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ORIGINAL PAPER

Use of Multimodality Intraoperative Neuromonitoring in Tethered Cord Syndrome – Experience from a Tertiary Care Center

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ABSTRACT

Detethering of the spinal cord is done in nearly all cases of tethered cord syndrome (TCS), which can damage nerve roots, and hence, there is a need to identify filum terminale during surgery. Multimodality intraoperative neuromonitoring (IONM) may be useful in this regard to prevent postoperative morbidity. Twenty-six patients (13 males and 13 females, age range: one year to 56 years) with TCS were recruited for the study. Triggered electromyography (t-EMG), transcranial motor evoked potential (TcMEP) and free-running electromyography (f-EMG) were used in the study on a case-to-case basis. Warning criteria were followed according to the standard guidelines. Nerve roots and filum terminale were successfully identified and detethered in all cases. There was no new postoperative deficit seen. Transcranial motor evoked potentials did not change during surgery and no new limb weakness was seen in any of the investigated cases. Triggered EMG successfully helps in identifying nerve roots and filum terminale, while TcMEP is a good prognostic indicator of motor viability. Multimodality IONM use during tethered cord surgery should be encouraged to prevent postoperative deficits.

Keywords: filum terminale, intraoperative neurophysiological monitoring, tethered cord syndrome, transcranial motor evoked potential.

INTRODUCTION

Tethered cord syndrome (TCS) results from pressure on the spinal cord which can be due to lower-than-normal conus medullaris, fatty infiltration of the filum terminale, lipomyelomeningocele (LMC), myelomeningocele, myelocystocele, meningocele, split cord abnormalities, intraspinal tumours, the dermal sinus and anorectal anomalies. These abnormalities can be presented either alone or in combination and require detethering of the spinal cord to relieve the pressure (1).

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Detethering is the procedure in which the spinal cord is relieved from surrounding attachments but contains the risk of injury to nerve roots, which may lead to the development of a new neurological deficit. Intraoperative neurophysiological monitoring (IONM) is required during these surgeries to reduce the risk of neurological deficit and also to differentiate filum terminale from other nearby neuronal structures (2).

Intraoperative neurophysiological monitoring has a role in neurosurgeries, orthopaedic surgeries and ENT surgeries where any neural structure is at risk. It includes various techniques that can be useful for monitoring neural structures throughout surgery or they can help in the identification of nerves, nerve roots or eloquent areas in the brain, which is known as mapping (3).

The use of intraoperative modalities like transcranial motor evoked potentials (TcMEPs), triggered electromyography (t-EMG) and free-running electromyography (f-EMG) can minimize the risk associated with surgery (4). In TcMEP, transcranial electrical stimulation is applied over the motor cortex and evoked potentials are recorded from muscles, which help to detect the patency of the motor tract throughout the surgery.

Identification of filum terminale is one of the crucial steps during detethering. If we stimulate filum terminale and do not get any response from the muscles, it denotes that it is filum terminale and free from nerve roots. This process is called t-EMG, which is useful for the identification of filum terminale (5).

Free-running EMG is recording of electrical activity from muscle without any stimulation. Mechanical trauma during surgical manipulation can irritate nerve roots, which can produce long-lasting nerve damage which can be detected by f-EMG (6).

We aim to highlight our experience of TcMEP, t-EMG, and f-EMG modalities during detethering surgery and the results are expressed hereof. ❑

MATERIAL AND METHODS

The study was conducted by the Departments of Physiology and Department of Neurosurgery, All India Institute of Medical Sciences, Jodhpur. All patients who underwent surgery for TCS between 2018 and 2023 were included in the present study.

Intraoperative neurophysiological monitoring (IONM)

We used TcMEP, t-EMG, and f-EMG during the procedures using the Medtronic NIM-ECLIPSE E4 SD™ system.

Transcranial motor evoked potentials (TcMEPs)

Stimulation was given by corkscrew electrodes placed over C1 and C2 (according to the international 10-20 electrode placement system) on the scalp and recorded using sterilized subdermal needle electrodes, which were placed in muscles supplied by the nerve roots that were supposed to be exposed at the site of surgery.

Train of electrical pulses with a pulse duration of 75 μs and a train count of 5 with the rate being 333 p/s, stimulus intensity below 700 V a low-frequency filter of 30 Hz, and a high-frequency filter of 1500 Hz and sweep length of 100 ms was used for recording.

The disappearance of signals or reduction in amplitude >50% was considered as the warning criteria (7). On all occasions, the repeatability of the TcMEP response was ensured by restimulating and recording the TcMEP two or more times. Only when two or more consistent records were obtained, the surgeon was immediately informed regarding the change, if any, in neurophysiological parameters.

TABLE 1. Recording muscles according to the nerve roots

Muscle	Nerve root
Quadriceps femoris	L2, L3, L4
Tibialis anterior	L4, L5
Abductor hallucis	S1, S2
Abductor pollicis brevis (for reference)	C8, T1
Sphincter	S2, S3, S4

Triggered EMG

Stimulation was given by a handheld bipolar probe stimulator at the site of interest and the response was recorded from the muscle using a pair of sterilized subdermal needle electrodes placed in the muscles of interest. Repetitive impulses at the rate of 3 Hz with stimulus strength ranging from 0.1 to 1 mA for nerve roots and between 1-10 mA for filum terminale was used. A low-frequency filter of 30 Hz and a high-frequency filter of 1500 Hz were applied with a sweep length of 100 ms.

For the identification of filum terminale, it was made clear that no neural elements were involved in it by stimulating it with a triggered EMG bipolar probe. The intensity of stimulation was kept at the higher side (up to 10 mA). The identification was confirmed by the non-generation of EMG signals at such high stimulation (5).

Anaesthesia

All procedures were conducted under general anesthesia using the total intravenous anaesthesia technique (TIVA), with propofol and fentanyl being used as anesthetic agents. Muscle relaxant was not administered during the procedure, except at the time of induction (8). ❑

RESULTS

Twenty-six patients (13 males and 13 females) operated on for detethering between 2018 and 2022 were included in the present study. Patients' age ranged between one year and 56 years. Table 2 shows disorders and a respective number of cases where a low-lying tethered cord was the commonest diagnosis.

Transcranial motor evoked potential

Transcranial motor evoked potential was monitored in 20 cases, while in six cases it was not recordable due to preoperative low power in the lower limb. Sphincter motor evoked potentials

TABLE 2. Distribution of cases according to the diagnosis

Sr No	Gender (male/female)	Age (years)	Diagnosis	Discharge after surgery in days
1	M	26	Lumbar meningomyelocele and tethering cord	4 days
2	M	1	TCS occult NTD with SCM	3 days
3	F	1	Diastametomyelia with tethered low-lying cord	3 days
4	M	16	Low-lying tethered cord	3 days
5	M	13	Dorsal lipoma with fatty filum and tethered cord at L3	4 days
6	F	2	Low- lying tethered cord	3 days
7	F	5	SCM type 2 with tethered cord	3 days
8	F	11	Low-lying tethered cord	3 days
9	F	6	Low-lying tethered cord	4 days
10	F	11	Occult spina bifida with LMC	6 days
11	M	10	SCM type 1	3 days
12	F	11	SCM type 2 with tethered cord L4	3 days
13	M	7	Low-lying tethered cord at L4 level	4 days
14	F	4	Low-lying tethered cord at L5 level	3 days
15	F	2	Low-lying tethered cord at L5 level	4 days
16	M	14	Tethered cord at L5 with fatty tissue	3 days
17	F	2	Spina bifida occulta with low-lying tethered cord	4 days
18	M	4	Low-lying tethered cord	3 days
19	F	4	Spina bifida with tethered cord	3 days
20	M	12	SCM type 1 with sacral cord tethering	6 days
21	F	17	SCM, low-lying tethered cord at L4-L5 level	4 days
22	M	56	Thick fatty filum till S1 detethering of filum at L5- S1 level	2 days
23	M	5	Low-lying tethered cord syndrome and lipoma	3 days
24	F	3	L4-S1 tethered cord-post LMC repair	3 days
25	M	2	Low-lying tethered cord at S1 level	3 days
26	M	6	Low-lying tethered cord	4 days

TCS=tethered cord syndrome; SCM=split cord malformation; NTD=neural tube defects; LMC=lypomielomeningocele

(MEPs) were recordable in only 16 out of 26 patients (61.5% of the total) as 10 patients had bladder dysfunction preoperatively. During the intraoperative period, TcMEP amplitude was decreased in four patients but not more than 50% to raise an alarm, which came back to baseline value before closure.

Also, no new limb weakness (loss of power) or sphincter weakness (bowel incontinence) was seen after surgery.

Triggered EMG

Initially, nerve roots were stimulated to check the normal functioning of the setup (Figure 1), followed by filum terminale stimulation (Figure 2) with the help of a bipolar handheld stimulator with current intensity increasing from 0.1 mA to 10 mA (5). Using t-EMG, we were able to successfully identify nerve roots and filum terminale in all 26 cases (100%).

Free running EMG

Phasic discharges in f-EMGs were noted when the surgeon tried to separate nerve roots from the filum terminal, but we did not find any neurotonic discharge or A-train activity during detethering, which was suggestive of a good prognosis. ❑

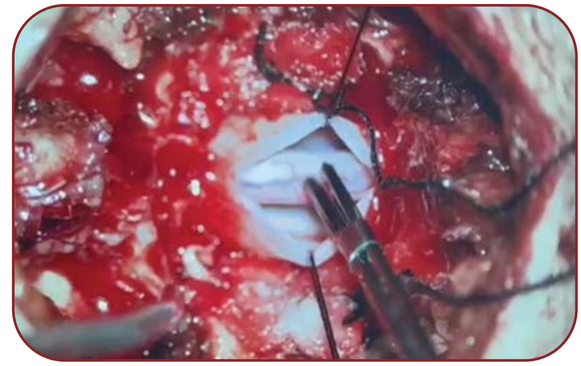

FIGURE 2. Intraoperative image showing filum terminale being stimulated by handheld bipolar stimulator

DISCUSSION

Neurophysiology has played a role in the operating room for a long time. A common procedure in the case of tethered filum terminal is detethering, where IONM can play a vital role. The techniques of t-EMG and transcranial MEPs are widely being used for monitoring and mapping motor tracts and roots, respectively (9).

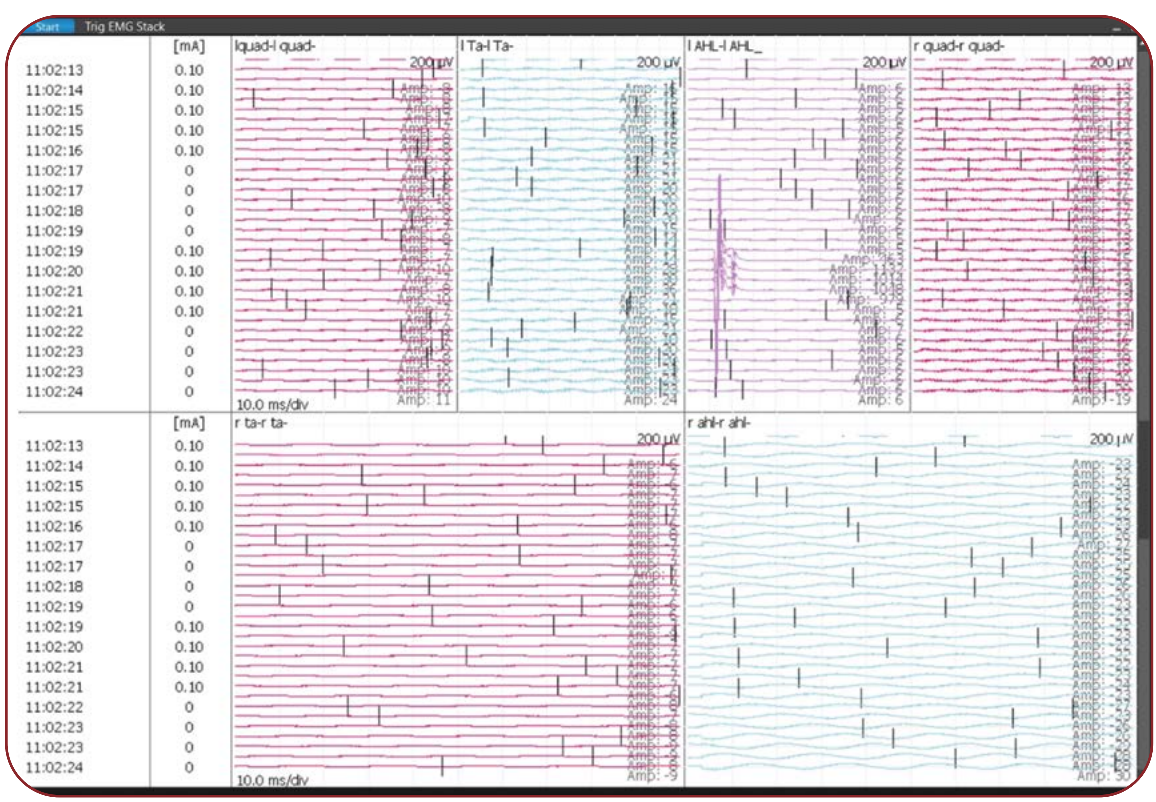

FIGURE 1. Stack view of triggered EMG recordings showing response from the left sided abductor hallusis muscle after stimulating nerve root at 0.1 mA stimulation strength

In our institute, 26 patients being monitored with t-EMG, TcMEP and f-EMG during tethered cord surgery, where we were successfully able to identify nerve roots from fibrous bands which are difficult to distinguish otherwise and were helpful to neurosurgeons to let off nerve roots supplying muscles. In addition, we were able to identify filum terminale, which helped neurosurgeons in separating filum from nerve roots (10).

In our experience, we found no new neurological deficit postoperatively and the TcMEPs remained stable throughout the surgery. Hereby demonstrating unchanged motor function, TcMEP evaluation can be taken as a tool for evaluation in these cases. Our findings were similar to those of Hoving *et al*, who reported only one case of nervous deficit out of a total of 65 (11).

Contradictory to the available results, Lalgudi Srinivasan H *et al* (2) studied the utility of IONM in filum terminale lipomas and compared two cohorts of detethering with IONM and without IONM and found that there was no new neurological deficit in both groups. These results are contrary to the findings of Pratheesh R *et al* (12), who compared postoperative neurological status with intraoperative MEPs and concluded that MEP was improved in 23 subjects out of 45 patients, and postoperative clinical outcome improved in 17 subjects, while in other patients it remained unchanged. In only one subject, TcMEP was worsened, with postoperative clinical outcome. They concluded that improvement in TcMEP occurs in 50% of cases with successful untethering.

Sala F *et al* (13) reported the utility of neuromonitoring in TCS, where they found a postoperative neurological deficit in only one patient out of a total of 47 patients, while all the rest remained stable postoperatively. These results are similar to those provided by our study, where we found no change.

Newer methods are developed to check bulbocavernosus reflex during the detethering procedure. The recording of TcMEP from the external urethral sphincter with the help of state-of-the-art electrodes embedded in the catheter was done by Jahangiri *et al* (14) to monitor the urethral sphincter during spine surgeries. These kinds of newer methods can also be implicated in future monitoring. ❑

CONCLUSIONS

Multimodality IONM in the form of TcMEP, t-EMG and f-EMG is a very useful technique that should be used during all detethering procedures to identify filum terminal during surgery and minimize risk to the nerve roots postoperatively. ❑

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