Functional performance following selective posterior rhizotomy: long-term results determined using a validated evaluative measure

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Object. Selective posterior rhizotomy (SPR) may result in considerable benefit for children with spastic cerebral palsy. To date, however, there have been few studies in which validated functional outcome measures have been used to report surgical results beyond 3 years. The authors analyzed data obtained from the McGill Rhizotomy Database to determine long-term functional performance outcomes in patients who underwent lumbosacral dorsal rhizotomy performed using intraoperative electrophysiological monitoring.

Methods. The study population was composed of children with debilitating spasticity who underwent SPR and were evaluated by a multidisciplinary team preoperatively and at 6 months and 1 year postoperatively. Quantitative standardized assessments of activities of daily living (ADL) were obtained using the Pediatric Evaluation of Disability Inventory (PEDI). Of 57 patients who met the entry criteria for the study, 41 completed the 3-year assessments and 30 completed the 5-year assessments.

Statistical analysis demonstrated significant improvement in the mobility and self-care domains of the functional skills dimension at 1 year after SPR. The preoperative and 1-, 3-, and 5-year postoperative scaled scores for the mobility domain were 56, 64, 77.2, and 77.8, respectively. The scaled score for the self-care domain increased from 59 presurgery to 67.9, 81.6, and 82.4 at the 1-, 3-, and 5-year postoperative assessments, respectively.

Conclusions. The results of this study support the presence of significant improvements in functional performance, based on PEDI scores obtained 1 year after SPR. The improvements persisted at the 3- and 5-year follow-up examinations. The authors conclude that SPR performed using intraoperative stimulation is valuable in the augmentation of motor function and self-care skills essential to the performance of ADL.

KEY WORDS • cerebral palsy • spasticity • dorsal rhizotomy • activities of daily living • functional outcome • children

UMBOSACRAL SPR aims to achieve a balance between elimination of lower-limb spasticity and augmentation of motor function in ambulatory children with spastic CP. Important efforts to evaluate functional outcomes, rather than just changes in the underlying impairments of CP, are necessary to evaluate fully the benefits of surgery. Using both subjective and objective parameters, authors of early follow-up evaluative studies reported reduction of spasticity as well as substantial progress in gait and other aspects of functional mobility. Suprasegmental benefits after SPR have also been reported. These include improved upper-limb coordination and function, positive changes in oral motor skills, and enhancement of visual attention, cognitive function, and speech. Unfortunately, only a handful of groups have described the outcomes of SPR beyond 3 years. Even fewer researchers have used statistical analysis of standardized functional assessment tools to determine long-term outcomes.

We believe that a thorough analysis of pertinent objective outcome scales, especially those focused on enhancement of function rather than simple elimination of spasticity, is critical to determine the true benefits of the EMG-guided procedure. We previously demonstrated that motor responses to orthodromic stimulation of posterior nerve roots are consistent and easily reproducible by both EMG and physiotherapy assessments. Recently, we determined that statistically significant improvements in lower-limb spasticity, passive range of motion, strength, and motor function occur up to 5 years following EMG-guided SPR (unpublished data). In this study, we examine the effects of SPR at 3 and 5 years postoperatively by using a rigorous analysis of quantitative functional outcome measurements of ADL.

A number of different tools have been used to study the effects of dorsal rhizotomy on ADL in children with spastic CP; however, to date no group has reported measures of functional skills beyond 2 years postoperatively in this population. Therefore, the purpose of this prospective investig-
Long-term functional performance after SPR
gation was to examine whether statistically significant
improvement in functional performance is associated with the
selective procedure and whether this effect is durable. A
validated evaluation instrument used to measure ADL, the
PEDI, was used.

Clinical Material and Methods

Patient Population

Data associated with a series of patients who underwent
SPR at the Montreal Children’s Hospital of the McGill Uni-
versity Health Centre since 1991 were collected prospect-
ively from the McGill Rhizotomy Database. This database,
which is continually updated, includes pre- and postopera-
tive evaluations of patients from the neurosurgery, neur-
ology, orthopedic surgery, physiotherapy, and occupational
therapy departments. The study population was composed
of all children with spastic CP who were evaluated by the
multidisciplinary team preoperatively and at 6 months and
1 year postoperatively. Thereafter, additional assessments
were made at yearly intervals. Patients selected for surgery
had a typical perinatal history, a static disease process, and
emerging locomotor functions. Patients in whom under-
lying low tone, dystonia, multiple prior orthopedic proce-
dures, or double hemiplegia were identified and excluded
from the study. Of 57 patients who met the entry criteria for
the study, 41 completed the 3-year postoperative evalua-
tion. Of these, 30 patients completed the 5-year postopera-
tive evaluation as well.

Patient Subgroups

All patients were placed into categories preoperatively
according to the age-related severity of functional locomo-
tive impairment by using a grading scale based on the New
York University classification system, as outlined in Ta-
tive impairment by using a grading scale based on the New
York University classification system, as outlined in Ta-
tive evaluation as well.

measurement. Of these, 30 patients completed the 5-year postopera-
tive evaluation as well.

Preoperative locomotive abilities and expected outcomes
following SPR*

<table>
<thead>
<tr>
<th>Group</th>
<th>Preop Function</th>
<th>Postop Goals</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>walks w/out assistive devices of walking</td>
<td>improve appearance &amp; efficiency of walking</td>
</tr>
<tr>
<td>II</td>
<td>walks w/ assistive mobility devices (such as canes, crutches, walkers)</td>
<td>improve quality of walking &amp; decrease amount of assistance required for ambulation</td>
</tr>
<tr>
<td>III</td>
<td>quadraped crawlers, reciprocal or nonreciprocals (such as bunny hoppers)</td>
<td>improve ability to move through development sequence; walk w/ assistive devices</td>
</tr>
<tr>
<td>IV</td>
<td>commando or belly crawlers; wheelchair bound</td>
<td>improve ease of care taking; facilitate function in sitting position</td>
</tr>
<tr>
<td>V</td>
<td>no locomotive abilities; fully dependent</td>
<td>improve ease of care taking; facilitate positioning in adaptive equipment</td>
</tr>
</tbody>
</table>

* Based on the New York University classification system.

Adjunctive Orthopedic Procedures

Some patients underwent adjuvant orthopedic proce-
dures during the follow-up period (Tables 2 and 3). These
complementary therapies must be taken into account in the
outcome analysis. Of note, however, no additional surgical
interventions were performed between the SPR and the
1-year follow-up evaluation.

Measurement of Functional Performance

All patients underwent a comprehensive standardized
assessment preoperatively, at 6 and 12 months postopera-
tively, and at yearly intervals thereafter. Functional perfor-
ance outcome measures were obtained by administration of
the PEDI questionnaire. Pediatric occupational ther-
pists who were highly experienced in the treatment of chil-
TABLE 2
Adju nctive orthopedic procedures performed in eight patients after SPR

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>No. of Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>sex</td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>4</td>
</tr>
<tr>
<td>F</td>
<td>4</td>
</tr>
<tr>
<td>spastic limb involvement</td>
<td></td>
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<tr>
<td>diplegic</td>
<td>7</td>
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<tr>
<td>triplegic</td>
<td>1</td>
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<tr>
<td>quadriplegic</td>
<td>0</td>
</tr>
<tr>
<td>prehizotomy locomotive abilities</td>
<td></td>
</tr>
<tr>
<td>Group I</td>
<td>2</td>
</tr>
<tr>
<td>Group II</td>
<td>4</td>
</tr>
<tr>
<td>Group III</td>
<td>2</td>
</tr>
<tr>
<td>Group IV</td>
<td>0</td>
</tr>
<tr>
<td>Group V</td>
<td>0</td>
</tr>
<tr>
<td>mean interval after SPR (yrs)</td>
<td>3.8</td>
</tr>
<tr>
<td>range</td>
<td>1.2–7.0</td>
</tr>
<tr>
<td>adjunctive orthopedic procedure</td>
<td></td>
</tr>
<tr>
<td>hamstring release</td>
<td>1</td>
</tr>
<tr>
<td>heel cord release</td>
<td>2</td>
</tr>
<tr>
<td>hip adductor release</td>
<td>2</td>
</tr>
<tr>
<td>iliopsoas release</td>
<td>1</td>
</tr>
<tr>
<td>subtalar arthrodesis</td>
<td>1</td>
</tr>
<tr>
<td>femoral osteotomy</td>
<td>1</td>
</tr>
<tr>
<td>posterior tibial transfer</td>
<td>4</td>
</tr>
</tbody>
</table>

TABLE 3
Adju nctive botulinum toxin A injections given to 20 patients after SPR

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>No. of Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>sex</td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>9</td>
</tr>
<tr>
<td>F</td>
<td>11</td>
</tr>
<tr>
<td>spastic limb involvement</td>
<td></td>
</tr>
<tr>
<td>diplegic</td>
<td>17</td>
</tr>
<tr>
<td>triplegic</td>
<td>1</td>
</tr>
<tr>
<td>quadriplegic</td>
<td>2</td>
</tr>
<tr>
<td>prehizotomy locomotive abilities</td>
<td></td>
</tr>
<tr>
<td>Group I</td>
<td>7</td>
</tr>
<tr>
<td>Group II</td>
<td>9</td>
</tr>
<tr>
<td>Group III</td>
<td>3</td>
</tr>
<tr>
<td>Group IV</td>
<td>1</td>
</tr>
<tr>
<td>Group V</td>
<td>0</td>
</tr>
<tr>
<td>mean interval after SPR (yrs)</td>
<td>3.0</td>
</tr>
<tr>
<td>range</td>
<td>1.4–5.7</td>
</tr>
<tr>
<td>muscle group treated by injection</td>
<td></td>
</tr>
<tr>
<td>deltoid</td>
<td>1</td>
</tr>
<tr>
<td>biceps</td>
<td>2</td>
</tr>
<tr>
<td>pronator</td>
<td>2</td>
</tr>
<tr>
<td>hamstring</td>
<td>6</td>
</tr>
<tr>
<td>gastrocnemius</td>
<td>16</td>
</tr>
<tr>
<td>tibialis anterior</td>
<td>1</td>
</tr>
</tbody>
</table>

Children with CP and experienced in the use of standardized evaluation tools took measurements by using a consistent technique.

The internal consistency of the scales and the inter- and intrarater reliability of the PEDI were good. Satisfactory reliability was found with respect to agreement on the functional status of individual children between parents and rehabilitation team members (data not shown).

Evaluation of ADL

The PEDI is a parental report questionnaire used for chronically ill and disabled children between the ages of 0.5 and 7.5 years. The reliability and validity of the PEDI have been well demonstrated. It is now recognized as a standardized instrument for evaluating functional performance. In children with CP, the sensitivity of the PEDI to evaluate changes in motor function following SPR has also been studied.

The PEDI, a judgment-based tool, was administered in the form of a structured interview with the child’s parents in conjunction with clinical observation of the child by the therapist. All patients were pretested, parents were interviewed, and therapists completed a questionnaire. The PEDI is used to measure both capability and performance of functional ADL situations in three domains. The focuses of the functional performance capacity (197 discrete items) is to explore the patient’s ability to perform various tasks. The caregiver assistance domain (20 complex functional activities) is used to describe the amount of assistance a child requires to complete a task. The environmental modifications domain (20 complex functional activities) details the adaptive equipment a child needs to perform a given task. Each domain is further divided into categories of mobility, self care, and social skills. Individual items of the questionnaire are used to measure distinct aspects of selfcare, bowel and bladder control, mobility and transfers, and communication and social function. The self-care (81 items) and mobility (66 items) dimensions of the functional skills and caregiver assistance domains of the PEDI contain parameters used to measure function in more concrete daily activity tasks. Because the focus of our study was on the children’s motor abilities, the social function domain is not discussed in this article. In addition, because the modification domain yields only frequency counts, the results of this section were not analyzed in the present study.

Two different scoring systems are used in the PEDI. For the functional skills domain, a score of 0 is assigned if the child is unable or limited in capability to perform each of the 132 discrete items of functional skills. Conversely, a score of 1 is given if the child is capable of performing the functional task or if the item had been previously mastered and the patient’s functional skills have progressed beyond this level. For the caregiver assistance domain, a six-point ordinal scale is used to grade the 20 complex functional activities, in which 0 represents the patient’s complete dependence (total assistance is required); 1 indicates that maximum assistance is needed; 2 that moderate assistance is needed; 3 that minimal assistance is needed; 4 that the patient can complete the task with supervision, prompting, or monitoring; and 5 that the patient can complete the task with complete independence. The scores for each PEDI domain are summed for a total raw score for each of the two dimensions (self care and mobility) in both the functional skills and caregiver assistance domains. Using PEDI conversion tables, raw scores for individual items and content areas are transformed into normative and scaled scores. Normative scores represent the child’s age-related functional skills and caregiver assistance levels, based on a mean of 50 and a standard deviation of 10. Scores outside the 10 to 90 range are recorded as lower than 10 or greater.
Long-term functional performance after SPR

TABLE 4
Demographics in the study population of 41 patients

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>No. of Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>sex</td>
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<tr>
<td>M</td>
<td>20</td>
</tr>
<tr>
<td>F</td>
<td>21</td>
</tr>
<tr>
<td>spastic limb involvement</td>
<td></td>
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<tr>
<td>diplegic</td>
<td>36</td>
</tr>
<tr>
<td>triplegic</td>
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<tr>
<td>quadriplegic</td>
<td>3</td>
</tr>
<tr>
<td>prerhizotomy locomotive abilities</td>
<td></td>
</tr>
<tr>
<td>Group I</td>
<td>16</td>
</tr>
<tr>
<td>Group II</td>
<td>18</td>
</tr>
<tr>
<td>Group III</td>
<td>6</td>
</tr>
<tr>
<td>Group IV</td>
<td>1</td>
</tr>
<tr>
<td>Group V</td>
<td>0</td>
</tr>
<tr>
<td>age at surgery (yrs)</td>
<td></td>
</tr>
<tr>
<td>minimum</td>
<td>3.0</td>
</tr>
<tr>
<td>maximum</td>
<td>7.5</td>
</tr>
<tr>
<td>mean</td>
<td>4.8</td>
</tr>
</tbody>
</table>

than 90. Because the normative or standard scores show how close the child’s ability is to that of the healthy population of the same age, they are not available for patients 7.5 years or older (that is, outside the scope of the PEDI). Scaled scores indicate the child’s individual performance and increasing levels of function along a 0 to 1 continuum of task difficulty.

Statistical Analysis

Sensitivity to changes in the functional parameters measured over time was tested by applying the Friedman test. To determine more specifically at what time during follow-up review any significant changes in function appeared, the differences in scores between the preoperative and 1-, 3-, and 5-year assessments were evaluated using Wilcoxon matched-pairs signed-ranks tests. Two primary outcome measures were considered most relevant for this analysis. Scaled scores for the self-care and mobility domains of the functional skills dimension of the PEDI were selected because they permit accurate assessments of progression of individual performance over time. In this manner, scaled scores show how much children have improved relative to themselves. Each functional measure was analyzed at four different time points (preoperatively and 1, 3, and 5 years postoperatively). Thus six different paired comparisons were possible. The Bonferroni method was used to adjust probability values for multiple paired comparisons and an α-error probability not exceeding 0.008 (0.05/six samples) was considered significant.

Results

Patient Demographics

The final study population was composed of 41 of the 57 eligible patients who had completed the 1-year postoperative assessment. There were 20 boys and 21 girls whose ages at surgery ranged from 3 to 7.5 years, with a mean age of 4.8 years (Table 4). There were 36 patients with spastic diplegia, two with triplegia, and three with quadriplegia. Thirty-four children (82.9%) were classified as having mild functional disabilities (Groups I and II, capable of walking

FIG. 1. Line graphs showing raw (upper left), normative (upper right), and scaled (lower left) scores of the self-care dimension of the functional skills domain of PEDI. Quantitative evaluations of self-care skills were made using a comprehensive standardized assessment of PEDI scores measured before rhizotomy, at 6 and 12 months postoperatively, and at yearly intervals thereafter. Because normative scores show how close the child is to the healthy population of the same age, they were not available for patients who were 7.5 years or older (the upper limit of the PEDI) at follow up. Because no child was younger than 7.5 years at the 5-year assessment, normative scores (upper right) were only available up to the 3-year follow up. Box-and-whisker plot (lower right) showing scaled scores of the self-care dimension of the functional skills domain of the PEDI. Each box defines the interquartile range, the line in each box represents the median, and the vertical bars represent the 5th and 95th percentile values. The increase in self-care skill from before rhizotomy to 1, 3, and 5 years after rhizotomy was found to be statistically significant (Friedman test, p < 0.001). *Outliers above 95th percentile or below 5th percentile values.

Self-Care Domain Scores

Postoperative assessment of ADL based on the PEDI demonstrated significant improvement in raw, normative, and scaled scores for the self-care dimension in the functional skills domain compared to baseline values before SPR (Fig. 1, Friedman test, p < 0.001). The scaled score for the self-care domain increased from 59 presurgery to 67.9, 81.6, and 82.4 at the 1-, 3-, and 5-year postoperative assessments, respectively. A progressive, clinically significant increase in scaled scores was seen up to 3 years postrhizotomy (Fig. 1 lower right). Thereafter, self-care skills seem to stabilize, as noted in the 5-year measurements. Paired comparisons of scaled scores demonstrated a statistically significant increase in self-care skills following SPR (Table 5); however, the improvement seen between the 3- and 5-year assessments was not significant. Moreover, when scaled scores were compared by patient subgroups (pre-rhizotomy locomotive function), a more pronounced difference was seen. Indeed, a greater benefit from SPR was noted in children with milder motor disabilities (Groups I and II, independent and dependent locomotor, respectively) compared with their less ambulatory counterparts (Group III).
Mobility Domain Scores

Application of the PEDI also showed significant improvement in raw, normative, and scaled scores for the mobility dimension of the functional skills domain (Fig. 2, Friedman test, \( p < 0.001 \)). The preoperative and 1-, 3-, and 5-year postoperative scaled scores for the mobility domain were 56, 64, 77.2, and 77.8, respectively. Follow-up assessments at 3 and 5 years postoperatively demonstrated that the increase in the mobility portion of ADL was durable. Further analysis of scaled scores showed statistically significant improvements in mobility (Fig. 2 lower right and Table 5). Similar to self-care skills, the differences in scores of mobility between 3 and 5 years postrhizotomy did not achieve statistical significance. Also, when scaled scores of mobility in patients in Groups I, II, and III were compared, a greater benefit from SPR was present in patients with mild motor disabilities (Groups I and II), compared with children classified in Group III (Fig. 3).

Functional Outcomes in Patients Excluded From the Valid Study Group

Outcomes were also analyzed for those patients in whom formal baseline and 1-year assessments were performed, but who were excluded from the valid study group because they did not undergo 3-year assessments. Of the 16 patients in this category, follow-up information at more than 18 months after rhizotomy was available for 12 patients. At a mean follow-up period of 25.8 months after SPR, in all children significantly improved self-care and mobility normative and scaled scores were found in both the functional skills and caregiver assistance domains of the PEDI, compared with prerhizotomy values.

Adjunctive Orthopedic Surgery Between 1 and 5 Years After SPR

Children with CP frequently require orthopedic surgery on the lower extremities, for example, tendon lengthenings and osteotomies for contractures and bone deformities that complicate spasticity. In this series, eight (19.5%) of 41 patients required a total of 12 orthopedic interventions (Table 2). No orthopedic procedure was performed during the 1st year following SPR. Four patients (9.8%) required soft-tissue correction within 3 years postrhizotomy and were included in the 3-year outcome analyses. The remaining four patients underwent adjunctive orthopedic surgery 4 or more years after they had undergone SPR.

Surgical Complications

Complications that appeared immediately after surgery were minor, transitory, and similar to those described in the literature. Three cases (7.3%) of urinary retention requiring intermittent catheterization for up to 14 days were documented. This avoidable complication occurred early in the series and has since been minimized by cutting no more than two thirds of the dorsal S-2 rootlets and by leaving the indwelling urinary catheter an additional 24 hours after discontinuation of intrathecal morphine. No cerebrospinal fluid leak, surgical infection, or kyphosis was encountered. No patient required orthopedic correction or trunk bracing of scoliotic deformity following SPR.

Discussion

Rationale for SPR

Selective dorsal rhizotomy has become an accepted treatment option for children with spastic CP. The procedure aims to relieve the velocity-dependent hypertonicity predominantly seen in the lower limbs and to improve motor function in ambulatory children. Several groups have shown that SPR can effectively increase the range of motion of the lower limbs and improve ambulation. The surgical technique consists in selectively inter-
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rupturing the afferent limb of the reflex arc, thereby reducing activity in the aberrant circuit that maintains spasticity. Once the cauda equina is exposed, individual dorsal rootlets are electrically stimulated and the rootlets believed to have the greatest abnormal response on EMG are sectioned. The efficacy of SPR to decrease spasticity is now well established. There is continuing controversy regarding the criteria and methodology for selection of the rootlets to be lesioned, however. In our experience, in addition to identifying pathological reflex circuits for interruption reliably, EMG-guided rhizotomy enables accurate identification of sacral nerve roots involved in bowel and bladder control. Most surgeons continue to use direct dorsal rootlet stimulation with intraoperative EMG response monitoring as an adjunct to clinical evaluation.

Quantitative Assessment of Functional Performance

Reduction of spasticity has predictable benefits, but does not automatically lead to functional improvements. Because the fundamental aim of spasticity-relieving surgical techniques is to improve function, a proper assessment of the effect of treatment must include functional outcome measurements. Once reduction of spasticity, improved joint range of motion, and increased motor strength are optimized through SPR, the therapists can focus on daily activities (such as oral–facial hygiene, grooming, and feeding) with particular emphasis on upper- and lower-extremity dressing and toileting. Mobility issues are further addressed, such as independent sitting and moving in bed; transfer onto a chair or toilet and into a bathtub or car; and indoor and outdoor walking skills. These functional skills, which serve as the foundation to all ADL, ultimately translate into a reduction in caregiver demands for patients with CP and, thus, improve patient independence.

The effects of selective dorsal rhizotomy have been studied from orthopedic and functional perspectives by using standardized assessment tools. A number of different measures have been used to examine the effects of SPR on ADL. In a review of instruments used to assess intervention for spasticity, the PEDI was reported to show promise for demonstrating changes in function with altered spasticity. Also, as pointed out by Campbell,11 opinions of the child’s parents are important and must be taken into account when setting goals, planning treatment, and evaluating outcome. Outcome measures also need to take into consideration the degree of caregiver assistance and independence in the child and family environment. In the PEDI, function is defined as the capacity to perform essential functional skills and complex ADL in the child’s environment. A child may have the necessary ability, but does not use it independently in a safe and appropriate manner, because of parental attitudes or because of differences in environmental factors or social expectations. The PEDI thus provides quantitative, objective measures of the child’s ability to accomplish ADL successfully. Raw scores are converted into normative scores, which are based on the average performance of children without disabilities and provide different kinds of information from scaled scores, which measure an individual’s changes in function over time, thereby showing how much the patient has progressed relative to him- or herself.

The WeeFIM is another evaluation scale of function that has been used to determine the parent’s perception of their child’s abilities. This validated self-care assessment tool is used to measure disability and is designed to track functional status and outcomes over time.

Long-Term Functional Performance

In this study, the PEDI was used as an interview tool to elicit parental assessments of what the child actually does achieve on average. Implementation of the PEDI in this way has been suggested to be more effective than professional assessments based on the PEDI because, owing to its administration in the clinical environment, the therapist is unable to observe the child’s performance of certain functional skills at home. Nevertheless, comparisons of scoring by parents and scoring by therapists have shown that there is a high level of agreement. Several investigators have reported beneficial effects of SPR on quantitative parameters used to assess functional limitations involving sitting ability, ambulation, and motor function. In almost all these studies, however, the researchers used nonvalidated outcome assessment tools. The WeeFIM has been used in two prospective studies, which showed significant improvements in ADL after SPR. The quantitative, validated tool most widely used to assess ADL in children is the PEDI. In three prospective case series in which the PEDI was used, statistically significant improvements in the self-care and mobility domains have been reported following dorsal rhizotomy. Unfortunately, none of these studies contained follow-up data beyond 2 years post-SPR. Our results show that important gains in functional performance are seen as early as 6 months after SPR (Figs. 1 and 2). Furthermore, these clinically significant benefits continue to occur up to 5 years following rhizotomy (Figs. 1 and 2, Table 5).

Milder Preoperative Disability Predicates Better Outcome

As noted earlier, all patients were classified into one of five groups according to their preoperative locomotive abilities (Table 1). Children with mild to moderate degrees of ambulatory dysfunction (Groups I–III) represented 97.6% (40 of 41) of the study population. More detailed analysis of these three subgroups revealed that patients with milder motor deficits (Groups I and II, independent and dependent ambulators) were more likely to improve functional performance at 3 and 5 years following surgery than those who were unable to walk preoperatively (Group III, four-point
crawlers) (Fig. 3). Therefore, children who have some baseline ambulatory function may potentially benefit the most from SPR. On the other hand, severely disabled, nonambulatory patients (Groups IV and V) are likely to attain more modest, yet worthwhile, improvements in ADL even though adequate elimination of lower extremity spasticity is achieved.

Adjunctive Orthopedic Procedures

The management of spasticity in patients with CP is complex and best handled by complementary rather than mutually exclusive neurosurgical and orthopedic treatment options. This study was not designed to determine precisely the effects of botulinum toxin injections or orthopedic interventions in children with spastic CP. They are mentioned in this analysis to help eliminate any potential contribution they could have on long-term functional outcome. The results of our data analysis do not suggest that adjuvant orthopedic procedures performed during the follow-up period had a significant impact on functional performance measures, because the significant gains in these measures occurred during the 1st postoperative year before institution of any orthopedic intervention (Tables 2 and 3). One could argue that significant ongoing gains in self-care and mobility observed at 3 and 5 years postrhizotomy could be partly influenced by orthopedic interventions. To answer this question, we note that only four (9.8%) of 41 patients underwent an orthopedic procedure before the 3-year assessment and that 11 (26.8%) of 41 children received botulinum toxin injections before the 3-year assessment. When these patients are excluded from the analysis of self-care and mobility domains of the functional skills section, a significant gain persists at the 3-year follow-up point compared with baseline and 1-year values. With the exclusion of these patients, at the 3-year follow up, the mean increase in scaled scores of self care was 22.9% (compared with 23.4%) and the mean increase in scaled scores of mobility was 21.1% (compared with 21.8%). Therefore, adjunctive orthopedic procedures do not account for the progressive improvement in ADL seen after SPR.

Areas of Criticism and Concern

Monitoring motor function over time in patients with CP can be quite complex. The child’s development will inevitably change with maturity, due to intensive treatment and enhanced motivation, or with environmental adaptation. The concept of function must remain central to proper assessment of surgical outcomes of patients who have undergone SPR. In the PEDI, the mobility function items are concrete and related to context. Methodological problems arise when the PEDI is used for measuring change over time in a child who gradually improves and uses different and, perhaps, fewer assistive devices. The focus of the PEDI is independent performance regardless of method. Ratings are based on the methods of mobility most commonly used by the child. When function is measured over time, the PEDI score represents the method most commonly used. As pointed out by Nordmark and colleagues,29 if a child used a wheelchair before rhizotomy, but walks with a walker in most situations postoperatively, there is a manifest improvement in walking ability, but a decrease in the capacity for independent mobility according to PEDI. This may be more common for children with severe impairments compared with those with milder impairments. The results of this study clearly indicate that the PEDI is able to measure sensitively and reliably longitudinal changes in functional performance in children with spastic CP who underwent SPR. The scaled scores used in this study allow accurate assessments of progression of individual performance over time, as well as demonstrate gains that these children acquire relative to their peers after SPR.

Another limiting factor observed when using the PEDI is that the skills assessed are unrelated to such higher-level developmental skills as running and cycling. The existence of a ceiling effect has also been confirmed by the developers,22 and is reflected in developmental tables for the normative sample in which 90% of children mastered most of the mobility items by the age of 4 to 4.5 years. Using statistical analysis of validated, standardized functional assessment tools, we have demonstrated that an excellent outcome could be achieved following EMG-guided SPR. This study was a prospective case series, however, and therefore subject to the shortcomings of such an analysis. Randomized controlled trials in which researchers have used the quantitative measures used in the present study, as well as other validated objective, task-oriented measures of ADL, such as the WeeFIM,29,37 would be necessary to make conclusive statements regarding functional performance outcomes following SPR.

Conclusions

The quality of life should be a focus when evaluating outcomes of interventions used in children with CP. Treatments that improve daily function and reduce the degree of disability of the child will be more meaningful than those that change muscle tone or some other aspect of impairment but do not alter function. In this report, we have clearly established that SPR performed using intraoperative electrophysiological monitoring results in significant improvements in ADL and that the benefits are maintained 5 years after surgery. One must be cautious extrapolating that these long-term benefits would be applicable to nonselective dorsal rhizotomy. Further long-term studies using equally validated quantitative outcome measures combined with rigorous statistical analysis are needed to demonstrate conclusively that SPR has a positive impact on functional impairment. This is especially true with a recent trend at some centers not to rely on rootlet stimulation responses. Continued reevaluation and measurement of functional outcomes are critical to the development of meaningful interventions for children with CP and their families.

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