American Journal of Medicine and Medical Sciences 2025, 15(1): 269-273
DOI: 10.5923/j.ajmms.20251501.53

Surgical Treatment of Tethered Cord Syndrome in Children with Spinal Dysraphism

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Abstract The results of surgical treatment of children who underwent surgery for fixed spinal cord syndrome were analyzed. The features of the surgical technique for eliminating fixation of the spinal cord in closed dysraphism were determined, which made it possible to improve the results of treatment. In total, from 2019 to 2024, 61 children were operated on for a fixed spinal cord. Of these, in 52 (85.2%) patients, fixation of the terminal filament was combined with lipomeningocele, diastematomyelia, or myelomeningocele. All patients underwent a detailed study with magnetic resonance imaging (MRI) and computed tomography MSCT, performed electroneuromyography (ENMG), as well as tractography. In all these patients, the release of the stretched spinal cord and roots, as well as the dissection of the arachnoid and fibrous cords, was performed surgically using intraoperative monitoring and microscopic techniques. The results of the study were compared with a retrospective control group of patients, consisting of 55 patients. At the same time, it was found that the approach used by us significantly improved the condition in the long-term period according to electroneuromyography and neurological deficit in 29.5% of patients with pelvic disorders and in 19.6% of patients with motor disorders of the main group.

Keywords Spina bifida, Tethered cord syndrome, Lipomeningocele, Diastematomyelia

1. Introduction

Tethered cord syndrome (TCS) occurs as a result of fixation of the spinal cord in the spinal canal due to structures of congenital origin. Primary TCS is observed in patients with intradural lipomas, lipomyelomeningocele, malformations of the split spinal cord - dystematomyelia, dermal sinus and neuroenteric cysts, thickened and shortened terminal filament [4,7,8,11]. TCS leads to mechanical torsion and ischemia in the distal parts of the spinal cord, including the conus medulla, therefore, in TCS, motor-sensory disorders in the lower extremities and urological complications are mainly observed.

The study of TCS began at the end of the 19th century by scientists from different countries. Virchow first used the term "hidden spina bifida" to describe skin-covered lesions and the term "horse-maned woman" for hypertrichosis in 1875. Jones of Great Britain was the surgeon who first successfully released a spinal cord fixation in 1891. Fuchs used the term "myelodysplasia" for the clinical picture, consisting of deep tendon reflex-sensitive disorders, enuresis, and foot deformities in patients with dystematomyelia. Yamada and co-authors reported that various neurological manifestations in TCS are the result of ischemia of the caudal spinal cord due to its mechanical stress [2,3,9,10,13].

Since TCS results from increased caudal tension on the spinal cord, the primary treatment for lesions and structures involving arachnoid cords, primitive neural placodes, thick or fibrofatty terminal filament, lipomyelomeningocele, diastomatemyelia, and fixation-released intradural lipomas is surgical [1,5,6,11,12].

The 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 fixation of the spinal cord in closed dysraphism.

2. Material and Methods

Surgical treatment of our studied main group for spinal cord release was carried out in 61 children with TCS for 5 years. 32 (52.4%) patients were girls and 29 (47.5%) boys. The median age was 53.67 months (30 days to 11 years). Symptoms were skin lesions in 22 patients (36.06%), urination and defecation disorders in 17 patients (27.8%), weakness in the legs or feet, numbness and/or spasticity or progressive deformity of the feet in 22 patients (36%), scoliosis and increasing back pain in 9 patients.

All patients underwent a detailed study with magnetic resonance imaging (MRI) and computed tomography CT, electroneuromyography (ENMG), as well as tractography.

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Received: Jan. 5, 2025; Accepted: Jan. 28, 2025; Published: Feb. 3, 2025
Published online at http://journal.sapub.org/ajmms

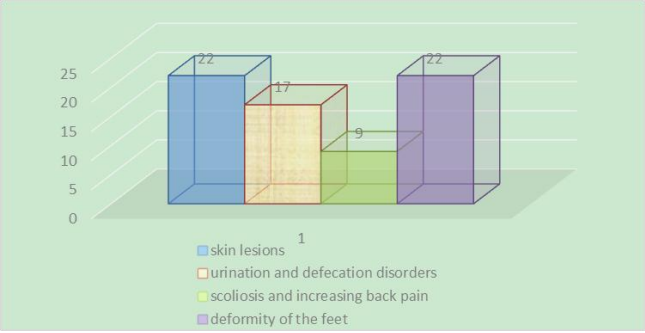

Diagram 1. Clinical manifestation of fixed spinal cord

Among 61 children who underwent surgery to eliminate tension and fixation of the spinal cord, 39 (63.9%) had a lipomeningocele, 17 (27.8%) had a spinal cord split, and 9 (14.7%) had a dermal sinus and 6 (9.8%) had a thickened terminal filament.

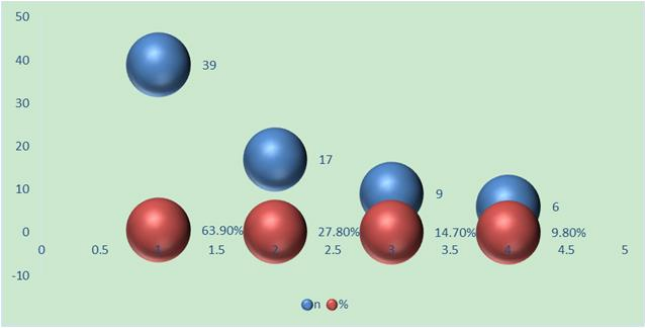

Diagram 2. Nosological forms of fixed spinal cord

In all these patients, the release of the stretched spinal cord and roots, as well as the dissection of the arachnoid and fibrous cords 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.

3. Results and Discussions

In total, from 2019 to 2024, 61 children were operated on for a fixed spinal cord. Of these, in 52 (85.2%) patients, fixation of the terminal filament was combined with lipomeningocele, diastematomyelia, or myelomeningocele. Fixed spinal cord surgery with these malformations has shown some variation, and the technique varies depending on the underlying lesion. Not only the cutting of the terminal thread, but also the cutting and cleaning of the arachnoid cords around the roots are important for effective defixation.

Features of surgical technique and conditions for the operation. The position of patients on the abdomen, with the installation of electrodes for intraoperative neuromonitoring (computer complex for neuromonitoring INOMED). The operation takes place under general anesthesia, with microscopic assistance.

The standard procedure is a laminectomy, depending on the level and extent of the anomaly, to expose the dura mater and then identify the terminal filament of the spinal cord. In the case of lipocele, additional opening and excision of the lipoma. In cases of hidden spina bifida, laminectomy at the level of the bony septum. If the spinal cord, due to fixation, continues to levels S1 or S2, giving rise to several sacral roots, laminectomy was performed down to that level. The dura mater was opened by us along the midline and secured with four sutures on both sides. After opening the dura mater, the terminal filament, 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, which becomes smaller along the distal path. The thickness of the terminal filament varied over a wide range - from 2 mm to 1 cm.

The most important issue is the differentiation of nerve elements from adhesions and fibrous bands and terminal thread. Only using external signs it is very easy to confuse roots and spider webs. The roots at the sacral level are bidirectional and can be identified by their size and position. The arachnoid bands are usually attached to the dura mater and roots (Figure 1).

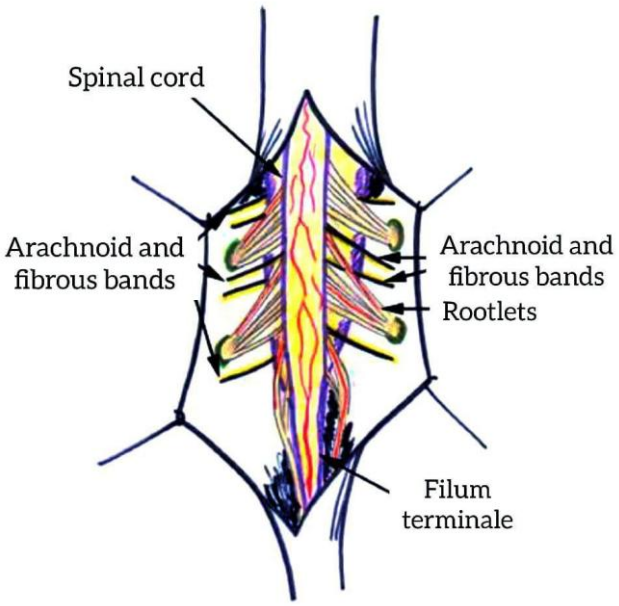

Figure 1. The line drawing shows spinal cord, filum terminale, rootlets and arachnoid and fibrous bands which are attached and tethered the spinal cord

In addition to 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 voice feedback with a neurophysiologist, who, according to the data from the monitor, controls the performance.

During the manipulation to expose the terminal filament, we divert the roots laterally using a microdissector and cut the arachnoid adhesions with microscissors.

In most cases, the terminal filament is thicker than normal (Figure 2), attaches to the dura mater posteriorly along the

midline, leaving practically no free subarachnoid space for the passage of cerebrospinal fluid. The terminal filament is coagulated and cut after visual and neurophysiological identification (Figure 3).

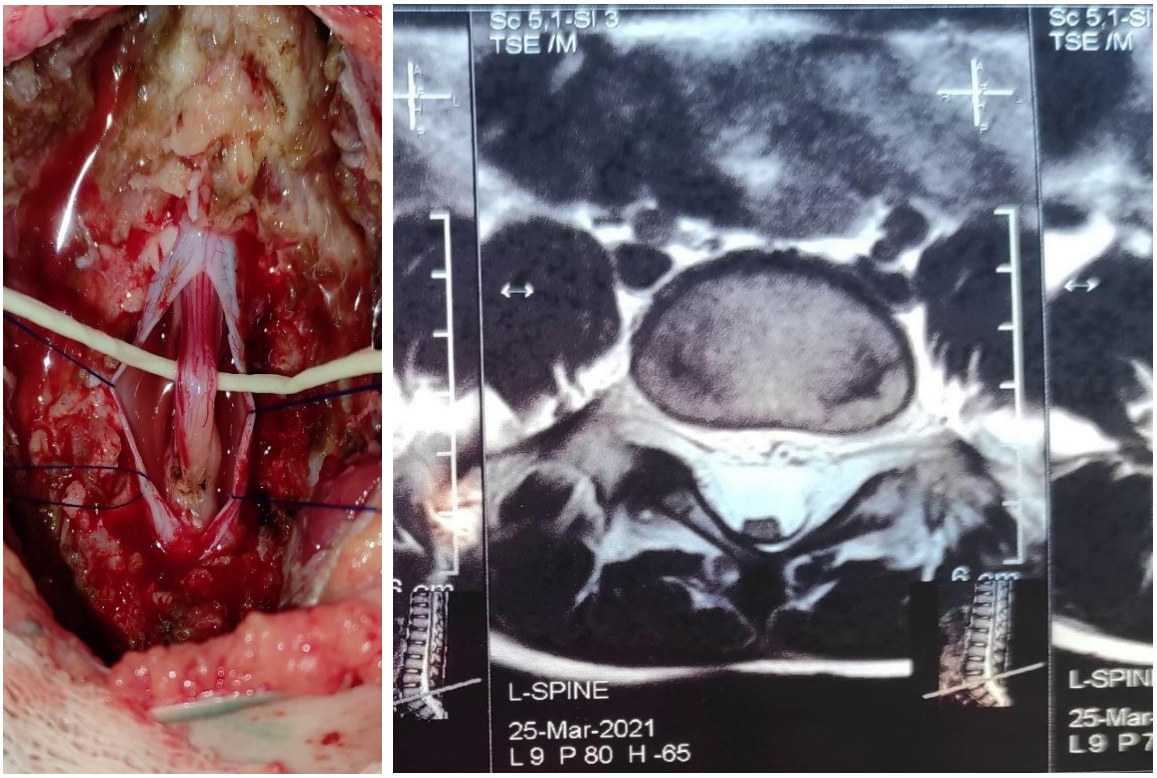

Figure 2. Thickened terminal thread. Posteriorly closely adjacent to the dura mater

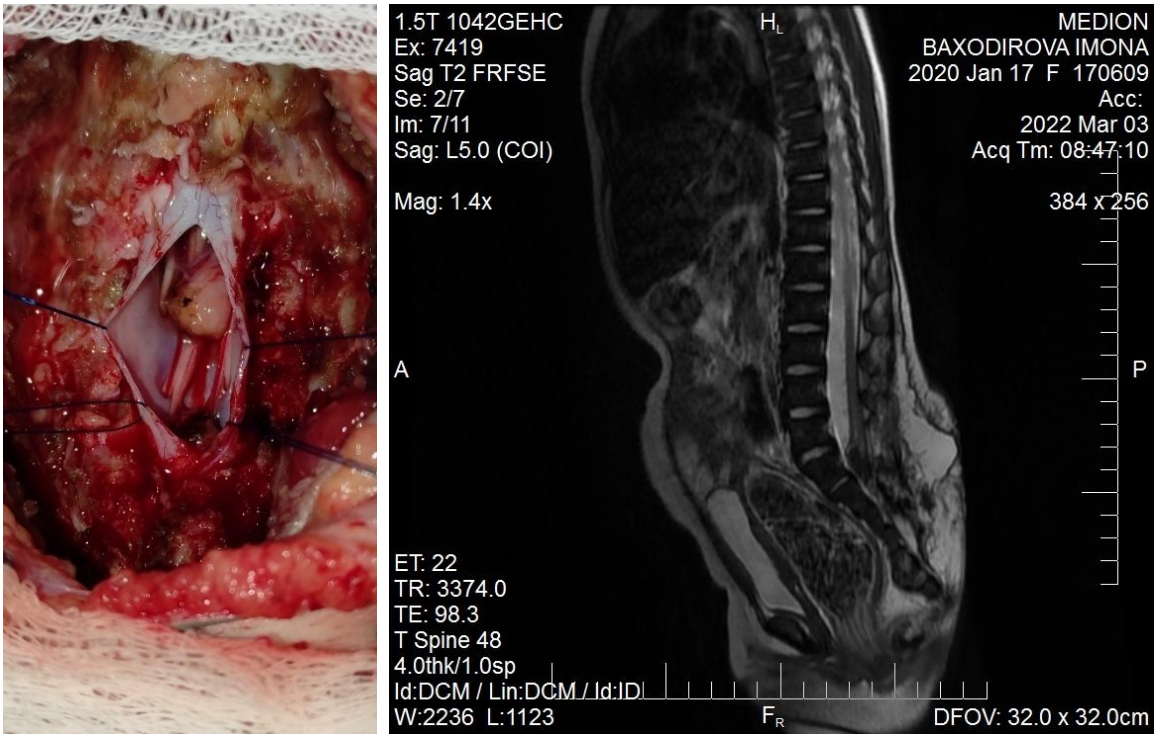

Figure 3. Transection of the terminal filament after careful coagulation

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

Survey's term	Neurological syndromes											
	Pain syndrome				Pelvic disorders				Motor disorders			
	1 group n=61		2 group n=55		1 group n=61		2 group n=55		1 group n=61		2 group 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
Nearest 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

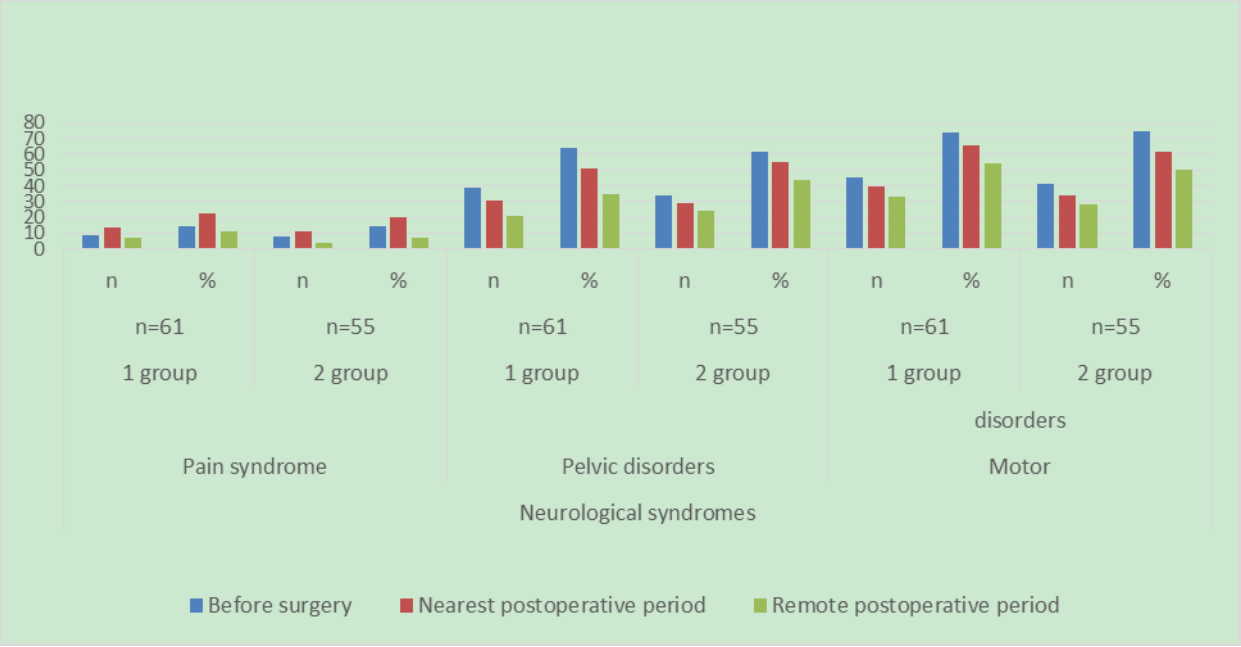

Diagram 3. Comparative evalution of the results of surgical treatment

A practical way to assess the degree of fixation during surgery and the effectiveness of the release is the cranial movement of the transected filament terminal immediately after release. In addition to cutting the filum terminale, all connective tissues attached to the caudal spinal cord and cauda equina should be released. The terminal thread and nerve roots should be free from surrounding tissues. In the case of the dermal sinus, the tracts may attach to the filum terminalis or other fibrous cords, so these structures must also be dissected to free the spinal cord. The next useful measure to prevent secondary fixation was to perform a dural plasty to create additional space to allow passage of cerebrospinal fluid between the lumbosacral roots and the dura mater.

We used this surgical technique and operational approaches on 61 children. Data on changes in neurological deficits were compared with a control group of 55 children.

Improvement in the condition was considered by us to be reliable and significant and was included in the statistics of patients "with improvement" in terms of changes in the total ENMG index and regression of neurological deficit.

From table 1 and diagram 3, we can conclude that the preoperative state of the children of the 2 presented groups of patients was comparable and no statistically significant differences were found between the groups ($p > 0.05$). In the near future, there was a tendency to improve the neurological condition in patients of the main group, especially in pelvic changes (improvement in 13.1% of patients), although the pain syndrome did not improve, and vice versa, worsening was noted, and in the main group more - this is primarily due to it was with the presence of a wound, traction and irritation of structures closely adjacent to the roots during microdissection.

In the long-term period, there is a significant prevalence of improvement in results in patients of the main group, and in all positions.

4. Conclusions

Thus, based on the results of our approaches to improving the surgical technique for eliminating the syndrome of a fixed spinal cord in closed dysraphism, we can draw the following conclusions:

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

2. Full-scale surgical intervention is possible only with the use of intraoperative neurophysiological control and microsurgical techniques.
3. Defixation should concern not only the terminal thread, but also arachnoid and fibrous adhesions. It is necessary to carry out plastic surgery of the dura mater sufficient for the free passage of CSF.
4. The approach we used improved significantly the condition in the long-term period according to electroneuromyography and neurological deficit in 29.5% of patients with pelvic disorders and in 19.6% of patients in the main group with motor disorders.

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