Upper Extremity Functional Changes Following Selective Posterior Rhizotomy in Children With Cerebral Palsy

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Key Words: activities of daily living • spasticity • upper extremities

Spasticity in children with cerebral palsy may inhibit function and reduce progress in therapy. Selective posterior rhizotomy, a neurosurgical procedure, has been found to effectively reduce spasticity in selected cases. The literature suggests that positive changes in upper extremity function result from this surgery. At the Alberta Children's Hospital in Calgary, Alberta, Canada, all candidates for this surgery are screened by the neuromotor clinic team, which includes an occupational therapist, a speech therapist, and a physical therapist. This paper outlines the specific changes seen in the upper extremity functions of 7 children over a 12-month period following their surgeries. The data collected suggest the children had improved function in activities of daily living, play skills, balance, and endurance. This paper focuses on the changes in activities of daily living and recommends future direction for research in this area.

Cerebral palsy is an inclusive term used to describe a group of nonprogressive motor disorders that are caused by an insult to the brain before, during, or after birth (Stanley & Alberman, 1984). It is usually classified as spastic, athetoid, ataxic, hypotonic, or mixed. The spasticity of children with spastic cerebral palsy is characterized by velocity-dependent increased tonic stretch reflexes with exaggerated tendon jerks (Katz & Rymer, 1989).

Spasticity and its complications are managed by a variety of strategies (Katz, 1988). Occupational therapists working with children with cerebral palsy have attempted to reduce spasticity by using such therapeutic strategies as handling and positioning, casting and splinting, and applying temperature changes (i.e., neutral warmth or topical cold). When these strategies were successful, however, the results were temporary (Katz, 1988). The continued presence of spasticity may interfere with a child's progress, often leaving the child, the parents, and the therapist frustrated and discouraged. Katz (1988) also described the use of pharmacologic intervention, including oral medications, phenol injections, and spinal blocks to reduce spasticity. These interventions were found to be temporary and were often accompanied by undesirable side effects. Katz (1988) found that orthopedic procedures such as tenotomy and tendon transfer produced more permanent changes, as did two neurosurgical procedures, neurectomy and rhizotomy.

An improved rhizotomy procedure called selective posterior rhizotomy (Staudt & Peacock, 1989) reduced spasticity and improved function in selected cases of spastic cerebral palsy. This paper presents preliminary upper extremity outcomes for 7 children with cerebral palsy who underwent selective posterior rhizotomy at Alberta Children's Hospital in Calgary, Alberta, Canada.

Literature Review

Recent articles about selective posterior rhizotomy in children with cerebral palsy have covered such topics as surgical procedures, selection criteria, and clinical outcomes. Specifically, Peacock, Arens, and Berman (1987) and Ploeger and Rockman (1987) discussed selective posterior rhizotomy for children with spastic cerebral palsy who had increased muscle tone caused primarily by the velocity-dependent increased tonic stretch reflex. These authors described the surgery as a midline laminectomy from the second to the fifth lumbar vertebrae with preservation of the facet joints. The posterior roots of the spinal nerves were separated bilaterally from the anterior roots and then subdivided into rootlets. The quality of the muscle response was noted as each rootlet was electrically stimulated. The rootlets producing abnormal responses were cut. Tactile and proprioceptive sensation remained intact (Berman, Vaughan, & Peacock, 1990).

The child who shows spasticity as the primary prob-
problem without significant underlying weakness is considered the ideal candidate for this procedure (Elk, 1984; Peacock et al., 1987; Staudt & Peacock, 1989). The candidate's underlying strength is determined by his or her ability to start, stop, initiate movement, and movements, and use isolated muscle groups. It is preferable that spasticity not be used to perform functional tasks such as standing upright or walking. Clonus may be present, but not athetosis, ataxia, or abnormal reflexes. Previous orthopedic surgeries and contractures may be contraindications. The candidate may be an ambulatory child whose gait pattern and endurance can be improved through the surgery or a severely impaired child whose spasticity interferes with positioning and hygiene.

Upper extremity postsurgical outcomes were presented in a number of articles. For example, Peacock and Arens (1985) studied 15 patients for 4 to 16 months after their selective posterior rhizotomies. The authors reported that 7 children experienced positive changes in upper extremity function, noting that 3 of these children had changes in grasp and dressing skills. Three children experienced no changes. Upper limb function was not reported for 5 of the children. In another study, 68% of 60 postrhizotomy patients showed positive changes in upper extremity function 1 to 5 years after their surgeries (Peacock et al., 1987). However, specific measures of change in upper limb function were not reported. Berman et al. (1990) followed 29 children for 4 to 14 months after their surgeries, with presurgical and postsurgical status focusing on functional positions and movements such as rolling, sitting, kneeling, half-kneeling, crawling, standing, and walking. One of the greatest postsurgery gains was in the children's ability to assume and maintain positions. This allowed for improved participation in activities, particularly activities of daily living. Berman et al. (1990) concluded that when a child could sit more easily, upper limb function became more efficient. However, the authors gave no description of how they measured this improvement in participation and efficiency.

Other articles on cervical posterior rhizotomy have also discussed positive changes in upper limb function, but did not describe how this improvement was measured. Heimburger, Slominski, and Griswold (1973) reported that even though spasticity of the neck, spine, arms, and legs decreased in 13 of the 15 subjects they studied, voluntary arm and hand movements improved significantly in only 1 subject. In addition, 3 subjects developed purposeful hand movements. Benedetti, Carbonin, and Colomba (1977–1978) reported the single case study of a patient with upper limb dyskinesia whose reduction in spasticity and recovery of fine motor function occurred without noteworthy sensory deficits. Fraioli, Nucci, and Baldassarre (1977–1978), whose postsurgical outcomes for 15 patients did not specify improvement in upper extremity function, reported that 7 patients showed improvement in voluntary movement of all four limbs. Eight patients showed no improvement.

Although all these studies reported positive changes in upper limb function, the information was, for the most part, anecdotal with no specific measurements of presurgical or postsurgical changes. Furthermore, none of these studies offered descriptions of preoperative or postoperative occupational therapy. The present paper is meant to provide a preliminary study of changes in upper extremity function as measured in the 7 children who had selective posterior rhizotomy at Alberta Children's Hospital during a 1-year period.

Method

Alberta Children's Hospital is a regional hospital serving southern Alberta and southeastern British Columbia. It primarily provides outpatient ambulatory care for children from birth to 18 years of age. All children with muscle tone abnormalities such as spasticity have access to the hospital's neuromotor clinic, which uses a multidisciplinary team approach to patient care. This team consists of a nurse coordinator, pediatrician, orthopedic surgeon, social worker, psychologist, occupational therapist, speech therapist, and physical therapist. The Alberta health care system covers the cost of all of these services. All families considering selective posterior rhizotomy for their children are referred to the neuromotor clinic. The nurse coordinator, who receives the initial referral, schedules appointments with the neurosurgeon, the neurologist, and members of the multidisciplinary team. All assessment results are sent to the neurologist and to the neurosurgeon, who are not part of the neuromotor clinic. The neurosurgeon makes the final decision concerning the suitability of each candidate.

Subjects

From March 1989 to February 1990, seven selective posterior rhizotomies were performed at Alberta Children's Hospital. The patients, all boys, ranged in age from 7 years to 16 years. Two of the boys had spastic diplegia and were ambulatory. The other 5 boys had spastic quadriplegia. Four of the boys used wheelchairs, and 1 used a walker for short distances.

All 7 children had significant spasticity (increased tone). Six of them showed spasticity in the upper extremities during periods of rest. Increased tone was present with effort for all 7 children; consequently, it interfered with upper extremity function in all of them. During activity, both the degree of increased tone and the degree of interference with function ranged from mild to severe. In the 2 children with spastic diplegia, the spasticity was manifested by decreased coordination and slowness in carrying out activities of daily living. In the 5 children with spastic quadriplegia, the spasticity was manifested by par-
and was videotaped. The physical therapist and I measured range of motion and tone (amount of spasticity) using the Modified Ashworth Scale (Ashworth, 1964). The occupational therapy assessment then focused on fine motor skills. Reach, grasp, placement, and release were measured by having the patients stack blocks, place pellets into a bottle (Folio & Fewell, 1983), and pick up and release five pennies serially. All tasks were timed. Graphic skills were measured with test materials geared to the abilities of each child, that is, 6 of the children were given the Developmental Test of Visual-Motor Integration (Beery, 1982) and were encouraged to copy the test items. (One child was unable to grasp a pencil.) The 2 children who had functional writing skills were also offered the Motor Accuracy Test—Revised (Ayres, 1980) and the Near-Copy subtest of the Slingerland Screening Test for Identifying Children with Specific Language Disability (Slingerland, 1974). Isolated finger movements, thumb-to-finger opposition, and rapid alternating pronation and supination were also observed. Information about activities of daily living was obtained through direct observation and through structured interviews with the family. Medical and social history, educational placement, and other relevant information was collected either directly by interview or from the medical chart. The family's reasons for seeking this surgical procedure were noted, and preoperative occupational therapy goals and treatment frequency were recorded during this initial assessment (see Table 2).

### Table 1

**Function of Three Activities of Daily Living Before and After Selective Posterior Rhizotomy (N = 7)**

<table>
<thead>
<tr>
<th>Subject</th>
<th>Dressing Before</th>
<th>Eating Before</th>
<th>Brushing Teeth Before</th>
<th>Dressing After</th>
<th>Eating After</th>
<th>Brushing Teeth After</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>I</td>
<td>I</td>
<td>I</td>
<td>I</td>
<td>I</td>
<td>I</td>
</tr>
<tr>
<td>2</td>
<td>I</td>
<td>I</td>
<td>I</td>
<td>I</td>
<td>I</td>
<td>I</td>
</tr>
<tr>
<td>3</td>
<td>D</td>
<td>A</td>
<td>A</td>
<td>D</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>4</td>
<td>D</td>
<td>A</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
</tr>
<tr>
<td>5</td>
<td>A</td>
<td>I</td>
<td>I</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>6</td>
<td>D</td>
<td>A</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
</tr>
<tr>
<td>7</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
</tr>
</tbody>
</table>

*Note: 1 = independent; A = assisted; D = dependent.*

### Procedure

As the assessing occupational therapist for the neuromotor clinic, I collected data on these children over a 12-month period. All assessments were done in concert with the speech therapist and physical therapist, with the exception of a 10-day postoperative occupational therapy reassessment. Each assessment lasted approximately 2 hr and was videotaped. The physical therapist and I measured range of motion and tone (amount of spasticity) using the Modified Ashworth Scale (Ashworth, 1964). The occupational therapy assessment then focused on fine motor skills. Reach, grasp, placement, and release were measured by having the patients stack blocks, place pellets into a bottle (Folio & Fewell, 1983), and pick up and release five pennies serially. All tasks were timed. Graphic skills were measured with test materials geared to the abilities of each child, that is, 6 of the children were given the Developmental Test of Visual-Motor Integration (Beery, 1982) and were encouraged to copy the test items. (One child was unable to grasp a pencil.) The 2 children who had functional writing skills were also offered the Motor Accuracy Test—Revised (Ayres, 1980) and the Near-Copy subtest of the Slingerland Screening Test for Identifying Children with Specific Language Disability (Slingerland, 1974). Isolated finger movements, thumb-to-finger opposition, and rapid alternating pronation and supination were also observed. Information about activities of daily living was obtained through direct observation and through structured interviews with the family. Medical and social history, educational placement, and other relevant information was collected either directly by interview or from the medical chart. The family's reasons for seeking this surgical procedure were noted, and preoperative occupational therapy goals and treatment frequency were recorded during this initial assessment (see Table 2).

### Table 2

**Preoperative and Postoperative Frequency and Goals of Occupational Therapy of Selective Posterior Rhizotomy Patients (N = 7)**

<table>
<thead>
<tr>
<th>Subject</th>
<th>Age at Surgery (years)</th>
<th>Diagnosis</th>
<th>Preoperative Therapy Frequency</th>
<th>Preoperative Therapy Goals</th>
<th>1-Month Postoperative Therapy Frequency</th>
<th>1-Month Postoperative Therapy Goals</th>
<th>Postoperative Therapy Frequency</th>
<th>Postoperative Therapy Goals</th>
<th>6-Month Postoperative Therapy Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>14</td>
<td>Spastic diplegia</td>
<td>School-based OT assessment only</td>
<td>Recommended computer &amp; OT consultation</td>
<td>Neuromotor clinic's assessing OT 3 x weekly</td>
<td>Improve fine motor control &amp; precision</td>
<td>na</td>
<td>na</td>
<td>School-based OT consultation</td>
</tr>
<tr>
<td>2</td>
<td>11</td>
<td>Spastic diplegia</td>
<td>Alberta Children's Hospital mobile OT weekly</td>
<td>Improve upper extremity function, oral motor control, &amp; use of computer</td>
<td>Neuromotor clinic's assessing OT 2 x weekly</td>
<td>Improve voluntary movement &amp; voluntary place &amp; release</td>
<td>ne</td>
<td>na</td>
<td>ACH mobile OT weekly</td>
</tr>
<tr>
<td>3</td>
<td>7</td>
<td>Spastic quadriplegia</td>
<td>School-based OT consultation monthly</td>
<td>Problem-solving approach</td>
<td>Neuromotor clinic's assessing OT 2 x weekly</td>
<td>Neuromotor clinic's assessing OT 1 x weekly</td>
<td>Not reported</td>
<td>Same as 1-month postoperative therapy</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>11</td>
<td>Spastic quadriplegia</td>
<td>Community-based OT consultation monthly</td>
<td>Problem-solving approach</td>
<td>Neuromotor clinic's assessing OT 2 x weekly</td>
<td>Neuromotor clinic's assessing OT 2 x weekly</td>
<td>Not reported</td>
<td>Same as 1 month postoperative therapy</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>7</td>
<td>Spastic quadriplegia</td>
<td>School-based OT consultation monthly</td>
<td>Problem-solving approach</td>
<td>Neuromotor clinic's assessing OT 2 x weekly</td>
<td>Neuromotor clinic's assessing OT 2 x weekly</td>
<td>Not reported</td>
<td>Same as 1 month postoperative therapy</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>16</td>
<td>Spastic quadriplegia</td>
<td>School-based OT consultation monthly</td>
<td>Problem-solving approach</td>
<td>Neuromotor clinic's assessing OT 2 x weekly</td>
<td>Neuromotor clinic's assessing OT 2 x weekly</td>
<td>Not reported</td>
<td>Same as 1 month postoperative therapy</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>6</td>
<td>Spastic quadriplegia</td>
<td>Community-based OT consultation monthly</td>
<td>Improve voluntary release &amp; promote use of switches</td>
<td>Same as preoperative therapy</td>
<td>Same as preoperative therapy</td>
<td>Same as preoperative therapy</td>
<td>Same as preoperative therapy</td>
<td>Same as preoperative therapy</td>
</tr>
</tbody>
</table>

*Note: na = not available; OT = occupational therapy.*
The average hospital stay for these patients was 10 to 14 days, during which time inpatient occupational therapy was available. I was the therapist for 2 of the children receiving inpatient occupational therapy; the other children received treatment from either the inpatient occupational therapist or the clinic's nonassessing occupational therapist. The patients received inpatient therapy 1 to 3 times, depending on their rate of recovery from surgery, their energy level, and the duration of their hospital stay. (The 2 children with spastic diplegia did not require inpatient occupational therapy because they did not lose any function following the surgery.)

Another assessment was done 10 days after surgery to determine outpatient occupational therapy needs and goals. The reassessment sessions, which were videotaped, lasted 45 min. The goals of the child and family were included in the occupational therapy goals determined at this time. Postoperative outpatient therapy differed for each child for several reasons, including the child's varying needs, the family's availability to bring the child to the hospital for treatment, and the availability of occupational therapists in the child's community (see Table 2). Table 2 also shows the provider of the occupational therapy services following discharge (i.e., the neuromotor clinic's assessing occupational therapist, the clinic's nonassessing occupational therapist, a school-based occupational therapist, or a community-based occupational therapist).

The neuromotor clinic's assessing occupational therapist, physical therapist, and speech therapist reassessed the children at 6 weeks, 3 months, 6 months, and 1 year following surgery.

Results

All 7 children experienced a reduction in spasticity following surgery. In addition, follow-up data indicate positive changes in upper limb function, particularly in activities of daily living. These changes are recorded in Table 1. The 2 children with spastic diplegia (Subjects 1 and 2), who could already dress independently, showed improvement in speed, coordination, efficiency, and endurance that are not reflected in Table 1. Two of the children with spastic quadriplegia (Subjects 3 and 4) showed changes in each of the activities of daily living that were reported, which were dressing, eating, and toothbrush use. In addition, Subject 4 became continent for both bladder and bowel. Subject 5 showed improvement in dressing and toothbrush use, progressing from being dependent on assistance to being independent. Subject 6 showed only minimal improvement in dressing ability, that is, he was able to more actively assist by flexing and extending his limbs as appropriate. Subject 7 remained totally dependent in all areas measured.

The fine motor tools of assessment used before and after surgery recorded positive changes in fine motor performance (see Table 3). Six of the 7 children showed changes in their ability to stack blocks. One child who was unable to stack any blocks before surgery was able to stack three to seven blocks postsurgically. The other 5 children showed an increase in the number of blocks stacked per trial, and 1 child also showed an increase in speed. Subject 7 remained unable to actively pick up blocks, so he was unable to stack them. Pellet dropping and penny manipulation remained difficult tasks for most of the children after surgery. Three children remained unable to pick up pellets, and 4 children remained unable to pick up pennies. Only Subject 2 showed increased speed dropping 10 pellets, and Subject 5 showed increased speed picking up five pennies serially. In several instances, data could not be collected on specific tasks because the child would not cooperate.

Graphical skills were assessed for 6 of the 7 children. However, only 3 of the 6 children produced results that could be scored on the Developmental Test of Visual-Motor Integration. The 2 children with writing skills were given the Motor Accuracy Test–Revised and the most appropriate (based on age and grade) Near-Copy subtest of the Slingerland Screening Test for Identifying Children with Specific Language Disability. Because of the small sample size, no conclusions could be drawn based on test scores changes. However, there were positive changes in pencil control in 4 of the 7 children following their selective posterior rhizotomies. These changes included an improved pencil grasp, a greater ability to target and stay within space provided for test items on the Developmental Test of Visual-Motor Integration, and an improved formation of shapes. One of the children who could write showed improvement in spacing and letter formation. However, the other child who could write showed decreased control; his larger letters and shakier lines suggested a tremor that, although evident before surgery, became more obvious after surgery.

No changes in isolated finger movements; thumb-to-finger opposition; or rapid, alternating pronation or supination were observed.

In postsurgical interviews, the children's parents expressed satisfaction with their child's surgical outcomes. The parents' subjective observations suggested improvements in play skills (i.e., blocks and pegs), endurance,

<table>
<thead>
<tr>
<th>Effect</th>
<th>Block Stacking</th>
<th>Pellet Dropping</th>
<th>Penny Manipulation</th>
<th>Pencil Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improved</td>
<td>6</td>
<td>1</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>No Change</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Unable</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Decreased</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>No Data</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

Note: Data presented are for dominant hand only.
sitting and standing balance, and activities of daily living (see Table 1).

In addition, positive changes were measured in speech and language development, including increased number of words per utterance, improved intelligibility, increased voice intensity, and decreased drooling (Flower, 1991).

Discussion

Although this study seems to confirm earlier reports of improved upper extremity function following selective posterior rhizotomy (Arens, Peacock, & Peter, 1989; Berman et al., 1990; Peacock & Arens, 1985), it had a number of limitations. First, the study compared presurgical upper extremity function with postsurgical upper extremity function, but the number of subjects was too small for statistical analysis. In addition, data collection included a limited number of trials per test item for block stacking, pellet dropping, and penny manipulation. More accurate assessments of each child's skills would have been obtained by repeated data collection over a number of days. This could not be done during this study because of a variety of conflicts, including school programs, parental schedules, and the difficulty some children had getting to and from the hospital. Further studies should be conducted using larger samples of children and repeated trials.

Additionally, the methods used to assess improvement should be considered further. For example, the children showed the most changes in block stacking and pencil control, but little to no change in pellet dropping and penny manipulation. When evaluating these results, one needs to consider the level of satisfaction gained by both the children and their parents to ensure that the measured changes are meaningful and directly related to quality-of-life issues.

Every effort was made in this study to perform assessments and reassessments under similar conditions. However, this was not always possible because of problems such as broken or lost eyeglasses and wheelchair trays and failure to bring the child's seating system each time. Finally, both the frequency and goals of preoperative and postoperative therapy varied significantly from child to child (see Table 2), making it difficult to determine the possible causes for any changes.

Although children with cerebral palsy who are candidates for selective posterior rhizotomy have a range of diagnoses and skill levels, this study did not emphasize these differences. Terms such as spastic diplegia, spastic quadriplegia, and mild, moderate, and severe spasticity are not consistently defined. There is a need for such definitions to be established. In addition, the ability to perform test items is dependent not only on physical abilities, but also on concentration, motivation, and cognitive skills. These factors were not considered during this study in the assessment of the children's performance on such tests.

Although some guidelines for norms within age ranges have been established for block stacking and pellet dropping (Folio & Fewell, 1983), norms have not been established for children with cerebral palsy. The same is true of the standardized Developmental Test of Visual-Motor Integration and the Motor Accuracy Test-Revised. Therefore, the validity and reliability of these measures of change need to be established for children with cerebral palsy. In the present study, changes in skill levels were based on recorded data, observation of videotapes, and parental reports.

Conclusion

The data presented in this study appear to confirm positive changes in upper extremity function after selective posterior rhizotomy. The reasons for these changes are not clear but may include reduction of spasticity, physical maturation, motivation, intelligence, increased expectations of the child and the family, and increased occupational therapy. A commitment to further research is necessary to determine the reasons for these changes. Nwaobi (1983) found that factors other than spasticity in upper motor neuron lesions may limit voluntary movement. These factors may include decreased anterior horn cell output, decreased firing frequency of motor units, and prolonged electromyography summation time for voluntary movement. Concentration, motivation, and cognitive skills also need to be considered as possible factors. For reliable and valid tools for measuring change in this population to be developed, working definitions for spastic diplegia; spastic quadriplegia; and mild, moderate, and severe spasticity must be established. It will also be necessary to assign the appropriate tools for measuring change within each category. Continued research will not only help clarify the role of the occupational therapist in preoperative screening and postoperative follow-up, but also help determine appropriate guidelines for occupational therapy goals and frequency.

References


