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Recommended Citation
Wu, Han-Lin; Liang, Muh-Lii; Chen, Hsin-Hung; Chou, Chen-Liang; and Yang, Tsui-Fen (2016) "Recording Somatosensory Evoked Potential of the Posterior Tibial Nerve with a Subdural Strip during Surgery for Spinal Dysraphism and Tethered Cord Syndrome," Rehabilitation Practice and Science: Vol. 44: Iss. 2, Article 5.
DOI: 10.6315/2016.44(2)05
Available at: https://rps.researchcommons.org/journal/vol44/iss2/5

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Recording Somatosensory Evoked Potential of the Posterior Tibial Nerve with a Subdural Strip during Surgery for Spinal Dysraphism and Tethered Cord Syndrome

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Objective: To investigate the feasibility of a subdural strip, placed just proximal to the surgical field, to record somatosensory evoked potentials (SSEPs) of the posterior tibial nerve (PTN) during detethering surgery for spinal dysraphism and/or tethered cord syndrome (TCS).

Method: Twenty three patients (thirteen boys and ten girls; age, 4 months to 15 years) were enrolled in this study. Eleven patients had lipomyelomeningoceles, seven had TCS, two had split cord malformations, one with terminal myelocystocele, one with VACTERL syndrome, and one had a spinal tumor at the T11 to L4 level. Aside from the routine preparation needed for functional mapping and monitoring during surgery for spinal dysraphism and TCS, a 1×4 strip was placed rostral to the surgical field where it was secured by a surgeon after opening of the dura. Under total intravenous anesthesia, we stimulated the PTN and simultaneously recorded SSEPs with this strip and subdermal needles at Cz-Fz.

Results: With the exception of one patient, SSEP amplitudes obtained by subdural recordings were much larger than cortical recordings. Moreover, much less averaging was necessary to get a clear subdural SSEP when compared to the averaging needed to obtain a clear cortical SSEP (10 vs. 200 averages, respectively). All recordings were stable throughout the surgical procedures and none of the patients sustained new functional deficits after surgery.

Conclusions: Recording SSEPs of the PTN through a subdural strip proved to be a feasible and valuable tool during detethering surgery in young patients. When compared to recordings obtained by conventional cortical SSEPs, this approach could improve both the safety and efficiency of surgical procedures. (Tw J Phys Med Rehabil 2016; 44(2): 103 - 109)

Key Words: somatosensory evoked potentials, intraoperative monitoring, spinal dysraphism, tethered cord syndrome
INTRODUCTION

Tethered cord syndrome (TCS) is a congenital condition frequently present in young children, in which the caudal end of the spinal cord is anchored to bony or inelastic tissue. Common causes of TCS include myelomeningocele (MMC), lipomyelomeningocele (LMC), terminal lipoma, thickened filum terminale, split cord malformation, etc. If left untreated, TCS frequently progresses into neurological deficits, which include motor paralysis associated with musculoskeletal deformity, sensory loss, and bowel and bladder dysfunction. When conducted early enough, detethering surgery can prevent further neurological deterioration and possibly reverse any preexisting neurological deficits. However, detethering involves the meticulous dissection of lumbosacral nerve roots from surrounding inelastic structures, which imposes risk of further neurological deficits.

For decades, neurophysiologic intraoperative monitoring (NIOM) has been used to guide surgical dissection and safeguard the integrity of neural function. Frequently used modalities include electromyography (EMG), transcranial motor evoked potential (TcMEP), somatosensory evoked potentials (SSEPs), and bulbocavernous reflex (BCR), etc. SSEPs of the posterior tibial nerve (PTN) are routinely used to safeguard the integrity of lower limb sensory function during surgery for spinal dysraphism and TCS. However, it is challenging to record cortical SSEPs in young children, particularly in infants younger than 1 year, owing to incomplete myelination and immaturity of the nervous system, as well as greater sensitivity to the effects of anesthetic agents. Subdural recordings of evoked potential is an alternative option, which possesses certain advantages over cortical recordings under this circumstance. However, based on our knowledge, this application has not been used before during detethering surgery in young children.

Therefore, in the present study, we attempted to investigate the feasibility of SSEP recordings using a strip, which was placed by a surgeon in the subdural space just rostral to the surgical field, to record SSEPs of the PTN. We then compared signals obtained by subdural recordings with those of conventional cortical SSEP recordings.

METHODS

Patients with spinal dysraphism and/or TCS who were eligible for detethering surgery were enrolled. Pre-operative studies included thorough neurologic examinations, imaging studies, and electromyography and urodynamic studies. Paired needle electrodes were left at muscle groups innervated by lumbosacral roots over bilateral lower limbs for TcMEP and EMG recordings after anesthesia. Recording of the BCR and SSEPs of the PTN were also prepared using the standard techniques. Total intravenous anesthesia was applied throughout the surgical course and no muscle relaxant was used except for one dose during induction.

Aside from the above-mentioned preparation for standard functional mapping and monitoring during spinal dysraphism and TCS surgery, a 1×4 strip was placed rostral to the surgical field where it was secured by a surgeon after opening of the dura (Figure 1). Under total intravenous anesthesia, we stimulated the PTN and simultaneously recorded SSEPs with this strip and subdermal needles at Cz-Fz, according to the 10-20 International Electroencephalography System. NIOM was conducted using 32 channels Cascade Elite, Cadwell Industries, Inc. in this study.

RESULTS

Twenty three patients (thirteen boys and ten girls, aged 4 months to 15 years,) were enrolled in the current study (Table 1). Twelve of the patients were younger than 1 year of age and fourteen of the patients were younger than 2 years of age at the time of surgery with median age 7 months. Eleven patients had lipomyelomeningoceles, seven had TCS, two had split cord malformations, one with terminal myelocystocele, one with VACTERL syndrome, and one had a spinal tumor at the T11 to L4 level. Eight of the patients who received primary repair of the LMC or TCS were neurologically intact, while clinical presentations of the remaining patients included
paraparesis of the lower limbs, bowel and bladder dysfunction or foot deformity at the time of surgery.

Latencies and amplitudes of PTN SSEPs are presented in Table 1. Mean amplitude and standard deviation (SD) of cortical and subdural SSEP by stimulating PTN were 2.28±1.69 µV and 28.07±42.06 µV respectively. There was significant difference of amplitude between the recordings of cortical and subdural SSEP, by using non-parametric the Mann-Whitney U test (p=0.001). We also found that, except for one patient (case 4), SSEP amplitudes obtained by subdural recordings were much larger than those obtained by cortical recordings (Figure 2). Furthermore, subdural SSEPs were used solely for monitoring sensory function because we were unable to elicit cortical SSEPs in nine cases. Moreover, much less averaging was needed to obtain clear subdural SSEPs when compared to cortical SSEPs (average of < 10 for subdural vs. 200 for cortical SSEPs). All subdural recordings were stable throughout the surgical procedures and none of the patients sustained new functional deficits after surgery.

### Table 1. Latency and amplitudes of SSEPs of the PTN recorded by either a subdural strip or subdermal needles at Cz-Fz

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age</th>
<th>Latency of SDR (ms)</th>
<th>Amplitude of SDR (µV)</th>
<th>Latency of CR (ms)</th>
<th>Amplitude of CR (µV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5 mo</td>
<td>8.9</td>
<td>14.7</td>
<td>30.6</td>
<td>1.49</td>
</tr>
<tr>
<td>2</td>
<td>6 mo</td>
<td>11</td>
<td>16</td>
<td>37.9</td>
<td>4.98</td>
</tr>
<tr>
<td>3</td>
<td>2 y</td>
<td>15.1</td>
<td>96.8</td>
<td>30.4</td>
<td>1.67</td>
</tr>
<tr>
<td>4</td>
<td>1.5 y</td>
<td>10.6</td>
<td>2.83</td>
<td>31.2</td>
<td>3.86</td>
</tr>
<tr>
<td>5</td>
<td>6 mo</td>
<td>11.2</td>
<td>18.9</td>
<td>21.2</td>
<td>0.63</td>
</tr>
<tr>
<td>6</td>
<td>5 mo</td>
<td>11.7</td>
<td>28.27</td>
<td>29</td>
<td>0.95</td>
</tr>
<tr>
<td>7</td>
<td>5 mo</td>
<td>12.9</td>
<td>5.7</td>
<td>43.3</td>
<td>2.06</td>
</tr>
<tr>
<td>8</td>
<td>7 y</td>
<td>16.2</td>
<td>186.21</td>
<td>32.6</td>
<td>3.76</td>
</tr>
<tr>
<td>9</td>
<td>10 y</td>
<td>14.5</td>
<td>13.3</td>
<td>29.2</td>
<td>0.53</td>
</tr>
<tr>
<td>10</td>
<td>15 y</td>
<td>24</td>
<td>12.11</td>
<td>44.3</td>
<td>2.2</td>
</tr>
<tr>
<td>11</td>
<td>4 y</td>
<td>11.8</td>
<td>8.31</td>
<td>No response</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>7 mo</td>
<td>11.1</td>
<td>41.1</td>
<td>No response</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>4 y</td>
<td>13.4</td>
<td>5.82</td>
<td>No response</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>2.3 y</td>
<td>10.3</td>
<td>12.84</td>
<td>25.9</td>
<td>5.71</td>
</tr>
<tr>
<td>15</td>
<td>6 mo</td>
<td>12.1</td>
<td>3.54</td>
<td>30.1</td>
<td>0.66</td>
</tr>
<tr>
<td>16</td>
<td>6 mo</td>
<td>15.4</td>
<td>7</td>
<td>No response</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>4 mo</td>
<td>9</td>
<td>15.79</td>
<td>No response</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>5 mo</td>
<td>11</td>
<td>19.06</td>
<td>No response</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>3 y</td>
<td>9.2</td>
<td>3.25</td>
<td>No response</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>2.5 y</td>
<td>9.6</td>
<td>85.46</td>
<td>34</td>
<td>2.68</td>
</tr>
<tr>
<td>21</td>
<td>6 mo</td>
<td>12.9</td>
<td>30.1</td>
<td>No response</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>16 y</td>
<td>27.05</td>
<td>11.02</td>
<td>36</td>
<td>0.8</td>
</tr>
<tr>
<td>23</td>
<td>6 mo</td>
<td>12.5</td>
<td>7.65</td>
<td>No response</td>
<td></td>
</tr>
</tbody>
</table>

*SDR* subdural recording, *CR* cortical recording
Figure 1. A 1×4 strip was placed in the subdural space just proximal to the surgical field to record SSEPs of the posterior tibial nerve.

Figure 2. SSEPs of the posterior tibial nerve obtained by cortical (upper trace, amplitude 1.7µV) and subdural recordings (lower trace, amplitude 96.8µV). (a) left PTN; (b) right PTN.

**DISCUSSION**

Children with spinal dysraphism and/or TCS are at risk of functional deterioration during development, and early detethering surgery can prevent this from happening. Moreover, in certain cases, this surgical option can even reverse functional deficits incurred by spinal dysraphism and/or TCS. However, surgical dissection of lumbosacral nerve roots during detethering does impose...
SSEP recordings of PTN with subdural strip

certain risk on neural structures and can predispose patients to further functional deterioration after operation. Thus, employment of NIOM is mandatory to guide a surgeon’s dissection and monitor vital neural function throughout procedures so as to optimize surgical outcome and minimize postoperative functional deficits. The findings that none of our patients sustained new functional deficits after surgery further confirm the important role of NIOM in detethering procedures.

Apart from using EMG mapping to safeguard the integral function of the motor nerves, monitoring SSEPs of the PTN helps to preserve the integrity of lower limb sensory function as well during detethering surgery. From previous experiences, recording cortical SSEPs of the PTN in young children is extremely challenging due to incomplete myelination, immaturity of the nervous system, and greater sensitivity to anesthetic effects compared to other subcortical recording montages. Subdural recordings of evoked potential should be affected less by the above mentioned factors given that the distance between stimulating and recording electrodes is much shorter compared to cortical recordings. However, from our understanding, none of previous researches had used this application during detethering surgery in young children. In the current study, subdural SSEP recordings with a strip just proximal to the surgical field proved to be a feasible way to replace conventional cortical recordings. This was because the amplitudes of subdurally recorded SSEPs were frequently larger than those of cortical responses (mean amplitude 28.07 vs. 2.28 µV) as the strip provided a larger recording area and it allowed us to record directly from the dorsal surface of the spinal cord as well. Another advantage of this approach was that much less averaging was needed to attain a monitorable subdural SSEP, which was less time consuming when compared to conventional cortical SSEP recordings (average of < 10 for subdural vs. 200 for cortical SSEPs). Furthermore, a shorter distance between stimulating and recording electrodes allowed for less interference and more stable SSEPs. In fact, there were nine patients that subdural SSEPs were used solely for monitoring sensory function because cortical SSEPs were not obtainable, which further supports the feasibility of this novel application. Finally, from our clinical experiences, placement of a subdural strip by surgeons to record SSEP imposes no further risk on these patients since dura is routinely opened during surgical procedures.

CONCLUSION

SSEP recordings of the PTN obtained through a subdural strip applied just rostral to the surgical site in young children proved to be a feasible and valuable tool during detethering surgery of spinal dysraphism and/or TCS. The major advantages of subdural recordings include more stable signals and larger amplitude, and less averaging required during signal acquisition. In comparison to conventional cortical SSEP recordings, this approach could serve to improve both the safety, as well as the efficiency of surgical procedure.

ACKNOWLEDGEMENTS

The authors acknowledge the funding by Taipei Veterans General Hospital, Taipei, Taiwan (grant number: 2013-12-022CC).

REFERENCES


研究目的：擬探討在進行脊柱裂及脊髓牽扯症候群的手術時，使用硬膜下電極紀錄後脛神經的體感
覺誘發電位的可行性。

研究方法：總共收集了 23 位患者，13 位男孩，10 位女孩，年齡在 4 個月大到 15 歲間。疾病診斷分
別為脂肪脊髓脊膜膨出(11)、脊髓牽扯症候群(7)、脊髓發育畸形(3)、VACTERL 症候群(1)及脊髓腫瘤(1)
等。除了常規使用的監測方法以外，在外科醫師打開硬膜後，會將一條硬膜下電極固定在手術部位的頭
端。在全靜脈麻醉下，刺激後脛神經時同時在頭頂 Cz-Fz 及硬膜下電極紀錄體感覺誘發電位。

結果：除了一位患者以外，所有患者用硬膜下電極紀錄記錄到的體感覺誘發電位的振幅都明顯大於
皮質體感覺誘發電位。同時有別於一般需連續電 200 下才能取得一個穩定的皮質體感覺誘發電位判讀，
硬膜下電極紀錄到的體感覺誘發電位只需要不到 10 下的刺激即可取得，節省了很多等待時間。本研究
中，所有的硬膜下電極紀錄到的體感覺誘發電位在術中都維持穩定，同時所有患者術後都沒有新的神經
功能障礙發生。

結論：在脊柱裂及脊髖牽扯症候群手術中，使用硬膜下電極紀錄後脛神經的體感覺誘發電位證實為
一個有價值的監測神經功能方法。與傳統的皮質體感覺誘發電位比較，這種紀錄法除了可以提升手術的
安全性以外，也可以促進手術的效率。（台灣復健醫誌 2016；44(2)：103 - 109）

關鍵詞：體感覺誘發電位(somatosensory evoked potentials)，術中監測(intraoperative monitoring)，脊柱裂
(spinal dysraphism)，脊髖牽扯症候群(tethered cord syndrome)