



Original Article

Double neurophysiological certification of the filum terminale during sectioning surgery in pediatric population

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ABSTRACT

Background: Surgery of thickened-fibrolipoma filum terminale (FT) is performed routinely and without conflict but is not a risk-free surgical procedure. Intraoperative neurophysiological monitoring with mapping techniques can help to certify the FT before sectioning. However, a tailored surgical approach to cauda equina and a low threshold of surrounding nerve roots can confuse the final surgical decision. The aim is to demonstrate the usefulness of this double methodology for FT certification.

Methods: A prospective study collected and reviewed retrospectively, from 2015 to 2018, 40 patients undergoing an FT surgery section were included in the study. After opening the dura mater and under the microscope, the cauda equina mapping is performed and the recording of muscles of the lower limbs and the external anal sphincter. In addition, a high-intensity stimulation of constant current of an isolated FT for a short period of time and in a dry surgical field, obtaining a bilateral-polyradicular-symmetrical response of cauda equina nerve roots.

Results: Traditional motor mapping identified FT in 65% (26/40) of patients. Although, 35% (14/40) of the patients still have low-intensity stimuli response (<1 mA) of a muscle, especially anal sphincter. When this happens, the optimization of the dissection around FT is performed. After that, 25% (10/40) of the patients still having a muscle response in spite of seem isolated FT. Increasing the stimulation intensity up to 20 mA evoked a cauda equina response in all cases. No postoperative neurological impairment was observed in this series.

Conclusion: This proposed methodology accurately confirms the FT so that it can be safely found and cut. The Double Neurophysiological Certification improves the gap of the traditional mapping techniques of cauda equina and can be used in a variety of more complex surgeries in this area.

Keywords: Cauda equina, Conus medullaris, Filum terminale, Intraoperative neurophysiological monitoring, Sectioning surgery

INTRODUCTION

The conus medullaris is connected to the dural sac through intradural filum terminale (FT), a not-well defined fibrous ligament which has received relatively limited and not recent attention in the literature regarding its anatomical and histological characteristics.^[4] Tethered cord syndrome (TCS) is a congenital condition in which the ends of the spinal cord and cauda equina are attached at different levels to the surrounding structures.

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Thickened FT or FT fibrolipoma require surgical section for prevention or treatment of neurological, musculoskeletal, and urological abnormalities,^[8] which are often reversed or enhanced by FT transection. FT sectioning surgery is gaining popularity due to its relative simplicity, avoiding a continuous conus medullaris trauma resulting in the development of new symptoms and/or new neurological deficit.

In spite of FT can be anatomically recognized, mapping techniques, that is, stimulating motor nerve roots to identify and locate the FT before cutting, are recommended.^[2] At present, this is one of the simplest surgeries for tethered cord which can be performed more quickly and in a perfectly tailored surgical field.^[1] However, in some cases, there is a positive mapping response with low intensity stimulation of the FT,^[6] affected by an individual threshold variability of motor rootlets in pediatric population. The aim of this study is to demonstrate the usefulness of a double methodology for FT certification.

MATERIALS AND METHODS

The prospective study collected and reviewed retrospectively, from 2015 to 2018, 40 patients undergoing a sectioning surgery for FT. We considered patients with magnetic resonance imaging (MRI) showing fibrolipoma FT or thickened FT aged from 6 months to 18 years old. The main indications of surgery were patients with urodynamic abnormalities ruling out other causes, neurogenic bowel/bladder, before scoliosis correction and FT abnormality, FT pathology with syringomyelia, progressive lower extremities orthopedic deformities, conus medullaris low inserted, and clinical symptoms of TCS. We excluded patients with other causes of TCS and patients who had previously undergone lumbosacral spine surgery to prevent the need for isolation of scar tissue in neural structures.

Anesthesia was performed with total intravenous anesthesia, avoiding neuromuscular blockade. Gauze bite blocks were intraorally used in all cases.

Intraoperative neurophysiological monitoring

We used the NIM Eclipse Medtronic IOM system, with disposable subdermal double needle electrodes, which are 12mm in length and 0.4mm in diameter (27 gauge).

The needle electrodes are placed in groups of muscles innervated by the nerve roots which had the greatest risk of injury during release. These muscles included the bilateral quadriceps femoris, tibialis anterior, gastrocnemius medial, abductor hallucis, and anal sphincter.

Recording parameters for free-run and triggered EMG are set with filters between 20 and 3.000 Hz, gain 100 μ V/Div, and time base 5 m/div.

Traditional mapping technique

Single-pulse stimulation is performed with repetitive constant current, 200 μ S pulse duration at 1–2 Hz, using a monopolar flush-tip/ball tip probe, or bipolar probe when is available preferably. Mapping technique comprises stimulating the motor nerve roots of cauda equina and getting a unilateral, asymmetrical, and single radicular response from muscles studied according to its dominance and participation. When the FT is stimulated, non-response is expected. Mapping of each motor or sensory nerve roots was not performed.

High intensity stimulation

This proposed methodology consists in stimulation of an isolated FT using high intensity current as much as 20 mA, obtaining a bilateral, symmetrical, and polyradicular response from all cauda equina nerve roots studied. This technique complements the traditional technique when stimulation of the FT with low intensity evokes a response from any muscle, despite proper separation and dissection of the surrounding neural elements. When the FT is stimulated, an all-response is expected. Latencies of the responses were not assessed and not compared.

Surgical technique

Minimally invasive posterior approach to L5-S1 level is performed and under microscopical view, the dura mater opened, the nerve roots are recognized, and any of them is stimulated for obtaining motor threshold. The FT is identified anatomically followed by arachnoidal dissection, isolated by vascular a band, maintaining a dry surgical field, and placing cottonoids over surrounding nerve roots. If the mapping technique does not evoke any muscle response using ≥ 3 mA, the FT is coagulated and cut. Alternatively, if any muscle response is obtained, the region surrounding the FT is explored certifying absence of neural elements; if the response persists, the current intensity is increased until 20 mA. When this stimulation evokes response from all muscles studied, the FT is coagulated and cut. During this study, we performed double neurophysiological certification in all cases, despite no response with traditional technique.

RESULTS

In all cases (40/40), patients were studied with MRI showing kind of FT and if conus medullaris is normally located [Figure 1a and b]. The surgery was performed using a tailored approach in all. The FT was identified, dissected of surrounding nerve roots, separated by vascular bands, stimulated, and finally cut [Figure 2a-e].

Traditional motor mapping technique could identify FT in 65% (26/40) of patients, using intensity >3 mA without

eliciting a response, increasing stimulation intensity up to 5 mA to ensure absence of nerve roots before sectioning, while threshold of motor nerve roots was elicited with <1 mA.

Despite low-intensity stimulation (<1 mA), muscle response was still present in 35% (14/40) of cases and was almost always an anal sphincter response, either unilateral or bilateral. When this happens, optimization of the dissection surrounding the FT is performed. In this scenario, 25% (10/40) of patients still have a muscle response despite an isolated FT.

After improved the dissection and isolation, an increment of the stimulation intensity up to 20 mA evoked response of the cauda equina in all cases (40/40), obtaining a bilateral-polyradicular-symmetrical response in all muscles included in the recording. This double certification allowed safely cut FT in all patients [Figure 3a and b].

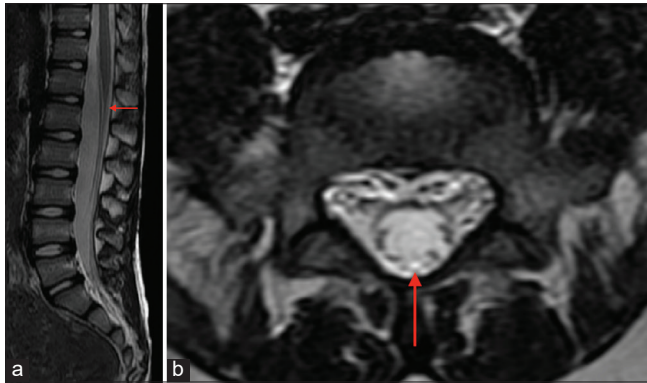


Figure 1: Magnetic resonance imaging of the thoracolumbar spine. (a) Sagittal view T2-weighted showing conus medullaris normally located. (b) Axial view T2-weighted at level of L5, note central hyperintensity compatible with fibrolipoma filum terminale (see arrows) (T1-weighted not shown).

Stimulating a non-isolated nerve root at 1 mA threshold was obtained and at 20 mA evokes a mainly unilateral-polyradicular-asymmetrical response [Figure 4a and b].

Notably, all patients of this case series did not develop a new neurological worsening.

DISCUSSION

As an integral methodology of intraoperative neurophysiological monitoring, motor root mapping techniques can accurately differentiate neurological tissues from other non-neurological surrounding structures.^[3] The FT is stimulated before release to ascertain if nerve roots are present around it, and comparing the threshold as a prognosis factor.^[2] The conus medullaris and cauda equina easily evoke a response with an appropriate stimulation technique, unlike FT. The FT sectioning surgery is currently rapidly evolving in a tailored surgical field.^[1] This may result in inappropriate stimulation as a result of current propagation, which could cause confusion in taking the final surgical decision despite a clear anatomical appearance of the FT.

FT is a midline non-neurological structure. However, in accordance with their common embryological origin, a true anatomical and histological continuum was found between the conus medullaris and FT.^[4] Considering this, another supportive fundamental element is a stimulation-induced response that is bilateral, symmetrical, and polyradicular, with the current ability to depolarize FT and in a antidromic way nerve roots arising from the conus medullaris [Figure 5]. We strongly believe that this is not spreading when FT is completely isolated and in a dry surgical field, and when a FT is stimulated outside the dura mater and is dissected from the arachnoid and other nerve roots. After nerve root stimulation,

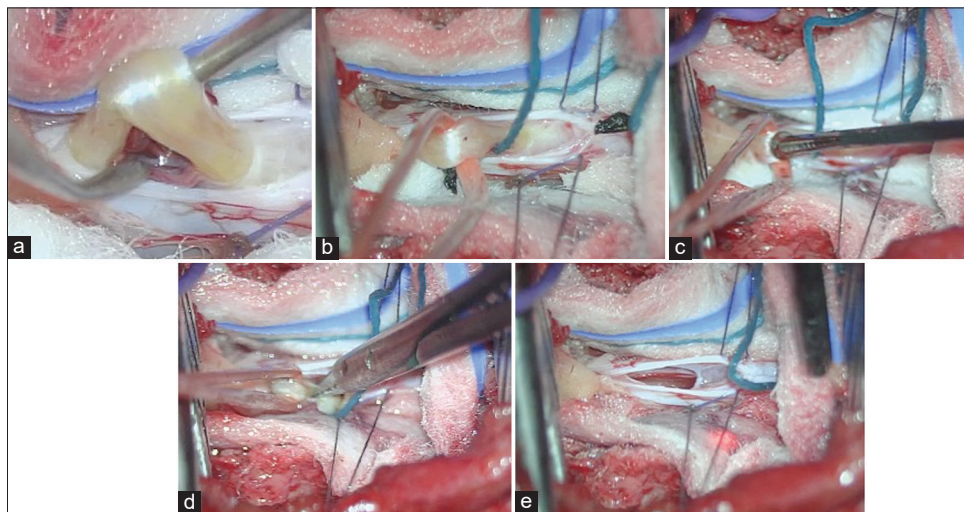


Figure 2: Surgical steps during filum terminale (FT) sectioning. (a) FT is exposed and separated of the surrounding nerve roots. (b) FT is carried outside the dura mater by a vascular band. (c) Isolated FT is stimulated after arachnoid dissection in a dry surgical field. (d) FT is cut with safety. (e) Dura mater is already to close with the pathology of FT resolved.

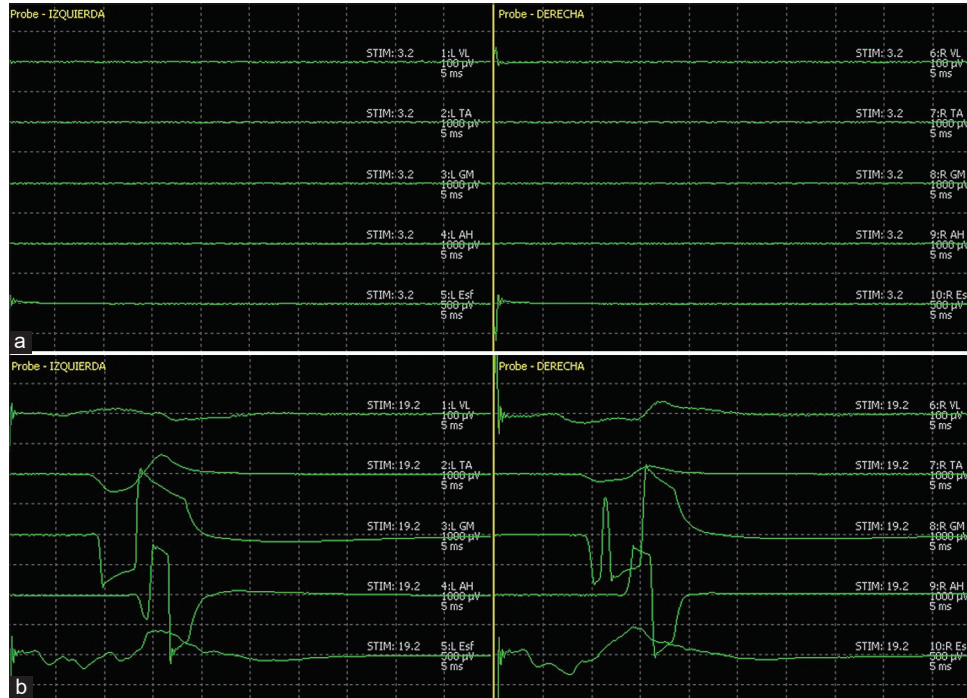


Figure 3: Double neurophysiological certification of filum terminale (FT). (a) Traditional mapping technique, stimulation of FT at 3.2 mA without motor nerve roots response, confirming FT. (b) High-intensity stimulation of the same FT. Note the bilateral, polyradicular, and symmetrical response in all muscles studied, confirming FT. Quadriceps femoris (vastus lateralis), tibialis anterior, gastrocnemius medial, abductor hallucis, anal sphincter.

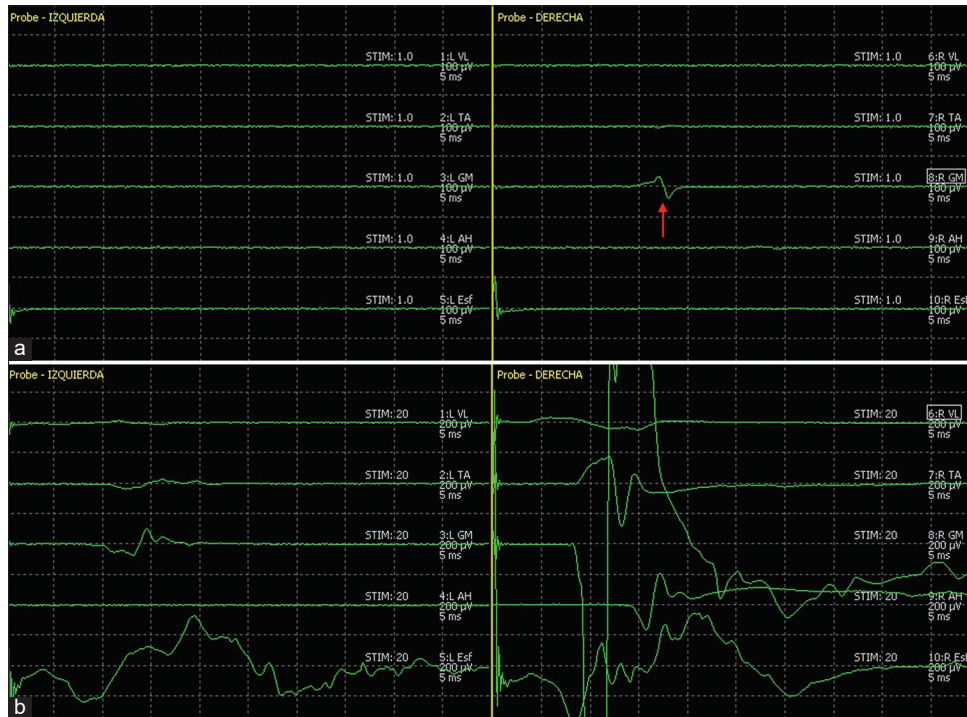


Figure 4: Stimulation of intradural, wet and non-isolated right sided nerve root. (a) Close to the threshold <1 mA, obtaining a single muscle response from the same side (arrow). (b) High-intensity stimulation at 20 mA of the same nerve root. Note the response preferably unilateral, polyradicular for current spreading, and highly asymmetrical. Quadriceps femoris (vastus lateralis), tibialis anterior, gastrocnemius medial, abductor hallucis, and anal sphincter.

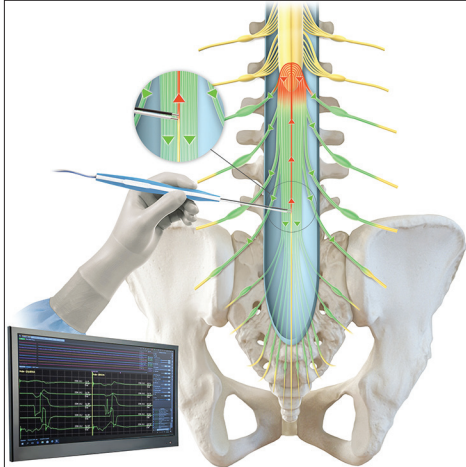


Figure 5: Representation of the proposed mechanism of response. Note the stimulation of the filum terminale (FT) obtaining a depolarization of all cauda equina nerve roots (green lines) through antidromic FT conduction and conus medullaris activation (red lines).

we expect a unilateral, asymmetrical, and monoradicular response with low current intensity, independent of high variability, and considerable radicular overlapping.^[7]

Some authors have reported that a 1:100 ratio between the motor root and the filum threshold for FT identification predicts that, if all nerve roots are sufficiently separated from FT in the adult^[5] and pediatric patients,^[9] using voltage stimulation, expecting no response elicited or activation of a motor nerve root secondary to contiguity. We used constant current and a ratio 1:20 to limit current spreading. The first neurophysiological certification of FT is no response, in which normal intensity above the threshold of the motor nerve roots is used. The second certification involves responses from all the motor nerve roots of the cauda equina. This double neurophysiological certification of FT is not time-consuming, highly reproducible, morbidity-free, cost-effective, and extremely accurate for FT identification.

CONCLUSION

From a practical point of view, this methodology is proposed to accurately confirm FT, locate it, and safely cut it. There is no doubt that future research is needed to rule out current spreading and understand the exact mechanism of the response. The Double Neurophysiological Certification improves the gap of the traditional motor mapping technique of the cauda equina in a tailored surgical approach and can be used in various more complex surgeries in this area.

Declaration of patient consent

Patient's consent not obtained as patients identity is not disclosed or compromised.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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