FEATURES OF SURGICAL TREATMENT OF THE SYNDROME OF FIXED SPINAL CORD IN CASE OF CLOSED SPINAL DYSRAPHISM.

Alikhodjayeva Gulnaraxan Alautdinovna:
Doctor of medical sciences, professor of Tashkent State Medical University
Yugay Igor Aleksandrovich:
Doctor of philosophy, neurosurgeon of Republican Specialized Scientific Practical Medical Center of neurosurgery in Uzbekistan
Abdullaev Doniyor Yorqinjonovich:
Doctor of philosophy, neurosurgeon of Republican Specialized Scientific Practical Medical Center of neurosurgery in Uzbekistan
Amanov Anvar Akmalovich:
Assitant of the 2nd traumatology, orthopedics, MFS and neurosurgery, Tashkent State Medical University,
Shamuratov Zokir Shokir o‘g‘li:
Assitant of the 2nd traumatology, orthopedics, MFS and neurosurgery, Tashkent State Medical University,
Axmedov Baxtiyor Elmurod o‘g‘li:
Assitant of Treatment and pediatrics faculty, Qarshi State University.

Abstract

Objective: *This study aims to evaluate the outcomes and surgical approaches in the treatment of tethered cord syndrome (TCS) associated with closed spinal dysraphism in pediatric patients.*

Methods: *A total of 61 children with TCS underwent microsurgical untethering procedures between 2019 and 2022. Preoperative diagnostics included MRI, MSCT, ENMG, and tractography. Surgical interventions incorporated laminectomy, resection of lipomas or dermal sinuses, and dissection of arachnoid and fibrous adhesions using intraoperative neurophysiological monitoring. Outcomes were compared with a retrospective control group of 55 patients.*

Results: *The most common pathologies were lipomeningocele (63.9%), spina bifida (27.8%), dermal sinus (14.7%), and thickened filum terminale (9.8%). Neurological improvement was observed postoperatively, especially in pelvic dysfunction (29.5%) and motor deficits (19.6%). Intraoperative neurophysiological monitoring played a crucial role in preserving neurological function. Duraplasty contributed to reducing the risk of retethering.*

Conclusion: *Early surgical intervention with precise microsurgical techniques and real-time neuromonitoring significantly improves neurological outcomes in*

children with TCS. Comprehensive defixation, including filum terminale and associated adhesions, along with duraplasty, is essential for long-term success.

Keywords: *Tethered cord syndrome, closed spinal dysraphism, pediatric neurosurgery, filum terminale, lipomeningocele, intraoperative neuromonitoring, duraplasty, spinal cord untethering, microsurgery, neurological outcomes.*

Annotatsiya

Maqsad: *Ushbu tadqiqotda bolalarda yopiq spinal disrafizm bilan bog‘liq bo‘lgan fiksatsiyalangan orqa miya sindromini (FOMS) jarrohlik yo‘li bilan davolash natijalari va amaliy yondashuvlari tahlil qilindi.*

Uslublar: *2019–2022 yillar davomida FOMS tashxisi qo‘yilgan 61 nafar bola mikroskopik usulda orqa miyani bo‘shatish operatsiyasini oldi. Operatsiyagacha MRI, MSKT, ENMG va traktografiya asosida batafsil tekshiruvlar o‘tkazildi. Jarrohlik aralashuvlar laminektomiya, lipoma yoki dermal sinuslar rezeksiyasi, shuningdek, araknoid va tolali bitishmalarni dissektsiya qilishni o‘z ichiga oldi. Operatsiyalar davomida intraoperatsion neyrofiziologik monitoringdan foydalanildi. Natijalar retrospektiv tarzda tuzilgan 55 nafar bemordan iborat nazorat guruhi bilan solishtirildi.*

Natijalar: *Eng ko‘p uchragan patologiyalar lipomeningotsele (63,9%), spina bifida (27,8%), dermal sinus (14,7%) va qalinlashgan terminal ip (9,8%) bo‘ldi. Operatsiyadan keyin ayniqsa, kichik chanoq a'zolari funksiyasi (29,5%) va harakat buzilishlari (19,6%)da sezilarli yaxshilanish kuzatildi. Neyrofiziologik monitoring nevrologik funksiyani saqlab qolishda muhim rol o‘ynadi. Dural plastika qayta fiksatsiyalanishning oldini olishda foydali bo‘ldi.*

Xulosa: *Erta yoshda, mikroxirurgik usullar va real vaqtli neyromonitoring asosida o‘tkazilgan jarrohlik aralashuvlar FOMS bilan kasallangan bolalarda nevrologik natijalarni sezilarli darajada yaxshilaydi. Filum terminale va bog‘langan to‘qimalarning to‘liq bo‘shatilishi, shuningdek, orqa miya suyuqligi erkin aylanishi uchun dural plastika muhim ahamiyatga ega.*

Kalit so‘zlar: *Fiksatsiyalangan orqa miya sindromi, yopiq spinal disrafizm, bolalar neyroxirurgiyasi, filum terminale, lipomeningotsele, intraoperatsion neyromonitoring, duraplastika, orqa miyani bo‘shatish, mikroxirurgiya, nevrologik natijalar.*

Аннотация

Цель исследования: *Оценить результаты и особенности хирургического лечения синдрома фиксированного спинного мозга (СФСМ) при закрытом спинальном дизрафизме у детей.*

Материалы и методы: *В период с 2019 по 2022 год 61 ребёнку с СФСМ была выполнена операция по устранению фиксации спинного мозга с применением микроскопической техники. Предоперационная диагностика*

включала МРТ, МСКТ, ЭНМГ и трактографию. Хирургические вмешательства включали ламинэктомию, резекцию липом и дермальных синусов, рассечение арахноидальных и фиброзных спаек с использованием интраоперационного нейрофизиологического мониторинга. Результаты сравнивались с ретроспективной контрольной группой из 55 пациентов.

Результаты: *Наиболее часто выявлялись липоменингоцеле (63,9%), спина бифида (27,8%), дермальный синус (14,7%) и утолщённая терминальная нить (9,8%). Послеоперационно наблюдалось улучшение, особенно в функции тазовых органов (у 29,5% пациентов) и моторных нарушениях (у 19,6%). Интраоперационный нейромониторинг сыграл важную роль в профилактике неврологических осложнений. Проведение дурапластики способствовало снижению риска повторной фиксации.*

Выводы: *Ранняя хирургическая интервенция с применением микрохирургической техники и интраоперационного нейромониторинга значительно улучшает неврологическое состояние детей с СФСМ. Эффективная дефиксация должна включать не только рассечение терминальной нити, но и устранение всех фиброзных и арахноидальных сращений, а также проведение дурапластики для восстановления циркуляции спинномозговой жидкости.*

Ключевые слова: *Синдром фиксированного спинного мозга, закрытый спинальный дизрафизм, детская нейрохирургия, терминальная нить, липоменингоцеле, интраоперационный нейромониторинг, дурапластика, расфиксация спинного мозга, микрохирургия, неврологические исходы.*

Literature review. Tethered cord syndrome (TCS) is caused by fixation of the spinal cord in the spinal canal by congenital structures. Primary TCS is observed in patients with intradural lipomas, lipomyelomeningocele, split cord malformations - distemic myelitis, dermal sinus and neuroenteric cysts, thickened and shortened terminal strand (7, 8, 14). TCS leads to mechanical recruitment and ischemia in the distal parts of the spinal cord, including the conus medullaris, therefore, TCS is mainly characterized by motor-sensory disorders in the lower extremities and urological complications.

The study of TCS began in the late 19th century by scientists from different countries. Virchow first used the term " spina bifida occulta " to describe lesions covered by skin and the term " woman with horse mane" for hypertrichosis in 1875. Jones from Great Britain was the surgeon who first successfully released the tethered spinal cord in 1891. Fuchs used the term "myelodysplasia" for the clinical picture consisting of deep tendon reflex-sensory disturbances, enuresis and foot deformities in patients with dystematomyelia. Yamada et al. reported that various neurological

manifestations in TCS are the result of ischemia of the caudal end of the spinal cord due to its mechanical tension (11, 12, 13).

Because TCS results from increased caudal traction on the spinal cord, the primary treatment for lesions and structures involving arachnoid cords, primitive neural placodes, thick or fibrofatty filum terminale, lipomyelomeningocele, diastomosis, and intradural lipomas with release from tethering is surgical (1, 5, 9, 11, 12).

Purpose of the study. To analyze the results of surgical treatment of children who underwent surgery for TCS. To determine the features of the surgical technique for eliminating spinal cord tethering in closed dysraphism.

Material and methods. In our main study group, 61 children with TCS underwent surgical treatment for spinal cord release over a 5-year period. 32 (52.4%) patients were girls and 29 (47.5%) were boys. The mean age was 53.67 months (30 days to 11 years). The symptoms were skin lesions in 22 patients (36.06%), bladder and bowel dysfunction (BBD) in 17 patients (27.8%), weakness in the legs or feet, numbness and/or spasticity or increasing foot deformity in 22 patients (36%), scoliosis and increasing back pain in 9 patients.

All patients underwent detailed examination with magnetic resonance imaging (MRI) and computed tomography MSCT, electroneuromyography (ENMG), and tractography.

Among 61 children who underwent surgery to eliminate tension and fixation of the spinal cord, 39 (63.9%) were found to have lipomeningocele, 17 (27.8%) - spinal cord bifida, 9 (14.7%) - dermal sinus, and 6 (9.8%) - thickened terminal strand.

In all these patients, release of the tensioned spinal cord and roots, as well as dissection of arachnoid and fibrous strands was performed surgically using intraoperative monitoring and microscopic techniques.

The results of the study were compared with a control retrospective group of patients consisting of 55 patients.

Results and discussion.

A total of 61 children with tethered spinal cords were operated on from 2019 to 2022. Of these, 52 (85.2%) patients had filum terminale fixation combined with lipomeningocele, diastematomyelia, or myelomeningocele. Surgery for tethered spinal cords with such malformations has shown some variations, and the technique varies depending on the underlying lesion. Not only dissection of the terminal thread, but also dissection and cleaning of the arachnoid cords around the roots are important for effective defixation.

Features of surgical technique and conditions for performing the operation. Patients are positioned prone, with electrodes installed for intraoperative

neuromonitoring (INOMED computerized neuromonitoring system). The operation is performed under general anesthesia, with microscopic assistance.

The standard procedure is laminectomy, depending on the level and extent of the anomaly, to expose the dura mater and then identify the terminal thread of the spinal cord. In case of lipocele, additional opening and excision of the lipoma. In cases of spina bifida occulta, laminectomy at the level of the bony septum. If the spinal cord continues to S1 or S2 due to fixation, giving several sacral roots, laminectomy was performed to this level. We opened the dura mater along the midline and fixed it with four sutures on both sides. After opening the dura mater, the terminal thread, arachnoid cords and roots were identified.

After opening the dura mater, we used a microscope and a set of microinstruments. The terminal thread appeared to us as a fibrovascular cord containing a large vessel that became smaller distally. The thickness of the terminal thread varied widely - from 2 mm to 1 cm. The vessel was not a reliable sign of the terminal thread, since we found similar vessels on the roots, or, conversely, there might not be vessels on the terminal thread.

The most important issue is the differentiation of nerve elements from adhesions and fibrous cords and the terminal thread. Using external signs alone, it is very easy to confuse roots and arachnoid cords. The roots at the sacral level are directed in both directions and can be identified by their size and position. Arachnoid cords are usually attached to the dura mater and roots (Figure 1).

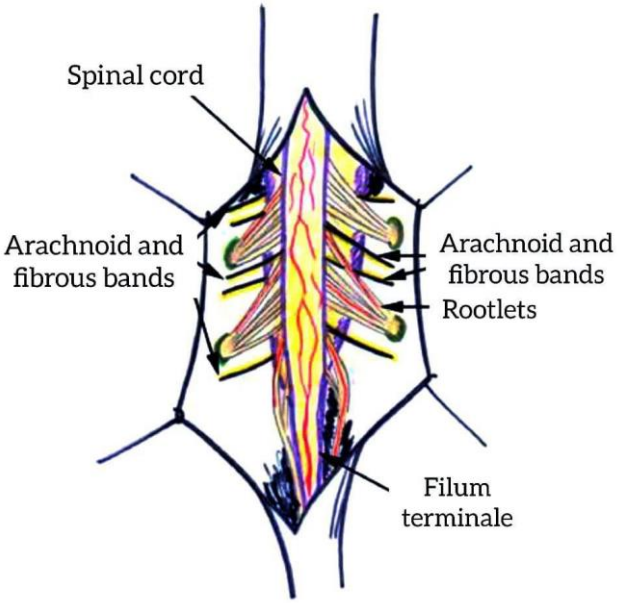


Figure 1: The line drawing shows spinal cord, filum terminale, roots, arachnoid and fibrous bands which are attached and tethered the spinal cord.

In addition to a good knowledge of neuroanatomy, the most modern and effective method for differentiating such structures is intraoperative

electrophysiological monitoring, which is very useful for safe surgical intervention. All manipulations are accompanied by stimulation neuromonitoring and speech feedback with a neurophysiologist, who controls the indicators based on the data from the motor.

During the manipulation to expose the terminal thread, we move the roots laterally with a microdissector and cut the arachnoid adhesions with microscissors.

In most cases, the terminal thread is thicker than normal (Figure 2), attached to the dura mater from behind along the midline, leaving virtually no free subarachnoid space for the passage of cerebrospinal fluid. The terminal thread is coagulated and cut after visual and neurophysiological identification (Figure 3).

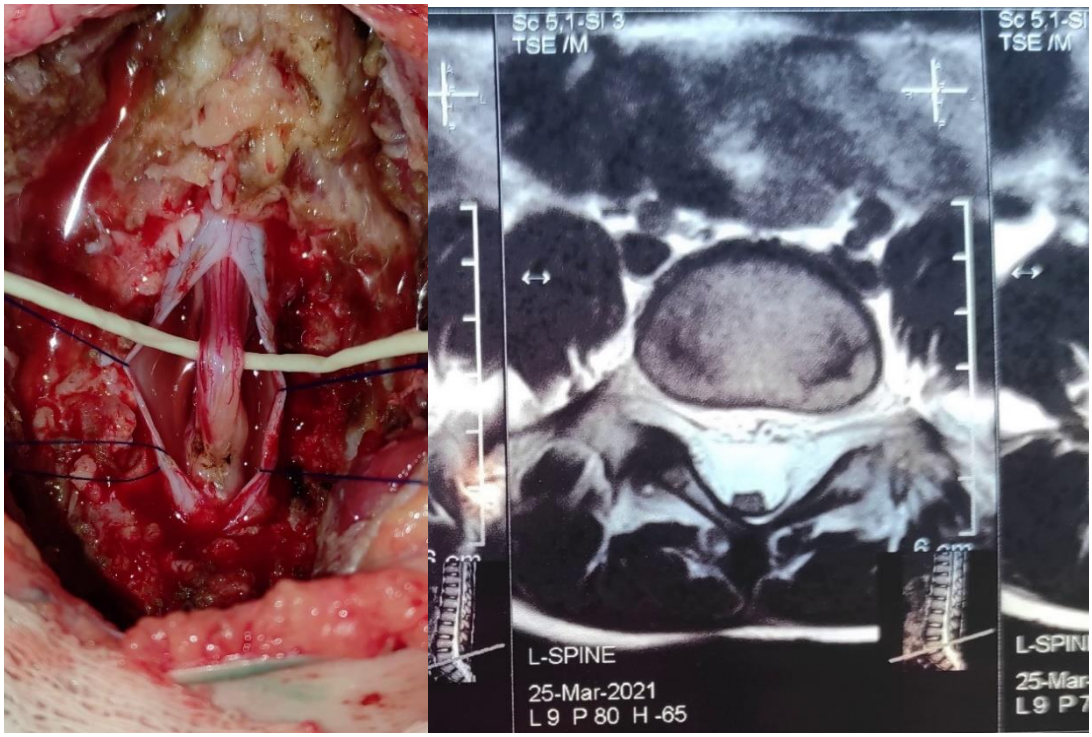


Figure 2. Thickened filum terminale. Closely adjacent to the dura mater at the back.

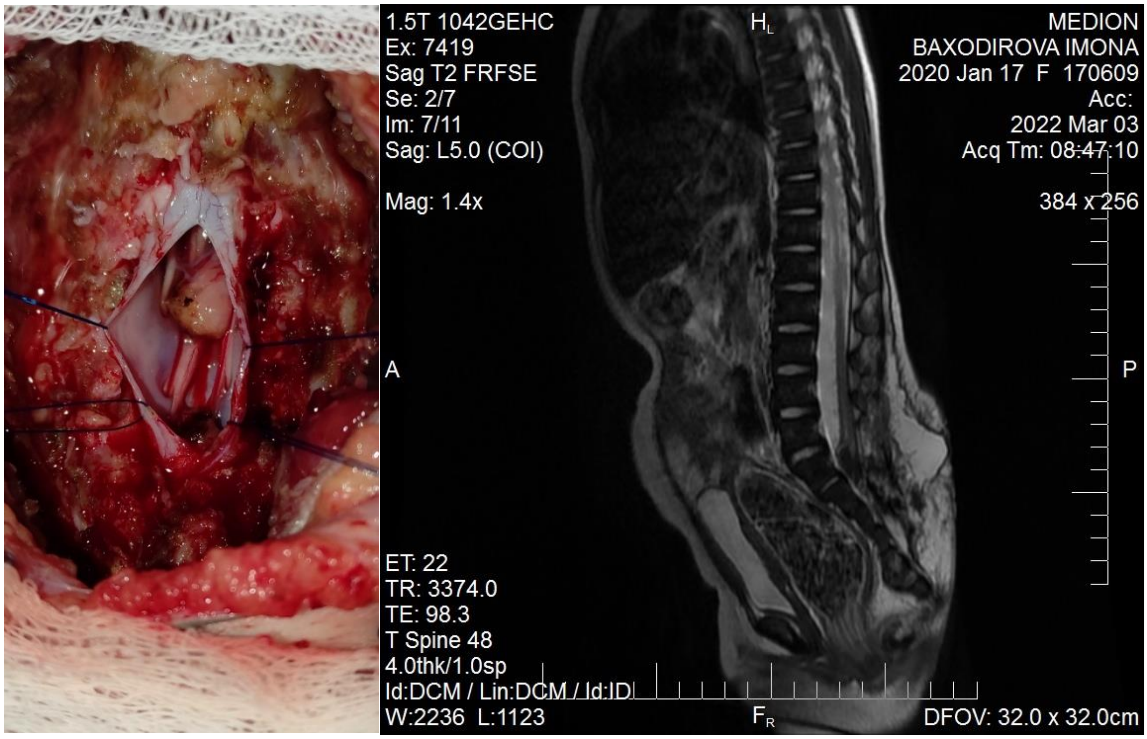


Figure 3. Transection of the filum terminale after thorough coagulation.

A practical way to assess the degree of fixation during surgery and the effectiveness of release is cranial movement of the transected filum terminale immediately after release. In addition to transecting the filum terminale, all connective tissues attached to the caudal portion of the spinal cord and cauda equina should be freed. The filum terminale and nerve roots should be free of surrounding tissues. In the case of the dermal sinus, tracts may attach to the filum terminalis or other fibrous bands, so these structures should also be divided to free the cord. Another useful measure to prevent secondary fixation was to perform duraplasty to create additional space to allow the passage of cerebrospinal fluid between the lumbosacral roots and the dura mater.

We used this surgical technique and operational approaches on 61 children. The data on changes in neurological deficit were compared with the control group consisting of 55 children. We considered the improvement of the condition to be reliable and significant and included it in the statistics of patients “with improvement” according to the change in the total ENMG indicator and regression of neurological deficit.

Table 1. Comparative assessment of the results of surgical treatment in patients of the main and control groups in the immediate and long-term periods.

Period of examination	Neurological syndroms					
	Pain syndrome		Pelvic disorders		Movement disorders	
	Group 1	Group 2	Group 1	Group 2	Group 1	Group 2

	n=61		n=55		n=61		n=55		n=61		n=55	
	n	%	n	%	n	%	n	%	n	%	n	%
Before surgery	9	14,7	8	14,5	39	63,9	34	61,8	45	73,7	41	74,5
The immediate postoperative period	14	22,9	11	20	31	50,8	29	55,0	40	65,5	34	61,8
Remote postoperative period	7	11,5	4	7,3	21	34,4	24	43,6	33	54,1	28	50,1

From Table 1 it can be concluded that the preoperative condition of children of the 2 presented groups of patients was comparable and statistically significant differences between the groups were not revealed ($p > 0.05$). In the immediate period, a tendency towards improvement of the neurological condition was noted in patients of the main group, especially in pelvic changes (improvement in 13.1% of patients), although the pain syndrome did not improve and, on the contrary, worsened, and in the main group more - this was primarily due to the presence of a wound, traction and irritation of structures closely adjacent to the roots during microdissection.

In the long-term period, a significant prevalence of improvement in results was noted in patients of the main group, and in all areas.

Conclusions. Thus, based on the results of our approaches to improving the surgical technique for eliminating the tethered spinal cord syndrome in closed dysraphism, the following conclusions can be made:

1. Surgical intervention is necessary in children of an early age group, immediately after the anomaly is detected.

2. Surgical intervention in full is possible only with the use of intraoperative neurophysiological control and microsurgical technique.

3. Defixation should concern not only the terminal thread, but also arachnoid and fibrous adhesions. It is necessary to perform plastic surgery of the dura mater sufficient for the free passage of cerebrospinal fluid.

4. The approach we used improved the neurological state in the late period according to electroneuromyography data and neurological deficit in 29.5% of patients for pelvic organ dysfunction and in 19.6% of patients for motor deficits.

References.

1. Сысоев, К.В. 3-Тл МР-трактография каудальных отделов спинного мозга при различных формах спинальных дизрафий у детей. К.В. Сысоев, Ю.В. Назинкина, В.А. Хачатрян. Лучевая диагностика и терапия. 2016;2:52-57.

2. Ходыкин, Е.А. порог возбудимости корешков спинного мозга при электростимуляции как дополнительный критерий прогноза оперативного

лечения аномалий развития спинного мозга у детей. Е.А. Ходыкин, К.В. Сысоев, В.А. Хачатрян. Вестник клинической нейрофизиологии. 2016;1(4):71-75.

3. Сысоев, К.В. Скрытый синдром фиксированного спинного мозга у детей (клиническое наблюдение и обзор литературы). К.В. Сысоев, Е.Н. Жарова, Ю.М. Забродская, и др. Нейрохирургия. 2016;3:53-58

4. Сысоев К.В. Результаты хирургического лечения детей с синдромом фиксированного спинного мозга. Прогноз на основании данных спинальной 3Тл МР-трактографии. К.В. Сысоев, А.Р. Тадевосян, Ю.В. Назинкина и др. Вопросы нейрохирургии им. Н.Н. Бурденко. 2016;3:66-73.

5. P. De Vloo: A Cadaver Study of Anatomy, Histology, and Elastic Properties. P.De Vloo, A.G. Monea, R. Sciot. World Neurosurg. 2016;90:565-573.

6. Young,R.L. Symtomatic retethering of the spinal cord following section of a tight filum terminale. R.L. Young, T.H. Habrock-Bach, Vaughan M. et all. Neurosurgery. 2011;68:15941602.

7. Yamada, S. Pathophysiology of tethered cord syndrome and similar complex disorders. S.yamada, D.J. Won, G. Pezeshkpour et all. Neurosurg focus. 2007;23(2):6.

8. Sanchez, T. Early identification of tethered cord syndrome: a clinical challenge. T.Sanchez, R.M. John. J Pedietr Health Care.-2014.-Vol.28(3).-E.23-33.

9. Rossi, A. Imaging in spine and spinal cord malformations. A. Rossi, R. Biancheri, A. Cama et all. Europ J Radiol.-2004.-Vol. 50(2).-P. 177-200.

10. Rinaldi,F. Tethered cord syndrome. F. Rinaldi, F/A/ Cioffi, L. Columbano et all. J Neurosugery Sci.-2005;49 (4):131-135.

11. Bowman, R.M. Tethered cord release: a long-term study in 114 patients. R.M. Bowman, A. Mohan, J. Ito et all. J Neurosurg Pediatr. 2009;l.3:181-187.

12. Deletis, V. Intraoperative neurophysiologic monitoring of the spinal cord during spinal cord and spine surgery: a review focus on the corticospinal tracts. V. Deletis, F. Sala. Clin Neurophysiol. 2008;119(2):248-264.

13. Hoving, E.W. The value of intraoperative neurophysiologic monitoring in tethered cord surgery. E.W.Hoving, E.Haitsma, C.M. Oude Ophuis et all. Childs nerv Syst. 2011;27(9):14451452.

14. Husain, A.M. Prognostic value of neurophysiologic intraoperative monitoring in tethered cord syndrome surgery. A.M. Husain, D. Shah. J Clin Neurophysiol. 2009;26(4):244-247.

15. Khealani, B. Neurophysiologic intraoperative monitoring during surgery for tethered cord syndrome. B.Khealani, A.M.Husain. J Clin Neurophysiol. 2009;26(2):76-81.

16. Kothbauer K.F. Intraoperative neurophysiology of the conus medullaris and cauda equine. K.F.Kothbauer, V. Deletis. Childs Nerv Syst. 2010;26(2):247-253.
17. Paradiso, G. Multimodality intraoperative neurophysilogic monitoring findings during surgery for tethered cord syndrome: analysis of a series of 44 patients with.