Article published online: 2025-02-28

THIEME OPEN ACCESS

Research Article

Role of Intraoperative Neurophysiological Monitoring in Pediatric Tethered Cord Syndrome Surgeries and Technical Insights

Wael Abd Elrahman Ali Elmesallamy[1] Alshaimaa Abdel Fattah Kamel[2] Ahmad Fahmy[2]
Mohamed Elbana[1] Mahmoud M. Taha[1]

[1] Neurosurgery Department, Faculty of Human Medicine, Zagazig University, Alsharkia, Egypt
[2] Intensive Care and Pain Management, Faculty of Human Medicine, Zagazig University, Alsharkia, Egypt

Address for correspondence Wael Abd Elrahman Ali Elmesallamy, MD, Faculty of Human Medicine, Zagazig University, Alsharkia, Egypt (e-mail: waelmesallamy@gmail.com).

Indian J Neurosurg

Abstract

Objectives Spinal cord tethering lesions in pediatric patients may cause neurological deficits through direct or indirect neural impairments, and untethering surgeries must be targeted to prevent further neural impairments. This study aimed to evaluate the role of intraoperative neurophysiological monitoring (IONPM) during spinal dysraphism untethering surgeries, with an emphasis on some technical insights.

Methods This retrospective study was conducted on 67 pediatric patients who suffered spinal dysraphismic lesions and underwent spinal cord untethering during the period from January 2017 to January 2023, with a follow-up period of at least 1 year. All surgeries involved the use of IONPM under total intravenous anesthesia. Spinal cord and root untethering were tried by neurolysis, sectioning of the filum terminale, and maximal lesion resection according to the offending pathology. In some cases, intraoperative ultrasound was used for tissue differentiation.

Results There was no significant difference between the preoperative and postoperative clinical conditions of the patients, while after 1 year of follow-up, there were significant clinical improvements regarding motor power, sensation, urinary control, and stool incontinence. Permanent warning changes in IONPM parameters occurred in 10 patients. Motor evoked potential monitoring recorded 100% specificity (true-negative probability rate) and accuracy of 98.51% (overall probability) in relation to the clinical condition of the patients, while electromyographic and bulbocavernosus reflex monitoring recorded 100% sensitivity (true-positive probability rate) with an accuracy of 95.52 and 96%, respectively.

Conclusion Technically, IONPM during pediatric spinal cord and untethering of roots provides safety when dealing with such delicate neural tissues with the aid of intraoperative ultrasound whenever needed, in addition to surgical assurance of maximal neural element untethering.

Keywords
- intraoperative neurophysiological monitoring
- intraoperative ultrasound
- pediatric tethered cord syndrome
- spinal dysraphism

DOI https://doi.org/10.1055/s-0044-1795106.
ISSN 2277-954X.

© 2025. The Author(s).
This is an open access article published by Thieme under the terms of the Creative Commons Attribution License, permitting unrestricted use, distribution, and reproduction so long as the original work is properly cited. (https://creativecommons.org/licenses/by/4.0/)
Thieme Medical and Scientific Publishers Pvt. Ltd., A-12, 2nd Floor, Sector 2, Noida-201301 UP, India

Introduction

Tethered cord syndrome is a common association with multiple congenital spinal dysraphisms, such as meningomyelocele and lipomyeloceles.[1,2] The clinical manifestations of tethered cord syndrome may be presented at any age by various neurological manifestations that have a progressive course and mandate surgical interventions.[3,4] Intraoperative neurophysiological monitoring (IONPM) during tethered cord release surgeries is safe, with results of stable or improvement in the neurological condition of the patients.[5] IONPM can be used to guide the surgeon to decrease neurological deficits. The sacral spinal system is most susceptible to neurological affection in tethered cord syndrome and should be monitored. Free-running electromyogram (EMG) and triggered EMG are useful to monitor the lumbosacral roots during surgery. Direct tissue stimulation can differentiate between viable and nonviable structures. Bulbocavernosus reflex (BCR) monitoring is predictive of postoperative sacral functions.[6] Several studies mentioned that motor evoked potential (MEP) is difficult to obtain in children younger than 6 years and impossible in those younger than 2 years due to immaturity of the corticospinal tracts and incomplete myelination.[7]

This study aimed to evaluate the role of IONPM during pediatric spinal dysraphism untethering surgeries, with an emphasis on some technical insights.

Methods

This retrospective observational study was conducted on 67 pediatric patients who presented with tethered cord syndrome due to spinal dysraphism and surgically treated at the neurosurgery department of our university hospital from January 2017 to January 2023, with a follow-up period of at least 1 year.

Written informed consent was obtained from the parents of the patients, and the study was approved by the Institutional Review Board (IRB#10376) in accordance with the Code of Ethics of the Declaration of Helsinki for studies involving humans. All surgeries were done by the neurosurgeons' authors, (all surgeries in this study were done by the neurosurgeons who were the authors of this study) who have had previous experience in tethered cord surgeries for more than 15 years.

The **inclusion criteria** were the following: pediatric patients with tethered cord syndrome due to spinal dysraphisms with preserved or semi-preserved neurological functions below the level of the lesion by clinical examination.

The **exclusion criteria** were the following: complete loss of neurological functions below the level of the lesion, history of fits or hydrocephalus, failure to gain baseline monitoring of at least two types of intraoperative physiological parameters, or incomplete data about the patient.

Preoperative and postoperative evaluations were done through full general and neurological assessments through clinical and investigational tools to determine the neurological and general status of each patient. Magnetic resonance imaging (MRI) of the spine was a routine preoperative investigation for each patient, and clinical evaluation was the main postoperative method for neurological evaluation, which had been done within 24 hours after surgery, during hospital stays, and during follow-up at our outpatient clinics for at least 1 year. Urological consultation was done for each patient at the outpatient clinic, during hospitalization, and during follow-up for assessment of the voiding condition and post-void urine residual by history and ultrasound evaluation of the urinary condition. Urodynamic studies were done on only 24 patients, both preoperatively and during follow-up. Motor power was evaluated according to the Medical Research Council's grading system.[8] Motor improvement or deterioration was defined as changes in motor power by 1 grade or more.

Normal physiological and mental developmental ages were considered in the evaluation as normal urine control at 5 years of age, stool control at 4 years of age, and sensory interception at 6 years of age. Urine catheter removal after surgery was a problem in 30 patients due to urine retention, and this problem resolved within 5 and 12 days after surgery, so evaluation of urinary control was done after 2 weeks from surgery as a postoperative baseline.

Procedures: All patients subjected to surgeries for spinal untethering in the prone position under total intravenous general anesthesia (TIVA).

Surgical insights: Under microscopic or surgical loupe–assisted surgeries, our patients underwent surgery for neural tissue release by neurolysis of the spinal cord and/or spinal roots, sectioning of the filum terminale whenever part of the pathology, and maximal resection of abnormal tissues was performed if identified as part of the pathology. The target was not only patient safety but also the future response of the surgery by making a free room for the neural elements, permitting their mobility during the growth of the patient. Intraoperative ultrasound is used in situations that require the determination of skin incision marking, tissue definition, or tissue differentiation. Intraoperative ultrasound machines with different probes and frequencies (ranges: 3–13 MHz) were used in our hospitals (►**Fig. 1**).

- Hitachi Aloka scanner with three probes (a 4- to 13-MHz linear hockey stick probe, a 3- to 8-MHz linear burr hole probe, and a 4.4- to 10-MHz microconvex probe).
- IBE 2500 D scanner with a 5- to 8-MHz endocavitary probe.

Real-time B mode was adjusted for clear view by choosing the appropriate megahertz, suitable gain, contrast, and depth of the ultrasound waves.

Surgical insights included delicate manipulations, avoidance of tractions on neural tissues, avoidance of cautery whenever possible, careful low-voltage bipolar hemostasis, working on the offending pathology with maximal resection of abnormal tissues, searching for other tethering factors as tight filum terminale, and release of surrounding adhesions and anchoring factors to achieve free neural elements inside the capacious spinal canal.

Anesthetic insights: Preoperative fasting for 6, 4, and 2 hours for solid, breastfeeding, and soft drinks, respectively. In the operating room, a full monitor (electrocardiogram [ECG], noninvasive blood pressure

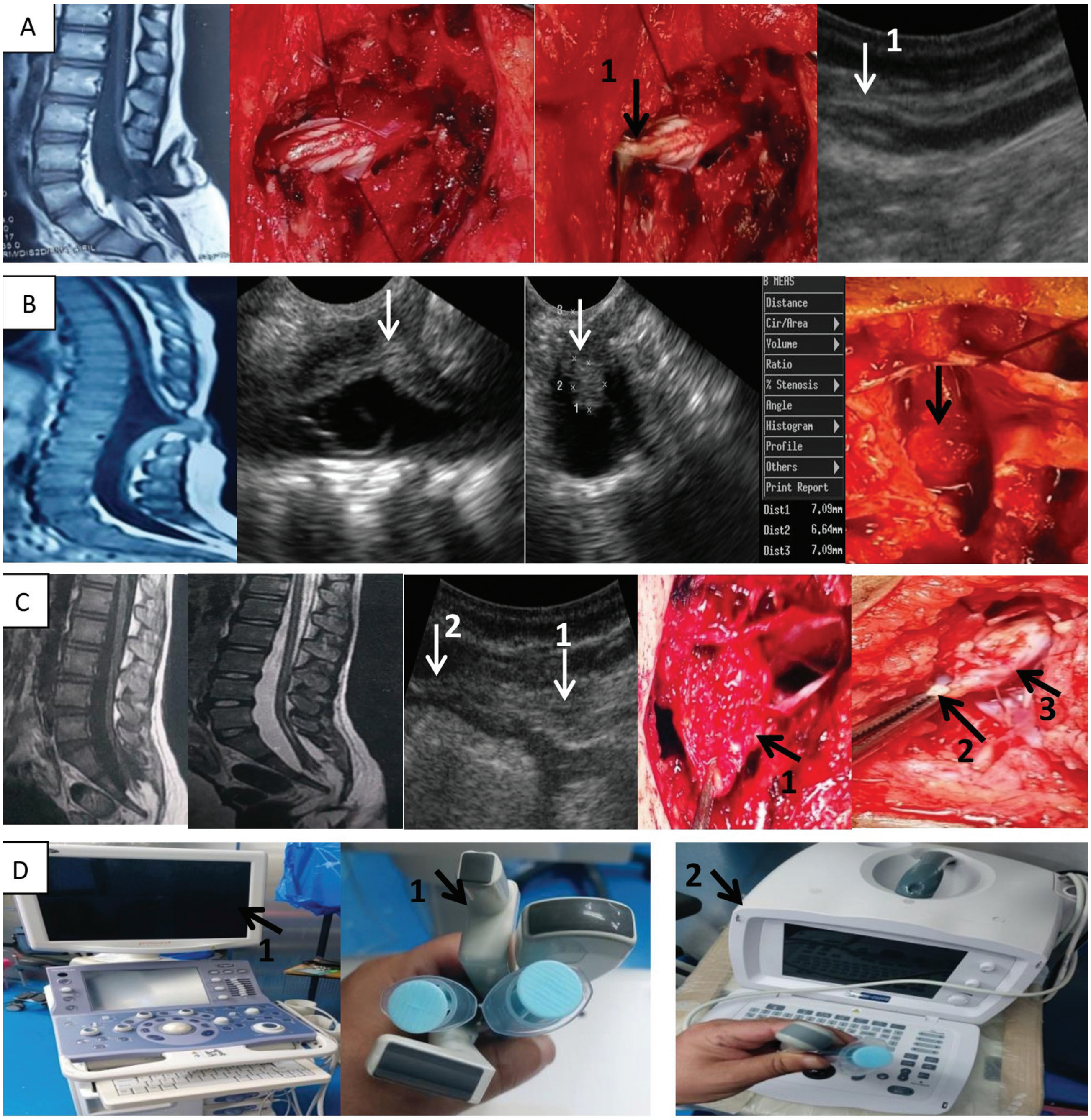

Fig. 1 Demonstration of intraoperative ultrasound during tethered cord surgeries. (**A**) Preoperative sagittal magnetic resonance imaging (MRI) shows the cord tethering, intraoperative dissection photographs for exposure of the cord and the filum terminale (*black arrow*), and intraoperative ultrasound images of the cord and the filum terminale (*white arrows* in sagittal images). (**B**) Preoperative MRI shows the kinked and tethered cord, intraoperative ultrasound images of the site, dimensions, and depth of the tethered cord (*white arrows* in sagittal and axial images), and an intraoperative photograph after untethering of the spinal cord (*black arrow*). (**C**) On MRI, T1 and T2 show the caudal end of the spinal cord blended and surrounded posteriorly and laterally with lipomatous tissues, intraoperative ultrasound image of the lipoma (*arrow 1*) and the filum (*arrow 2*) and photographs of intraoperative dissection of the lipoma (*arrow 1*), the filum (*arrow 2*), and the caudal part of the cord after removal of the lipoma (*arrow 3*). (**D**) Intraoperative ultrasound machines; Hitachi Aloka scanner with three probes (*arrow 1*) and IBE 2500 D scanner with an endocavitary probe (*arrow 2*).

[NIBP], and pulse oximeter) was attached. The intravenous line was inserted; it could be facilitated with inhalational sevoflurane. Preoxygenation was performed with 100% O_2 for 3 to 5 minutes, followed by induction of anesthesia with a loading dose of 0.5 µg/kg intravenous (IV) dexmedetomidine (Precedex; Hospira, Worldwide Inc.) diluted in 10-mL saline infused over 10 minutes, fentanyl 0.5 µg/kg, and facilitation of intubation using 0.5 mg/kg IV rocuronium. Maintenance of anesthesia in children included 0.5 µg/kg/h dexmedetomidine and 0.5 µg/kg/h fentanyl IV infusion. No additional muscle relaxant was injected (induction dose only). A peripheral nerve stimulator was used to detect any residual muscle relaxant effects (train of four [TOF]; ►**Fig. 2**). The child

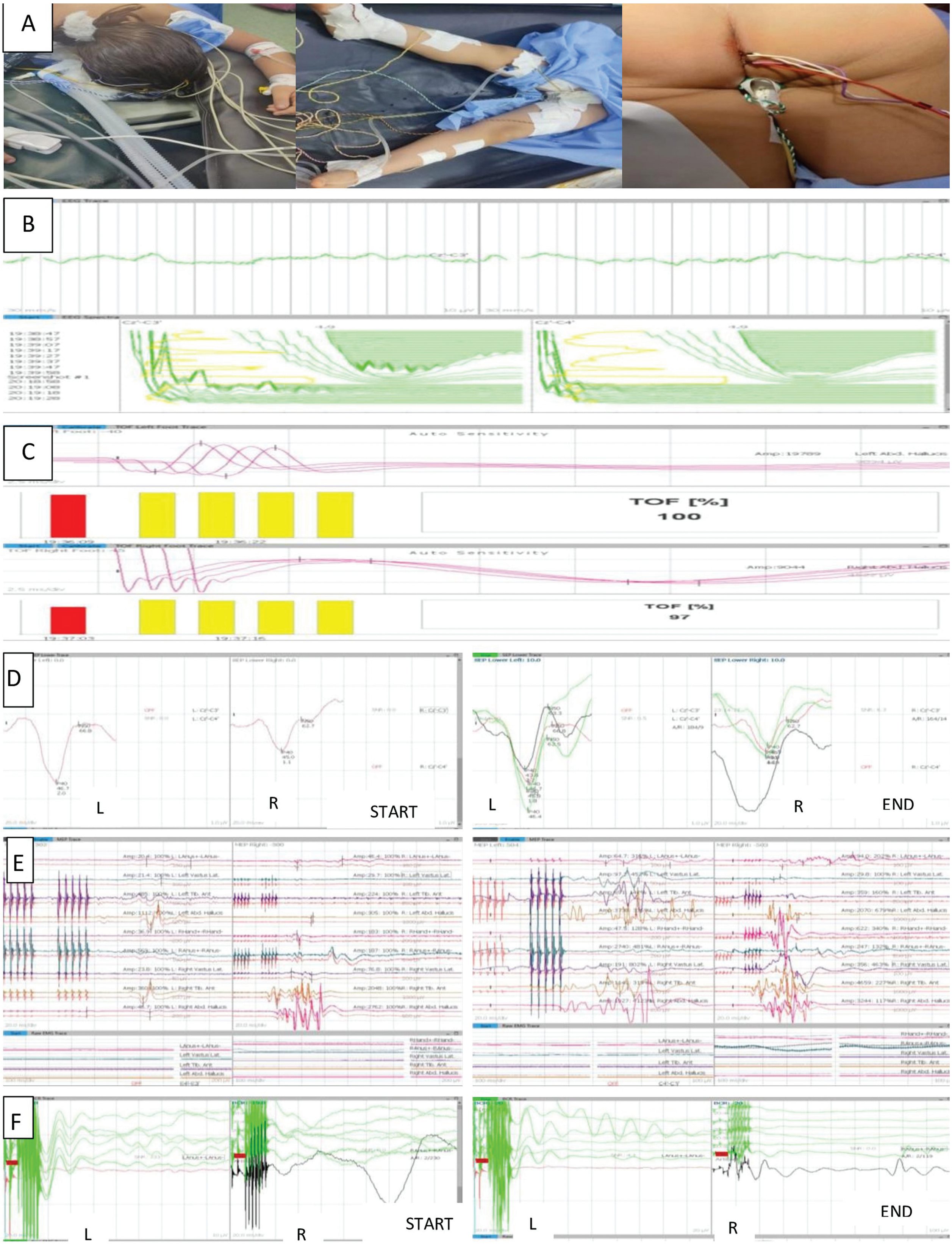

Fig. 2 Neurophysiological monitoring during tethered cord surgeries. (**A**) Scalp, control upper limb, lower limbs, genitalia, and anal electrode connections. (**B**) Electroencephalographic (EEG) monitoring of the spontaneous electric activities of the brain shows normal limits. (**C**) Train of four (TOF) stimulation to detect anesthetic depth; it shows weakness of the right foot of the patient and normal left side at the start of the surgery. (**D**) Somatosensory evoked potential, (**E**) Motor evoked potential and free running **EMG**, and (**F**) Bulbocavernosus reflex; the baseline traces obtained before the skin incision (start mark side) and the traces obtained at the end of the surgery (end mark side), L mark refers to left side monitoring and R refers to right side monitoring. The parameters show improvement at the end of the surgery.

was kept on spontaneous breathing and end tidal CO_2 between 35 and 40 mm Hg.

Neurophysiological monitoring (►**Fig. 2**): Transcranial MEP **(TcMEP)** was adapted by scalp corkscrew electrodes for stimulation over the brain motor area and different lower limb muscle receivers according to the level of the lesion, such as the abductor halluces muscle for the second sacral root (S2) and bilateral external anal sphincter receivers and the control receiver in an upper limb muscle. First, we tested the baseline motor function and then functional integrity during the procedure by neurophysiologist stimulation and recording. The somatosensory evoked potential **(SSEP)** was adapted by a twisted paired needle stimulator according to the level of the lesions, such as over the tibial nerve at the ankle and the pudendal nerve at the clitoris or glans of the penis, and the responses were received by corkscrew scalp electrodes over the primary somatosensory area. We tested the baseline of sensory functions and then functional integrity during the procedure by stimulation and recording. Electroencephalography (EEG) monitoring of the spontaneous electric activities of the brain was recorded. **EMG** was performed for continuous free-running recording and trigger recording using bipolar or monopolar probe stimulators ranging from 0.1 to 5 mA and pulse durations of 75 to 200 µs. **BCR** is an anal contraction detected by EMG when the pudendal nerve (S2, S3, S4) is stimulated using ventral and dorsal penile electrodes in males or electrodes placed between the labia minora and the clitoris in females with padding between the electrodes. BCR is a local conus medullaris reflex. Interpretation of compromised BCR to differentiate the pathway source of disruption can be done by testing TcMEP and SSEP. **Warning signs** during neurophysiological monitoring were adopted as persistent TcMEP amplitude drops greater than 50% of the baseline, SSEP amplitude drops greater than 50% of the baseline, and continuous neurotonic free-running EMG discharges greater than phasic discharges. The warning signs are in debate and differ according to many factors, such as the location of the surgery (brain or spine), neurophysiologists' discretion, and the patient's neurological condition. Also, untethering surgeries may represent special neurophysiological concerns as the nervous tissues may be affected by this developmental insult in different entities than acquired diseases and the presence of diseased neural tissues either actually or potentially, so we considered the mentioned parameters to be the warning signs. The routine actions when the warning signs evolved were: stopping of surgical manipulations, removal of instrumentation, washing with warm saline, revision of the anesthesia protocol (including drugs, hemodynamics, temperature, and blood gases), and revision of neurophysiological connections. These actions may extend up to 20 minutes, after which a surgical decision is made whether to continue as usual or modified for the patient's safety.

Statistical Analysis

The data were statistically analyzed using the 2015 IBM SPSS for Windows, Version 23.0 (IBM Corp., Armonk, NY, United States). Qualitative data were expressed as numbers and percentages. The percentage of categorical variables was compared using the Fisher exact test when appropriate. Cochran's *Q* test was used to compare multiple paired categorical variables. The McNemar test was used to compare pairs of categorical variables. All tests were two-sided. A *p*-value less than 0.05 was considered statistically significant.

Sensitivity is the probability that a test result will be positive when the disease is present (true-positive rate and expressed as a percentage). Specificity is the probability that a test result will be negative when the disease is not present (true-negative rate and expressed as a percentage). Positive predictive value is the probability that the disease is present when the test is positive and expressed as a percentage. Negative predictive value is the probability that the disease is not present when the test is negative and expressed as a percentage. Accuracy is equal summation of true positive and true negative divided by all studied patients.

Results

A total of 67 pediatric patients who underwent spinal cord untethering surgeries for treatments of spinal dysraphisms with IONM were included in this study. ►**Table 1** represents the basic characteristics of the patients and their lesions, including age, sex, type of spinal dysraphism, site of the lesion, surgical procedures, clinical presentation, and the clinical condition of our patients (motor weakness, sensory deficits, urinary control, and stool control) during preoperative examinations, postoperative examinations, and after 1 year from surgery. There was no significant difference between preoperative and postoperative clinical conditions. Motor weakness, sensory deficits, urinary control, and stool incontinence were significantly improved by comparing postoperative conditions and after 1 year from surgery, with the highest significance ($p = 0.0001$) for motor improvement. The patulous anus showed an insignificant difference between the postoperative condition and after 1 year.

Deterioration of the IONM parameters from the base records was registered in 25 patients, of which 10 patients showed permanent warning changes (at least one IONM type, for at least 20 minutes of revising actions). Forty-two patients were stable or showed IONM parameter improvements during surgeries.

►**Table 2** presents the correlation between IONM parameters and the neurological status of the patients:

- MEP and EMG IONPM were done for all patients and correlated to the postoperative motor condition of the patients. A permanent warning drop of MEP occurred in six patients; however, seven patients presented with postoperative motor power deterioration with a specificity of 100% (true-negative rate), sensitivity of 85.71% (true-positive rate), positive prediction (PP) of 100%, negative prediction of 98.36%, and accuracy of 98.51%. False-negative MEP results occurred in one patient and true-positive results in six patients. Permanent warning EMG changes occurred in 10 patients (same patients with MEP drops plus 4 other

 © 2025. The Author(s).

Table 1 Demographic, pathological, operative, and follow-up data of the studied patients

Parameters	Values
Age	
Range	3 mo–14 y
Median	12 mo
Mean	40 mo
Sex	
Males	26/67 (39%)
Females	41/67 (61%)
Dysraphism	
Lipomas	34/67 (51%)
Myelomeningocele	13/67 (19%)
Limited myeloschisis	3/67 (4%)
Diastematomyelia	9/67 (13%)
Dermoid	3/67 (4%)
Tight filum terminalis	5/67 (7%)
Site	
Lumbosacral region	48 (72%)
Dorsolumbar region	12 (18%)
Dorsal region	7 (10%)
Surgical procedures	
Release of adhesions	57/67 (85%)
Filum resection	27
Lipoma resection	34
Total	26/34 (76%)
Subtotal	8/34 (24%)
Clinical manifestations	
Back pain (>6 y)	12/14 (86%)
Back signs	
Lump	47/67 (70%)
Skin stigmata (hair, hemangioma, dimple, sinus)	21/67 (31%)

Clinical follow-up of the studied patients						
Parameters	**Preoperative**	**Postoperative**	**After 1 y from surgery**	***p***	***p*1**	***p*2**
Motor weakness	50/67 (75%)	52/67 (78%)	23/67 (34%)	0.0001	0.5	0.0001
Sensory deficits (>6 y)	12/14 (86%)	12/14 (86%)	7/14 (50%)	0.007	1	0.003
Urinary control						
Always wet (< 5 y)	22/49 (49%)	26/49 (53%)	18/49 (37%)	0.002	0.125	0.008
incontinent (>5 y)	16/18 (89%)	16/18 (89%)	9/18 (50%)	0.001	1	0.016
Stool control						
Patulous anus (<4 y)	10/44 (23%)	10/44 (23%)	7/44 (16%)	0.07	1	0.25
Incontinent (>4 y)	21/23 (91%)	22/23 (97%)	16/23 (70%)	0.006	0.99	0.31

Note: *p*: compared three clinical conditions by Cochran's *Q* test. Paired data: compared by the McNemar test; p1: compares preoperative and postoperative clinical conditions; p2: compares postoperative and follow-up after 1-year clinical conditions. $p < 0.05$ is significant.

patients). Three patients showed the same preoperative motor condition (false positive) with a specificity of 95%, sensitivity of 100%, PP of 70%, negative prediction of 100%, and accuracy of 95.52%. Postoperative motor weakness occurred in seven patients, of whom two were intact preoperatively.

- SSEP was performed for all patients and correlated to the postoperative sensory condition of only 14 patients (>6

 © 2025. The Author(s).

Table 2 Intraoperative validity of neurophysiological monitoring

Intraoperative neurophysiological monitoring	Clinical (postoperative in relation to preoperative)			Specificity (%)	Sensitivity (%)	Negative prediction (%)	Positive prediction (%)	Accuracy (%)
	Same	Deteriorated	Total					
MEP ($n = 67$)								
• Same or improved • Deteriorated • Total	60 0 60	1 6 7	61 6 67	100	85.71	98.36	100	98.51
EMG ($n = 67$)								
• Same or improved • Deteriorated • Total	57 3 60	0 7 7	57 10 67	95	100	100	70	95.52
BCR ($n = 50$)								
• Same or improved • Deteriorated • Total	44 2 46	0 4 4	44 6 50	95.65	100	100	66.7	96
SSEP ($n = 14$)								
• Same • Deteriorated • Total	12 2 14	0 0 0	12 2 14	85.71		100		

Abbreviations: BCR, bulbocavernosus reflex; EMG, electromyogram; MEP, motor evoked potential; SSEP, somatosensory evoked potential.

 © 2025. The Author(s).

years). A permanent warning drop of SSEP occurred in two patients without clinical sensory deficits (false positive), with a specificity of 85.71% and a negative prediction of 100%.
- BCR was performed in 50 patients with sensitivity of 100%, specificity of 95.65%, PP of 66.67%, negative prediction of 100%, and accuracy of 96%.

Discussion

The safety and long-term release of the neural elements are the targets of the surgical treatment of spinal dysraphism. Pediatric neural elements are very delicate structures that must be handled with great caution to avoid their affection and maintain their blood supply. For these reasons, surgical manipulations should be accompanied by sufficient surgical experience and efficient surgical tools.

The IONPM can detect on-the-spot neurological changes from the base records, alerting the surgeon to take actions, which may include waiting and reviewing the situation or stopping the surgery. Also, the in-doubt tissues can be tested to exclude neural components. The surgery team, including the surgeon, anesthesiologist, and neurophysiologist, must be constant touch during the surgery to detect any deviation from baseline neurological status immediately.[9,10] The primary aim of neurophysiological monitoring is to provide early warning of neurological affection with the potential for reversal to decrease the possibility of postoperative new neurological deterioration.[11]

There was no significant difference between the preoperative and postoperative clinical conditions of our patients, but after 1 year of follow-up, there were significant clinical improvements regarding motor power, sensation, urinary control, and stool incontinence. All patients presented with postoperative neurological deterioration and recovered within a few weeks. These results support the rescue of the neural tissues before permanent damage occurs during IONPM.

Hoving et al[5] concluded that there were benefits of IONPM during tethered cord surgeries, as 64 of 65 patients were still stable or improved after surgeries, with a recommendation to use it for its safety. Niljianskul and Prasertchai[12] documented the role of IONPM during spinal tumor surgeries, as the IONPM group showed significant clinical improvements over the duration of 2 years of follow-up, and the non-IONPM groups showed a significant decrease in neurological status at 1 month of follow-up, which was explained by neural injury without real-time detection and so could not be respected when lacking IONPM. In contrast, Drolet et al[13] reported that there were no benefits from using IONPM during tethered cord surgeries. Also, other studies on spinal cord surgeries such as intramedullary spinal cord tumor resection[14] and intradural extramedullary spinal tumor resection[15] found no statistically significant difference in neurological outcome with the use of IONPM.

Alarm criteria and guidelines for neurophysiological monitoring are still in debate, and different alarms were set for spinal and cranial surgeries.[9,16]

We considered the lowest alarm criteria for patient safety in our surgeries because of the delicate and complicated congenital nature of these types of lesions.

Combined neurophysiological monitoring types are recommended to avoid the limitations of individual type[17] and cover different neurofunctional pathways. The results of this study documented the absence of 100% accuracy in any IONPM type, with the highest MEP having 98.51% accuracy. Our records showed 100% specificity in the validation of the MEP for neurological conditions and 100% sensitivity when considering EMG or BCR monitoring. Kim's[6] study on spinal dysraphism with IONPM discussed the difference between spinal dysraphism surgeries and other spinal surgeries regarding the use of IONPM. Key concerns included the more frequent use of tonic or phasic running EMG than other surgeries, the recommendation to use a low MEP alarming parameter, and the greater specificity of MEP, all of which matched with our results and the documentation of the role of IONPM during such surgeries.

Multimodal monitoring in dysraphism surgeries regarding motor and sensory systems is mandatory for several reasons: (1) the different locations of the ascending sensory tracts and descending motor tracts; (2) the different sources of blood supply to these tracts while also taking into consideration the abundant connections and the anomalous factors; (3) intraoperative SSEP is much less affected by anesthesia than MEP but may take several minutes after an acute insult to be interpreted with low sensitivity to root injury[18,19]; (4) free-running EMG of normal nerve roots is flat in line; irritation by traction or temperature changes may cause neurotonic discharges in spite of the absence of neural injuries (false-positive results and low specificity); (5) both MEP and EMG are affected by muscle relaxants, but EMG carries the advantage of continuous monitoring during surgery; and (6) wet operative field may lead to high false-positive triggered EMG results due to multiple electrical passes.[20,21] Our results were matched with the importance of multimodal IONPM, as MEP showed a specificity of 100%, while EMG and BCR showed a sensitivity of 100%. Intraoperative interpretations of IONPM should take into consideration the values and fallacies of each type for better management of patients.

Intraoperative ultrasound can be used during surgeries of pediatric spinal dysraphisms in some situations of complex conditions for tissue differentiation by real-time imaging, and its use in this study was of value to differentiate complex components of the dysraphisms and locate the neural tissues and the filum terminale beside neurophysiological testing and monitoring. The difference between ultrasound and neurophysiological monitoring can be summarized as follows: (1) neurophysiological monitoring provides continuous support with alarming signs that modulate the surgical situation for patient safety and has the ability of probe testing to differentiate neural tissues from other tissues by stimulation and recording and (2) intraoperative ultrasound can be used as real-time imaging to evaluate the hidden or invisible structures either before skin incision or during the surgical process. The location of the nerve roots inside the cystic component, the depth of neural structures, and localization of the filum terminale are the main values of intraoperative ultrasound (►**Fig. 1**).

Alvarado et al[22] documented spinal ultrasound application in spinal dysraphisms and the ability to localize the level of the conus, filum terminale, central echo complex, nerve roots, cystic components, and masses. Ultrasound was found to be comparable to MRI and can be used in preoperative evaluation of spinal dysraphism, during surgery, and during follow-up with those patients.[23] Strong sedation or general anesthesia was needed during MRI examinations in most patients. Aside from the difficult supine position with back masses and potential absence of special sequence techniques, the limitations of preoperative MRI to provide conclusive results in complex malformations highlight the need for intraoperative ultrasound. Mehta[24] stated that the proper protocol for MRI examination is mandatory detecting abnormalities.

Surgical management of spinal diastematomyelia involves not only resection of the bridge that crosses the spinal canal from posterior to anterior but also releasing any adhesions or filaments around the ridge, anchoring the dura to the vertebral bodies anteriorly to achieve smooth and free rooming. The patients presented with motor weakness due to diastematomyelia showed rapid improvement after surgeries, as all patients presented with left lower limb weakness before surgery, with improvements within a few weeks after surgeries despite differing ages, which ranged from 2 months to 5 years.

During the treatment of spinal lipoma, radical resection at the neural tissue interface is recommended to allow future mobility of the neural tissue with the growth of the patient. Untethering may be done for multiple lesions in the same patient to achieve free neural elements, such as resection of the spinal lipoma and filum terminale, in one sitting of surgery.

Redundant skin can be sewed by a simple, safe technique with the benefit of mechanical hemostasis, as shown in ►**Fig. 3**, by using two long, straight artery forceps fixed

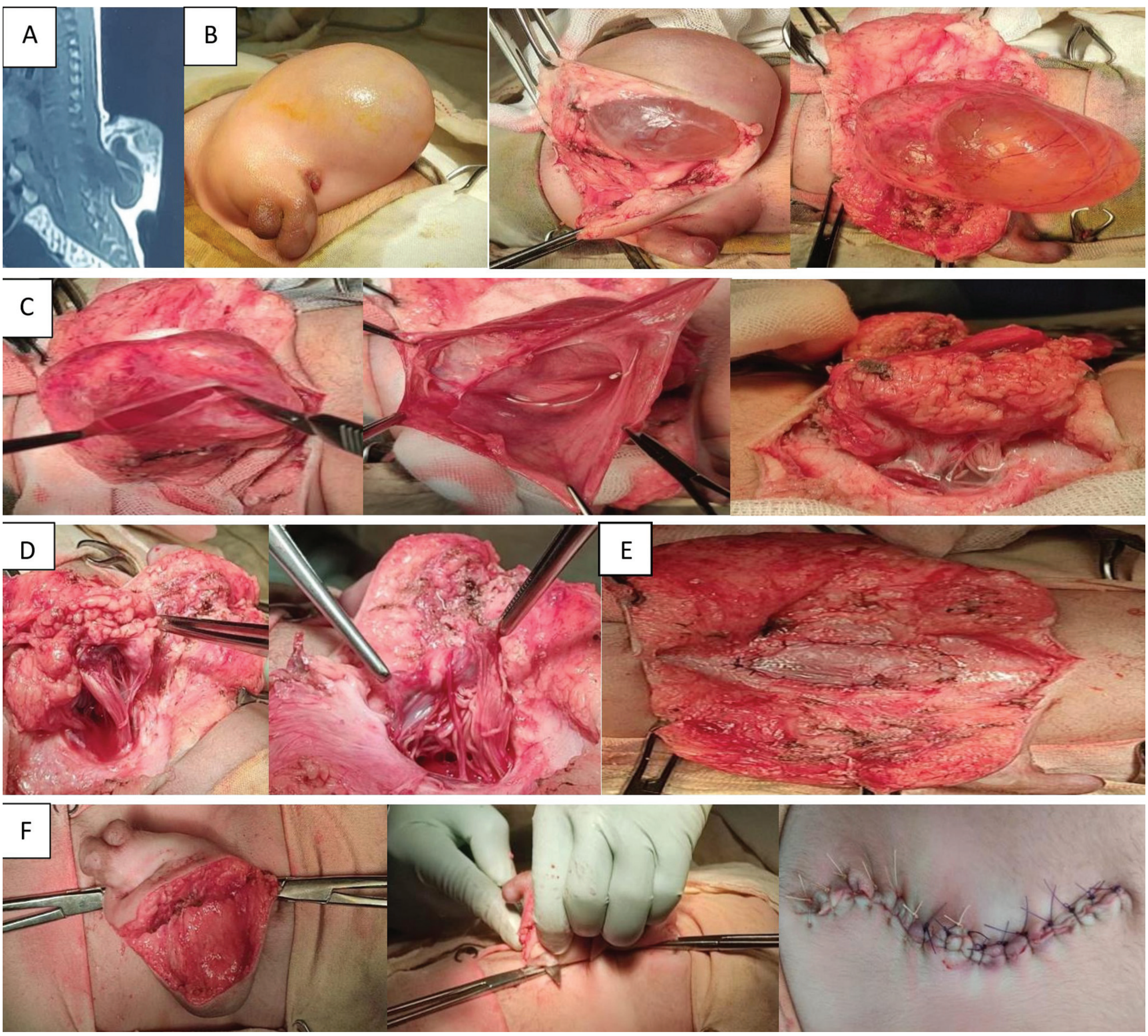

Fig. 3 Lipomyelomeningocele with male genitalia. (**A**) Inconclusive magnetic resonance imaging. (**B**) Photographs of skin dissection. (**C**) Photographs of exploration of the contents by starting with the cystic part to expose the neural elements. (**D**) Photographs of dissection of the lipoma from the neural tissues at the placode. (**E**) Photograph of repair of the spinal canal. (**F**) Photographs of skin shaving technique, and skin closure

 © 2025. The Author(s).

against each other, grasping the redundant skin in flushing with normal skin, and then cutting the redundant skin with a surgical knife flushing with the upward surfaces of the forceps.

No previous studies collected different surgical tools and techniques that were important in saving neural integrity during pediatric tethered cord surgeries regarding IONPM and intraoperative ultrasound.

The limitations of this study are the following: (1) lack of a comparative arm including conventional surgical management of pediatric spinal dysraphisms without IONPM and intraoperative ultrasound, (2) short-term follow up of the patients, and (3) small number of patients.

Conclusion

Neurophysiological monitoring during spinal dysraphism surgeries is valuable as it can detect intraoperative neurological conditions and give the surgeon a real-time situation to manage the patients safely. Team cooperation between the neurosurgeon, anesthetist, and neurophysiologist during surgery is essential to achieve optimal results. Intraoperative ultrasound may be an adjunct surgical tool in certain situations during such surgeries.

Conflict of Interest
None declared.

Acknowledgment
The authors thank all neurosurgery department staff for their support.

References

1 Schoenmakers MA, Gooskens RH, Gulmans VA, et al. Long-term outcome of neurosurgical untethering on neurosegmental motor and ambulation levels. Dev Med Child Neurol 2003;45(08):551–555
2 McLone DG, La Marca F. The tethered spinal cord: diagnosis, significance, and management. Semin Pediatr Neurol 1997;4(03):192–208
3 Al-Holou WN, Muraszko KM, Garton HJ, Buchman SR, Maher CO. The outcome of tethered cord release in secondary and multiple repeat tethered cord syndrome. J Neurosurg Pediatr 2009;4(01):28–36
4 Elmesallamy W, AbdAlwanis A, Mohamed S. Tethered cord syndrome: surgical outcome of 43 cases and review of literatures. Egypt J Neurosurg. 2019;34:4
5 Hoving EW, Haitsma E, Oude Ophuis CM, Journée HL. The value of intraoperative neurophysiological monitoring in tethered cord surgery. Childs Nerv Syst 2011;27(09):1445–1452
6 Kim K. Intraoperative neurophysiology monitoring for spinal dysraphism. J Korean Neurosurg Soc 2021;64(02):143–150
7 Nair BR, Ramamani M, Singh G, Babu KS, Rajshekhar V. Feasibility and diagnostic accuracy of intra-operative monitoring of motor evoked potentials in children <2 years of age undergoing tethered cord surgery: results in 100 children. Childs Nerv Syst 2021;37(07):2289–2298
8 Medical Research Council. Aids to the Investigation of the Peripheral Nervous System. London: Her Majesty's Stationary OfficeMedical Research Council; 1943
9 Korean Society of Intraoperative Neurophysiological Monitoring Korean Neurological Association Korean Academy of Rehabilitation Medicine Korean Society of Clinical Neurophysiology Korean Association of EMG Electrodiagnostic Medicine. Clinical practice guidelines for intraoperative neurophysiological monitoring: 2020 update. Ann Clin Neurophys 2021;23(01):35–45
10 Baig Mirza A, Vastani A, Syrris C, et al. Intraoperative neurophysiological monitoring for intradural extramedullary spinal tumours. Global Spine J 2021;21:21925682221139822
11 Rajappa D, Khan MM, Masapu D, et al. Multimodal intraoperative neurophysiological monitoring in spine surgeries: the experience at a spine centre through years. Asian Spine J 2021;15(06):728–738
12 Niljianskul N, Prasertchai P. The effect of intraoperative neurophysiological monitoring on neurological outcomes after spinal tumors operations: a single institution experience. Interdiscip Neurosurg Adv Techn Case Manag 2023;3:101703
13 Drolet BA, Chamlin SL, Garzon MC, et al. Prospective study of spinal anomalies in children with infantile hemangiomas of the lumbosacral skin. J Pediatr 2010;157(05):789–794
14 Choi I, Hyun SJ, Kang JK, Rhim SC. Combined muscle motor and somatosensory evoked potentials for intramedullary spinal cord tumour surgery. Yonsei Med J 2014;55(04):1063–1071
15 Harel R, Schleifer D, Appel S, Attia M, Cohen ZR, Knoller N. Spinal intradural extramedullary tumors: the value of intraoperative neurophysiologic monitoring on surgical outcome. Neurosurg Rev 2017;40(04):613–619
16 Hadley MN, Shank CD, Rozzelle CJ, Walters BC. Guidelines for the use of electrophysiological monitoring for surgery of the human spinal column and spinal cord. Neurosurgery 2017;81(05):713–732
17 Weinzierl MR, Reinacher P, Gilsbach JM, Rohde V. Combined motor and somatosensory evoked potentials for intraoperative monitoring: intra- and postoperative data in a series of 69 operations. Neurosurg Rev 2007;30(02):109–116, discussion 116
18 Ali Z, Bithal PK. Intra-operative neurophysiological monitoring. J Neuroanaesth Crit Care. 2015;2:179–192
19 Hilibrand AS, Schwartz DM, Sethuraman V, Vaccaro AR, Albert TJ. Comparison of transcranial electric motor and somatosensory evoked potential monitoring during cervical spine surgery. J Bone Joint Surg Am 2004;86(06):1248–1253
20 Bose B, Sestokas AK, Schwartz DM. Neurophysiological detection of iatrogenic C-5 nerve deficit during anterior cervical spinal surgery. J Neurosurg Spine 2007;6(05):381–385
21 Lall RR, Lall RR, Hauptman JS, et al. Intraoperative neurophysiological monitoring in spine surgery: indications, efficacy, and role of the preoperative checklist. Neurosurg Focus 2012;33(05):E10
22 Alvarado E, Leach J, Caré M, Mangano F, OHara S. Pediatric spinal ultrasound: neonatal and intraoperative applications. Semin Ultrasound CT MR 2017;38(02):126–142
23 Elmesallamy WAEA. Perioperative ultrasound imaging versus magnetic resonance imaging in management of lumbosacral spinal dysraphisms. Egypt J Neurosurg 2019;34:39
24 Mehta DV. Magnetic resonance imaging in paediatric spinal dysraphism with comparative usefulness of various magnetic resonance sequences. J Clin Diagn Res 2017;11(08):TC17–TC22

 © 2025. The Author(s).