Intraoperative Electrophysiological Monitoring During Selective Dorsal Rhizotomy in Children with Spastic Cerebral Palsy

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ABSTRACT

Background: Selective dorsal rhizotomy (SDR) is an established strategy for treating spastic cerebral palsy. The applied techniques and criteria of intraoperative electrophysiological monitoring (EPM) for selected transected rootlets vary between different centers; therefore its validity has been questioned. Objective: The aim of this study is to evaluate the applied techniques of EPM used during SDR for treating spasticity in Egyptian children with cerebral palsy. Methods: Twenty-two children (14 boys and 8 girls) underwent EPM guided SDR. Percentage of abnormal (grades 3+ and 4+) and transected rootlets and presence of anal sphincter related fibers in S₁ were estimated. Postoperative clinical outcome after 6 months was assessed for 8 cases including assessment of power of quadriceps; range of movement (ROM) of hip abduction; and tone grading of adductor muscles. Results: Using EPM, 52.8% of stimulated rootlets in each dorsal root was graded as 3+ or 4+ was transected. In 6 children (27%), the first sacral (S₁) dorsal root produced anal sphincter contraction. At 6 months postoperative, significant increase of ROM of hip abduction; insignificant decrease of spasticity of adductor muscles; and insignificant improvement of motor power of quadriceps are detected. No postoperative complications were detected. Conclusion: The present study demonstrates that the applied EPM procedures during SDR provide an objective way for selecting transected rootlets and avoiding postoperative complications. [Egypt J Neurol Psychiat Neurosurg. 2010; 47(3): 505-510]

Key Words: electrophysiology, spasticity, rhizotomy, cerebral palsy.

INTRODUCTION

In the developing world, the prevalence of cerebral palsy (CP) is not well established but estimates are 1.5-5.6 cases per 1000 live births.¹ Selective dorsal rhizotomy (SDR) is a widely practiced form of surgical treatment for children with spasticity of cerebral origin, predominately due to cerebral palsy.² In SDR, partial sectioning of the dorsal roots from L₂ to S₁ or S₂ is usually performed.³-⁶ Clinically significant improvements in functional outcome have been reported by several groups.⁴-⁶

Percentage of sectioned rootlets is guided by clinical findings and interoperative electrophysiological monitoring (EPM).¹⁰,¹⁷,¹⁸ Intraoperative monitoring uses continuous recording of electromyography (EMG) in lower limb muscles and anal sphincter, and its response to simulation of selected rootlets.¹⁶,¹⁸,¹⁹ Intraoperative electrophysiological (EP) stimulation can be valuable in achieving a balance between elimination of spasticity and preservation of underlying strength.¹⁶,¹⁸,²⁰ EMG monitoring helps also to avoid complications, especially sphincter paralysis and sensory loss in extremities.²¹ There are significant variations among centers in many aspects of the EP guidance and applied criteria for dorsal rhizotomies.¹⁶,¹⁸-²⁰

The aim of this study is to evaluate the applied techniques of EPM used during SDR for treating spasticity in Egyptian children with cerebral palsy.

SUBJECTS AND METHODS

Twenty two children (fourteen boys and eight girls) with spastic cerebral palsy underwent selective dorsal rhizotomies (SDR), using intraoperative EMG recording, between May 2006 and September 2009. All patients presented to Neurology or Neurosurgery outpatient clinics at Ain Shams university hospitals with intractable spasticity (showing progressively decreasing or even no response to medical and/or physical therapy).

The patients' ages at surgery ranged from 4 to 15 years, with a median age of 8.3 years. Informed consents were taken from patients' parents for surgery and research. The inclusion criteria were lower extremity spasticity which interfered with passive movement, positioning and care, and was
intractable to other treatment modalities. Children with severe fixed contractures at multiple lower limb joints, dyskinesia, trunk hypotonia and radiological (Magnetic resonance imaging (MRI)) abnormality of the basal ganglia were excluded.

Children underwent full preoperative clinical assessment including history taking (especially perinatal, developmental history and bowel control), general and neurological examination, and assessment of power of quadriceps (using Medical Research Council Scale (MRCS))\(^2\), cervical-junction tension.\(^2\), range of movement (ROM) of hip abduction (using manual goniometer\(^2\)); and tone grading of adductor muscles\(^2\). Routine laboratory investigations and MRI brain studies were conducted for all children. In 8 cases, postoperative clinical assessment after 6 months was performed and clinical outcome was estimated.

**Operative Technique**

Surgery was performed under endotracheal anesthesia without the use of long-acting muscle relaxants. Levels of anesthetic agent were adjusted as needed to obtain good reflex recording. The patient was positioned prone and the cauda equina was exposed through a L1-S2 laminotomy/ laminectomy, and the sacral roots were identified. The dorsal roots were then separated from the ventral ones. Rootlets associated with abnormal responses to electrical stimulation were divided. A very conservative approach to the S2 level was taken. After identifying the S1 and S2 levels and confirming the presence of anal sphincter response, lumbar roots were mapped. During stimulation, the surgeon held the root or rootlet clear of the subcutaneous fat. The hooks were separated by 5-10 mm and each root or rootlet was held without tension.

**Intraoperative EMG Recording**

EMG recording and stimulation of posterior roots and rootlets were performed, in all children, using a Myto-II, 4 channel system, EBNeuro, Florence-Italy (2004). Two insulated (teflon coated) electrodes were used for the stimulation of rootlets. Pairs of needle electrodes were placed in 5 muscle groups of each lower extremity: adductor longus, quadriceps (vastus lateralis), hamstrings, tibialis anterior, and gastrocnemius. Needles were spaced 3-5cm apart depending on the size of the muscle. Two additional electrodes were placed in the external anal sphincter. A ground plate was placed on the calf of one limb. As EMG apparatus is a four-channel system, connected electrodes for different muscles were changed during the stimulation of different roots.

The interpretation of EMG recording and observation of motor responses were made by neurologist. The stimulus intensity varied from 2 to 200mV, stimulation duration of 1 millisecond, and tetanic stimulation of 50Hz frequency and pulse duration of one millisecond was then applied for one second. Anterior roots required low amplitude single stimulus to produce a response, compared with dorsal roots.

At each root level, the whole posterior root was first tested with single stimuli then individual rootlets were separated from each other and tested by turn. Trains of stimuli were applied at gradually increasing voltages, until a motor response was obtained. Currently, clinical observation and palpation of muscles’ contraction during stimulation were performed. Decisions to cut or spare rootlets were made sequentially as testing proceeded.

The motor response of each root and rootlet was recorded and assigned a grade of 0, 1+, 2+, 3+, or 4+ (Table 1, Figure 1), as employed by previous studies.\(^2,5,18,25,26\) The principal criteria for division of rootlets included spread of response (includes response which occurs in muscle groups not innervated by tested level or/and responses recorded in contralateral side at the same tested level) or observed/palpated abnormal limb contractions (i.e. grades as 3+ or 4+). Anal sphincter responses were monitored in all patients.

The number of rootlets tested and divided at each spinal level was recorded and the average percentages were calculated by the surgeon based on visual assessment for all patients. The percentage of S1 roots producing anal sphincter contraction was recorded as well.

**Table 1.** Grading of motor responses\(^2\) during intraoperative electrophysiological monitoring during selective dorsal rhizotomy in children with spastic cerebral palsy.

<table>
<thead>
<tr>
<th>Grade</th>
<th>Motor Response</th>
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<tbody>
<tr>
<td>Grade 0</td>
<td>Unsustained CMAP in any muscle (normal response).</td>
</tr>
<tr>
<td>Grade 1+</td>
<td>Sustained CMAP from muscles innervated by the segmental level of the stimulated dorsal rootlet.</td>
</tr>
<tr>
<td>Grade 2</td>
<td>Same as grade 1+ with CMAP in muscles innervated by adjacent segmental level.</td>
</tr>
<tr>
<td>Grade 3</td>
<td>Same as grade 2+ with CMAP in muscles innervated by multiple ipsilateral segmental levels.</td>
</tr>
<tr>
<td>Grade 4</td>
<td>Same as grade 3+ with motor response in the contralateral leg or upper extremity.</td>
</tr>
</tbody>
</table>

*CMAP* compound muscle action potential.
Figure 1. EMG record shows continuous response of ipsilateral tibialis anterior on stimulating L₄ (below); while absence of contralateral response (above) [grade 1+] during selective dorsal rhizotomy in children with spastic CP.

Statistical Analysis

It was performed by SPSS (Statistical program of social signs) version 8.0 as follows: description of quantitative variables in the form of mean, standard deviation and range, description of qualitative variables in the form of numbers and percentage; and paired t-test used to compare change in mean values after six months of the intervention within groups as regard quantitative variables.

RESULTS

From the twenty two children, there were 12 patients with diplegia (54%), and 10 patients with quadriplegia (46%). In all patients, the underlying etiology was perinatal hypoxia. In thirteen severely disabled children, the goal of surgery was to facilitate comfort and care, and in nine children the aim was to improve ambulation.

Mean number of tested rootlets in each level was 5.5 on right side and 6 on left side; mean number of cut rootlets was 3 on both sides. In all children, 52.8% of stimulated rootlets in each stimulated dorsal root graded as 3+ or 4+ were selected to be sectioned (figure 2). In 6 children (27%), the S₁ dorsal root produced anal sphincter contraction so it was spared.

In one child the grade 3+ or 4+ were met in L₄ and L₅ dorsal roots bilaterally only, while none of the other stimulated roots had met the criteria. Postoperatively, bowel control is preserved in all continent children.

Clinical outcome after 6 months of the 8 cases revealed significant increase of ROM of hip abduction; insignificant decrease of spasticity of adductor muscles, and insignificant improvement of motor power of quadriceps (Table 2 and Figure 3).
Table 2. Mean outcome measurements of selective dorsal rhizotomy in children with spastic cerebral palsy.

<table>
<thead>
<tr>
<th>Outcome parameter</th>
<th>Baseline (preoperative)</th>
<th>6months postoperative</th>
<th>p-value</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spasticity of hip adductors</td>
<td>4.13</td>
<td>1.51</td>
<td>0.2</td>
<td>Insignificant decrease</td>
</tr>
<tr>
<td>Range of motion of hip abductor muscles</td>
<td>68.85</td>
<td>95.85</td>
<td>0.03*</td>
<td>Significant increase</td>
</tr>
<tr>
<td>(degrees)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motor power (MRCS)</td>
<td>2.75</td>
<td>2.87</td>
<td>0.22</td>
<td>Insignificant increase</td>
</tr>
</tbody>
</table>

MRCS medical research council scale
*Significant at p<0.05

Figure 3. Comparison of outcome parameters between preoperative and postoperative assessment at 6 months following selective dorsal rhizotomy in children with spastic cerebral palsy.

DISCUSSION

The concept of SDR is improving spasticity and range of movement, with preservation of muscle strength, by identifying components of dorsal roots involved in spasticity on the basis of intraoperative electrophysiological stimulation. Comparable to other studies, a decrease of spasticity, and increase of ROM, with preservation of power were detected. The impact of EPM on clinical outcome, a matter of debate, could be addressed and needs further comparable research; EP guided SDR versus non EP guided SDR.

Controversy regarding the utility of EPM has centered around the lack of technical standardization, absence of normal controls, the inconsistency of motor responses, the effect of anesthetic drugs on spinal reflexes, time consumption by the procedure, and the variability of segmental innervations of lower-extremity muscles. Variation in EPM techniques during SDR is established in different centers and the need for EPM has been questioned. To overcome different obstacles facing EPM recording; muscle relaxants are not used, depth of anesthesia were minimal during recording, and time consumption is decreased.

The intraoperative EPM during SDR provides valuable information and help to neurosurgeons. It differentiates ventral roots; that need low amplitude to be stimulated; hence decreasing its related motor complications. EPM, beside intraoperative clinical assessment, provide objective way to determine the percentage of selected rootlets. The alternative way is the random transection of dorsal roots from L2-S1 according to clinical severity. The average percentage of different groups ranges from 18% to 68%, with most centers cutting more than 40%. A high percentage (64%) is associated with using other criteria for selecting transected rootlets as tonic contraction of related muscle during stimulation and occurrence of after discharge. Percentage of transected rootlets in this study (52.8%) is within the reported range of the previous studies.

Also, EMG mapping of anal sphincter fibers running in S1 roots enables safe transaction of S1 rootlets producing optimum functional outcome.
without sphincteric dysfunction. Delclos and his colleagues recorded sphincteric EMG response from stimulation of S1 in 8 patients out of 31 patients (25%) underwent SDR. Moreover, Ojemann and his colleagues detected EMG responses on stimulation of dorsal roots of L4 and caudally. Similarly, we spared 27% of S1 roots that produced anal sphincter EMG response on stimulation. This explains the preserved sphincteric control in all patients. The preservation of other sacral roots (S2-4) is essential for protecting bladder and sexual functions. EPM, in SDR and other cauda equina and sacral surgery, identifies and distinguishes roots from fibrous tissue or filum terminalis.

The present study demonstrates that the applied EPM procedures during SDR provide an objective way for selecting transected rootlets and avoiding postoperative complications, similar to the results of other centers. The study also recommends routine use of EPM during SDR, further research on larger numbers of cases and for longer follow-up periods to determine its impact on clinical outcome and usage of more advanced 8 channels EMG devices.

[Disclosure: Authors report no conflict of interest]

REFERENCES