg JR, Pfister DG, Bennett CL, Recht A, Smith TJ, Weeks JC, Winn RJ, Durant JR.** ASCO clinical practice guidelines: progress, pitfalls, and prospects. Class Pap Curr Comments. 2000;4:881–886.
6. **Hudgins RJ, Gilreath CL.** Tethered spinal cord following repair of myelomeningocele. Neurosurg Focus. 2004;16:E7. DOI: 10.3171/foc.2004.16.2.8.
7. **Copp AJ, Adzick NS, Chitty LS, Fletcher JM, Holmbeck GN, Shaw GM.** *Spina bifida*. Nat Rev Dis Primers. 2015; 1:15007. DOI: 10.1038/nrdp.2015.7.
8. **Yamada S, Won DJ, Yamada SM.** Pathophysiology of tethered cord syndrome: correlation with symptomatology. Neurosurg Focus. 2007;16:E6. DOI: 10.3171/foc.2004.16.2.7.
9. **Caldarelli M, Boscarelli A, Massimi L.** Recurrent tethered cord: radiological investigation and management. Childs Nerv Syst. 2013;29:1601–1609. DOI: 10.1007/s00381-013-2150-4.
10. **Mazzola CA, Tyagi R, Assassi N, Bauer DF, Beier AD, Blount JP, Durham SR, Flannery AM, Klimo P Jr, McClung-Smith C, Nikas DC, Rehring P, Tamber MS.** Congress of Neurological Surgeons systematic review and evidence-based guideline on the incidence of tethered cord syndrome in infants with myelomeningocele with prenatal versus postnatal repair. Neurosurgery. 2019;85:E417–E419. DOI: 10.1093/neuros/nyz266.
11. **Adzick NS, Thom EA, Spong CY, Brock JW 3rd, Burrows PK, Johnson MP, Howell LJ, Farrell JA, Dabrowiak ME, Sutton LN, Gupta N, Tulipan NB, D,Alton ME, Farmer DL.** A randomized trial of prenatal versus postnatal repair of myelomeningocele. N Engl J Med. 2011;364:993–1004. DOI: 10.1056/NEJMoa1014379.
12. **Verbeek RJ, Heep A, Maurits NM, Cremer R, Hoving EW, Brouwer OF, van der Hoeven JH, Sival DA.** Fetal endoscopic myelomeningocele closure preserves segmental neurological function. Dev Med Child Neurol. 2012;54:15–22. DOI: 10.1111/j.1469-8749.2011.04148.x.
13. **Ogiwara H, Lyszczarz A, Alden TD, Bowman RM, McLone DG, Tomita T.** Retethering of transected fatty filum terminals. J Neurosurg Pediatr. 2011;7:42–46. DOI: 10.3171/2010.10.PEDS09550.
14. **Filippi CG, Andrews T, Gonyea JV, Linnel G, Cauley KA.** Magnetic resonance diffusion tensor imaging and tractography of the lower spinal cord: application to diastematomyelia and tethered cord. Eur Radiol. 2010;20:2194–2199. DOI: 10.1007/s00330-010-1797-4.
15. **Massimi L, Peraio S, Peppucci E, Tamburrini G, Di Rocco C.** Section of the filum terminale: is it worthwhile in Chiari type I malformation? Neurol Sci. 2011;32 Suppl 3:349–351. DOI: 10.1007/s10072-011-0691-4.
16. **Yamada S, Won DJ.** What is the true tethered cord syndrome? Childs Nerv Syst. 2007;23:371-375. DOI: 10.1007/s00381-006-0276-3.
17. **Khachatryan VA, Orlov YuA, Osipov IB, Elikbaev GM.** Spinal Dysraphism: Neurosurgical and Neurourological Aspects. St. Petersburg, 2009.
18. **Hertzler DA 2nd, DePowell JJ, Stevenson CB, Mangano FT.** Tethered cord syndrome: a review of the literature from embryology to adult presentation. Neurosurg Focus. 2010;29:E1. DOI: 10.3171/2010.3.FOCUS1079.
19. **Horrion J, Houbart MA, Georgiopoulos A, Bottosso N.** Adult intradural lipoma with tethered spinal cord syndrome. JBR-BTR. 2014;97:121. DOI: 10.5334/jbr-btr.43.
20. **Danzer E, Thomas NH, Thomas A, Friedman KB, Gerdes M, Koh J, Adzick NS, Johnson MP.** Long-term neurofunctional outcome, executive functioning, and behavioral adaptive skills following fetal myelomeningocele surgery. Am J Obstet Gynecol. 2016;214:269e1–269e8. DOI: 10.1016/j.ajog.2015.09.094.
21. **Hsieh PC, Stapleton CJ, Moldavskiy P, Koski TR, Ondra SL, Gokaslan ZL, Kuntz C.** Posterior vertebral column subtraction osteotomy for the treatment of tethered cord syndrome: review of the literature and clinical outcomes of all cases reported to date. Neurosurg Focus. 2010;29:E6. DOI: 10.3171/2010.4.FOCUS1070.
22. **Hoving EW, Haitsma E, Oude Ophuis CM, Journee HL.** The value of intraoperative neurophysiological monitoring in tethered cord surgery. Child's Nerv Syst. 2011;27:1445–1452. DOI: 10.1007/s00381-011-1471-4.
23. **Hsieh MH, Perry V, Gupta N, Pearson C, Nguyen HT.** The effects of detethering on the urodynamics profile in children with a tethered cord. J. Neurosurg. 2006;105(5 Suppl):391–395. DOI: 10.3171/ped.2006.105.5.391.
24. **McCarthy DJ, Sheinberg DL, Luther E, McCrea HJ.** Myelomeningocele-associated hydrocephalus: nationwide analysis and systematic review. Neurosurg Focus. 2019;47:E5. DOI: 10.3171/2019.7.FOCUS19469.
25. **Barley JL, Mooney JF, Glazier SS, Johnson T, Kornegay AL, Turner RP, Edwards JC.** Sudden appearance of new upper extremity motor function while performing neurophysiologic intraoperative monitoring during tethered cord release: a case report. J Pediatr Orthop. 2010;30:624–628. DOI: 10.1097/BPO.0b013e3181e79041.
26. **Shobeiri P, Presedo A, Karimi A, Momtazmanesh S, Vosoughi F, Nabian MH.** Orthopedic management of myelomeningocele with a multidisciplinary approach: a systematic review of the literature. J Orthop Surg Res. 2021;16:494. DOI: 10.1186/s13018-021-02643-8.
27. **Blount JP, Tubbs RS, Wellons JC 3rd, Acakpo-Satchivi L, Bauer D, Oakes WJ.** Spinal cord transection for definitive untethering of repetitive tethered cord. Neurosurg Focus. 2007;23:E12. DOI: 10.3171/FOC-07/08/E12.
28. **Barson AJ.** The vertebral level of termination of the spinal cord during normal and abnormal development. J Anat. 1970;106:489–497.
29. **Henderson FC, Geddes JF, Vaccaro AR, Woodard E, Berry KJ, Benzel EC.** Stretch-associated injury in cervical spondylotic myelopathy: new concept and review. Neurosurgery. 2005;56:1101–1113.
30. **Sharma U, Pal K, Pratap A, Gupta DK, Jagannathan NR.** Potential of proton magnetic resonance spectroscopy in the evaluation of patients with tethered cord syndrome following surgery. J Neurosurg. 2006;105(5 Suppl):396–402. DOI: 10.3171/ped.2006.105.5.396.
31. **Furtado LMF, Da Costa Val Filho JA, Dantas F, Moura de Sousa C.** Tethered cord syndrome after myelomeningocele repair: a literature update. Cureus. 2020;12:e10949. DOI: 10.7759/cureus.10949.
32. Framework for FDA's Real-World Evidence Program. Food and Drug Administration, Center for Medicare Services, and Acumen Team. 2018. Available at: https://www.fda.gov/media/120060/download. Access date: 2020 Jul 25.

**Address correspondence to:**
Kalashnikov Aleksey Andreyevich
Speransky Children's City Clinical Hospital No. 9,
29 Shmitovsky proezd, Moscow, 123317, Russia,
glandibula@gmail.com

*Received 01.03.2023*
*Review completed 13.11.2023*
*Passed for printing 17.11.2023*

*Sergey Olegovich Ryabykh, DMSc, Head of the Department of Traumatology and Orthopedics, Veltishchev Research and Clinical Institute for Pediatrics and Pediatric Surgery of the Pirogov Russian National Research Medical University, 2 Taldomskaya str., Moscow, 125412, Russia; traumatologist-orthopedist, St. Petersburg State University's Pirogov Clinic of High Medical Technologies, 154 Fontanka River Embankment, St. Petersburg, 190103, Russia, ORCID: 0000-0002-8293-0521, rso_@mail.ru;*
*Sergey Aleksandrovich Gorchakov, MD, PhD, Chief of the Department of Pediatric Neurosurgery at Speransky Children's City Clinical Hospital No. 9, 29 Shmitovsky proezd, Moscow, 123317, Russia, ORCID: 0000-0003-0795-6921, sagorchakov@mail.ru;*
*Aleksey Andreyevich Kalashnikov, Pediatric Neurosurgeon of the Department of Pediatric Neurosurgery at Speransky Children's City Clinical Hospital No. 9, 29 Shmitovsky proezd, Moscow, 123317, Russia, ORCID: 0009-0009-2987-7950, glandibula @gmail.com.*