Selective Cervical Dorsal Rhizotomy to Relieve Upper-limb Spasticity after Stroke or Spinal Cord Injury- Report of Five Cases

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ABSTRACT
Objective: Myelopathy is the most serious sequela after central nervous system insult. Due to loss of inhibition from upper neurons, hyperreflexia, spasticity, cramping pain, and paresthesia are typically noted with numbness over the limbs. Severity of spasticity is measured with the modified Ashworth scale (MAS). For patients with low-grade spasticity (MAS 1, 1+, and 2), oral medication, physical therapy, and occupational therapy can provide satisfactory results. However, for patients with high-grade spasticity (MAS 3 and 4), adjuvant therapies, such as selective dorsal rhizotomy, are needed. Materials and Methods: Since 2001, we have used selective cervical dorsal rhizotomy in Taiwan for eight spastic upper limbs in five patients. A posterior approach to the spinal canal is made under general anesthesia. After opening the dura, the selected roots are identified with anatomic landmarks and confirmed with intraoperative nerve-root stimulation. Two dorsal roots (C-5, C-6) are selected for spasticity of the upper arm, whereas C-7, C-8, and T-1 are selected for spasticity of the forearm and hand. A 50% to 80% mechanical section is performed one by one for each root. Results: At the 3 month follow-up, reduction of mean MAS grade from 3.5 to 1+ was demonstrated (p = 0.008). Spasticity of both elbow and wrist joints was reduced by C-7, C-8 and T-1 dorsal rhizotomy. Conclusions: In our experience with a limited number of patients, selective cervical dorsal rhizotomy relieves upper-limb spasticity after central nervous system insults such as stroke or spinal cord injury. (Tzu Chi Med J 2004; 16:371-375)

Key words: dorsal root section, rhizotomy, spasticity, spinal cord injury, stroke

INTRODUCTION

Upper-limb spasticity can be a handicapping sequela to any kind of central nervous system insult [1-5]. Usually, it is accompanied by dysesthesia or cramping pain. The degree of spasticity can be assessed with use of the modified Ashworth scale (MAS) (Table 1) [4,6]. Medication and physical therapy are the usual modes of treatment for patients with low-grade spasticity (MAS 1, 1+ and 2). In upper limbs with high-grade spasticity (MAS 3, 4), focal botulinum injection can be effective [7]. However, this option is expensive in a developing country or area. In Taiwan, medical insurance coverage for botulinum injections is limited to children with cerebral palsy. For people who cannot receive repeated botulinum injections, several surgical options can be considered: soft-tissue release or lengthening, bone surgery, or selective dorsal rhizotomy.

Dorsal rhizotomy was developed more than a century ago, in 1908 [8]. Gros and colleagues developed partial dorsal rhizotomy in 1967 [9], and most surgeons have used this method. According to one recent study, the C-5, C-6, and C-7 dorsal roots are selected for spasticity over the patient's shoulder and elbow joints. The C-7 and C-8 dorsal roots are selected for spasticity over...
the patient's wrist and hand [10-12].

We introduced selective dorsal rhizotomy in 2001 for patients with high-grade spasticity secondary to a central nervous system insult in adulthood. Physicians and surgeons are included in the spasticity team for pre-, intra-, and post-operative evaluations. Selective cervical dorsal rhizotomy is used for upper-limb or four-limb spasticity. Selective lumbar dorsal rhizotomy is used for purely lower-limb spasticity [1,10,13-17].

**MATERIALS AND METHODS**

From January 2001 to December 2003, 51 stroke patients and 25 patients with cervical spinal cord injury were evaluated for spastic limbs. At enrollment, every patient had been followed for more than six months since the acquired insult. Older patients (> 65-years-old) and patients with completely paralytic limbs were excluded. C-spine dynamic X-ray study and magnetic resonance imaging (MRI) were performed to assess the degree of cervical spine stenosis and stability, and whether or not intraspinal adhesions had developed. Patients with prominent anomalies of the cervical spine structure were also excluded from this study.

The study population consisted of five adult patients with eight high-grade (MAS 3 or 4) spastic upper limbs (mean age, 43.4 years) (Table 2). Among these patients, two (1 man, 1 woman) had strokes and three men had spinal cord injuries. All five patients underwent selective cervical dorsal rhizotomy.

In the two stroke patients, involuntary flexed elbow, wrist, and hand contractures were noted with hand eczema and poor hygiene. One received C-5, C-6, C-7, C-8, and T-1 selective dorsal rhizotomy to relieve spasticity over the whole left upper limb. The other patient received C-7, C-8, and T-1 selective dorsal rhizotomy for dominant symptoms over the forearm (elbow and wrist) and hand. In all three cervical cord injury patients, we performed bilateral C-7, C-8 and T-1 selective dorsal rhizotomy.

Table 1. The Modified Ashworth Scale (MAS) [Bohannon & Smith]

<table>
<thead>
<tr>
<th>MAS grade</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No increase in muscle tone</td>
</tr>
<tr>
<td>1</td>
<td>Slight increase in muscle tone, manifested by a catch and release or by minimal resistance at the end of the range of motion when the affected part(s) move in flexion or extension</td>
</tr>
<tr>
<td>1+</td>
<td>Slight increase in muscle tone, manifested by a catch, followed by minimal resistance throughout the remainder (less than half) of the range of movement</td>
</tr>
<tr>
<td>2</td>
<td>More marked increase in muscle tone through most of the range of movement, but affected part(s) easily moved</td>
</tr>
<tr>
<td>3</td>
<td>Considerable increase in passive muscle tone, with difficult movement</td>
</tr>
<tr>
<td>4</td>
<td>Affected part(s) rigid in flexion or extension</td>
</tr>
</tbody>
</table>

Table 2. Characteristics of Study Patients

<table>
<thead>
<tr>
<th>Patient</th>
<th>Sex</th>
<th>Age</th>
<th>Cause</th>
<th>Duration from Insult to Evaluation</th>
<th>MAS Grade</th>
<th>Region of Spasticity</th>
<th>Selected Dorsal Roots and Percentage of Block</th>
<th>3 Month Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Male</td>
<td>44</td>
<td>CVA</td>
<td>2 years &amp; 11 months</td>
<td>4</td>
<td>Right elbow, wrist and hand</td>
<td>Right C-7,8 &amp; T1 80% block</td>
<td>MAS 1 at right elbow, 2 at right wrist and hand</td>
</tr>
<tr>
<td>2</td>
<td>Female</td>
<td>43</td>
<td>CVA</td>
<td>2 years &amp; 9 months</td>
<td>4</td>
<td>Left upper limb</td>
<td>Left C-5,6,7,8 &amp; T1 80% block</td>
<td>MAS 1+ at left upper limb</td>
</tr>
<tr>
<td>3</td>
<td>Male</td>
<td>49</td>
<td>C-spine injury</td>
<td>11 months</td>
<td>3</td>
<td>Right elbow and wrist</td>
<td>Right C-7,8 &amp; T1 50% block</td>
<td>MAS 1+ at right elbow and wrist</td>
</tr>
<tr>
<td>4</td>
<td>Male</td>
<td>46</td>
<td>C-spine injury</td>
<td>2 years &amp; 4 months</td>
<td>3</td>
<td>Left elbow and wrist</td>
<td>Left C-7,8 &amp; T1 50% block</td>
<td>MAS 1+ at left elbow and wrist</td>
</tr>
<tr>
<td>5</td>
<td>Male</td>
<td>35</td>
<td>C-spine injury</td>
<td>2 years &amp; 10 months</td>
<td>4</td>
<td>Right elbow and wrist</td>
<td>Right C-7,8 &amp; T1 80% block</td>
<td>MAS 1+ at right elbow and wrist</td>
</tr>
</tbody>
</table>

CVA: cerebrovascular accident; MAS: modified Ashworth scale
rhizotomy for dominant symptoms over the elbow and wrist (Table 2).

Surgery was performed under general anesthesia. Patients were placed in the prone position with application of a Mayfield pin head-holder. The spinal level was confirmed with fluoroscopic examination. Laminectomy was done over the chosen segments with preservation of the facet joints. After the dura was opened, the selected dorsal roots were identified with anatomic landmarks. Intra-operative nerve-root stimulation was done and target roots were confirmed (Fig. 1). For each selected root, a 50% to 80% mechanical section was performed with microscissors [15,16]. The dura was closed with water-tight sutures and bone chips from the laminectomy were implanted for posterior-lateral reconstruction. Patients wore cervical collars for three months postoperatively. There was no surgical morbidity in any of the five patients during follow-up.

The spasticity of the affected joints was recorded 3 months postoperatively. We quantified MAS grades to numbers (MAS 1 to 1, MAS 1+ to 2, MAS 2 to 3, MAS 3 to 4, MAS 4 to 5) for mathematical calculations. The Wilcoxon sign-rank test was used for statistical analysis and the significant level was set at 0.05.

**RESULTS**

The degree of spasticity was reduced at the 3 month follow-up. Fig. 2 shows MAS grades before and 3 months after surgery. The mean MAS grade was reduced from 3.5 to 1+ (p = 0.008). With reduced spasticity, patients could flex and extend their upper-limb joints much more easily. Hand grasp and upper limb coordination also became smoother. Although the elbow joint is predominantly innervated by the C-5 and C-6 roots, we found that spasticity in both major joints (elbow and wrist) of the forearm was relieved in patients who received C-7, C-8, and T1 selective dorsal rhizotomy.

No patient had newly developed loss of sensory or motor function after surgery. There was some reduction in cramping pain and paresthesia accompanying the reduction of spasticity, however these subjective symptoms were hard to categorize or quantify. Continuing physical therapy and occupational therapy were encouraged after surgical wounds had healed. In our patients, oral baclofen was not stopped, but it was possible to reduce dosage during the follow-up period to achieve better assessment and quality of life.

Decreased lower-limb spasticity was observed in 2 patients. In these patients with this unexpected effect, gait postoperatively showed improvement of fluency and coordination.

**DISCUSSION**
The results of other studies and our surgical results show that selective cervical dorsal rhizotomy is an effective method to relieve upper-limb spasticity. However, the sectioned percentage of dorsal roots is still controversial [10,11,15,16]. Bertelli and colleagues reported that there was no complete hand anesthesia in patients with 100% cervical dorsal root section. Their results indicated that light touch and pain sensation in the affected hand might be conducted along unmyelinated fibers of the ventral roots [12]. They could not offer a clear explanation as to why sensibility was preserved after dorsal root section other than this hypothesis. We prefer subtotal cervical dorsal rhizotomy to avoid the possibility of complications due to loss of afferent fibers. More evidence regarding this point is needed to help surgeons make decisions in the future.

Based on our surgical results, we believe that the C-5 and C-6 dorsal roots should be selected for spasticity over the upper arm and shoulder joint. On the other hand, C-7, C-8, and T-1 dorsal rhizotomy should suffice for spasticity over the forearm (including elbow and wrist joints) and hand. Our findings reveal "the effect of near segments" by dorsal rhizotomy. More far-segment effects have been noted in other reports documenting speech and upper-limb improvement after lumbar dorsal rhizotomy [18,19]. Other authors have also reported the unpredictable effect of selective cervical dorsal rhizotomy on lower-limb spasticity [10,13,17]. Benedetti and Kottke suggested that the afferent fibers of cervical dorsal roots could sustain the proprioceptive impulses of the cervical spinal cord and cause the spasticity. A partial decrease of cervical afferents, meanwhile, could reduce four-limb spasticity. By this hypothesis, C-5, C-6 dorsal rhizotomy is not necessary to reduce spasticity of the elbow joint. C-7, C-8, and T-1 dorsal rhizotomy can cover the elbow through the near-segment effect. Therefore, surgery can be done over limited segments without significantly different results.

Conclusions

Selective cervical dorsal rhizotomy is a very effective treatment of upper-limb spasticity after stroke or spinal cord injury. This surgical procedure not only reduces spasticity but also improves motor function in affected limbs.

REFERENCES

選擇性頸背根神經切割治療腦中風或脊髓損傷後上肢緊繃—五病例分析

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摘要
目的：中樞神經受損後上神經元症狀是常見的嚴重後遺症。在失去上神經元的調控之下，病患會表現反射亢進、肢體緊繃，甚至會有緊縮痛、刺痛等肢體症狀。這些症狀比肢體感覺麻木更造成病患的困擾。依照國�新modified Ashworth scale (MAS)對肢體緊繃的評分標準，我們能建立一個客觀的評定系統對腦中風或脊髓損傷的病患來評分。低度肢體緊繃 (MAS 1, 1+或 2 分) 的病患藉由口服藥物，物理或職能治療便能控制他們的不適。然而對於少數高度肢體緊繃的病患 (MAS 3或4 分)，積極性的輔助治療，比如手術，才能幫助他們。材料與方法：我們自2001年起建立了肢體緊繃評估團隊，並應用選擇性頸背根神經切割來治療那些腦中風或脊髓損傷後高度肢體緊繃的病患。在2001年1月至2003年12月之間，我們應用此種手術治療了5位病患的8隻上肢高度緊繃。其中2位是腦中風病患併有單側上肢症狀，3位是脊髓損傷病患併有雙側上肢障礙。術前評估時完全的無力癱瘓或高度的頸椎狹窄是排除性的重點。在這8隻上肢緊繃個案的手術中，我們採用頸後方手術式切除頸椎椎板。打開髖膜後，藉由顯微手術技巧分離出預先計劃的背根神經。在手術中，我們會施行神經刺激術確認所要的背根神經。在上臂緊繃的情形，我們作C-5，C-6背根神經 50%-80% 的切斷。在前臂及手部緊繃的情形，我們作C-7，C-8及T-1背根神經 50%-80% 的切斷。結果：在三個月的追蹤與術前作比較之中，我們使用Wilcoxon sign-rank test統計法可見到平均降低上肢緊繃MAS 2.5分。結論：在我們追蹤的病患之中，初步的報告顯示了選擇性頸背根切割可以有效的治療腦中風或脊髓損傷後上肢緊繃的病情。 (慈濟醫學2004; 16:371-375)

關鍵語：背根切除，神經切割，緊繃，脊髓損傷，中風

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