

Functional outcomes following selective posterior rhizotomy in children with cerebral palsy

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✓ The recent increase in popularity of selective posterior rhizotomy demands objective documentation of surgical outcome. For this reason, the authors have analyzed the status of 25 children with spastic cerebral palsy before and after rhizotomy to determine the effects of this therapy on muscle tone, range of movement, and motor function. Postoperative tests showed a reduction in muscle tone compared with preoperative assessments. Range of motion in the lower extremities was significantly increased and improvements in functional gross motor skills were noted. An increase in range of motion in the knees and thighs during gait was detected in 18 ambulatory patients studied with computerized two-dimensional motion analysis. Preliminary findings indicate that selective posterior rhizotomy reduced spasticity, thereby increasing range of motion and contributing to improvements in active functional mobility.

KEY WORDS • spasticity • rhizotomy • cerebral palsy • children

THE selective posterior rhizotomy procedure for spastic cerebral palsy has been increasingly used by pediatric neurosurgeons at major medical centers throughout the United States. Although the value of this treatment has been demonstrated in carefully selected cases,^{1,10} objective documentation of surgical outcome is difficult to achieve and has only recently been addressed.^{6,11} As cerebral palsy is a complex motor disorder which varies in type and severity, and the population under study is maturing with time, several research design issues can be raised. Comparing preoperative and postoperative status without evaluation of the stability of the measurements over time in this population could be misleading. Matching patients to similarly affected controls is nearly impossible as well as controversial. There are also ethical obstacles to randomly assigning patients to treatment groups rather than recommending the best treatment approach based on clinical findings and realistic goals. Although technology for measuring muscle tone, strength, and motor behavior is improving, few clinically applicable tools have been developed for objective measurement of changes in children with cerebral palsy.

We have therefore approached the evaluation of patients undergoing rhizotomy with the following questions in mind. Does selective posterior rhizotomy decrease spasticity? If so, do patients subsequently have increased range of motion? Is function thereby im-

proved? We addressed these questions through a consistent assessment protocol using clinically applicable yet objective measures which were performed before and after surgery. Repeated preoperative assessment of a subset of surgical candidates was added at a later date, allowing preliminary evaluation of maturational effects and the stability of the measures used. By assessing a subset of patients approximately 6 months prior to surgery and then again immediately preoperatively, we could evaluate changes which may be attributed to factors such as growth and development or physical therapy treatment. Repeating the assessment 6 months after surgery allowed evaluation of the effects of surgical intervention.

Clinical Material and Methods

Patient Selection

All potential candidates for surgery were examined by the pediatric neurosurgeon and physical therapist at the same time, and many were evaluated in a special clinic which was also attended by a pediatric orthopedic surgeon. The clinical history was taken from each patient's family to help confirm the diagnosis of cerebral palsy. A history of premature birth was found in 18 of the 25 patients who participated in this study. A neurological examination emphasizing evaluation of muscle tone and movement was performed and the patient's

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strength, range of motion, motor control, postural reactions, reflexes, gait, and functional motor skills were assessed. The presence of contractures and orthopedic deformities was noted. The condition of the hips and spine on x-ray studies was evaluated directly or obtained by report from the child's orthopedist.

Patient selection criteria included the presence of primary spasticity which seriously interfered with function or care but was associated with little or no rigidity, dystonia, hypotonia, athetosis, or ataxia and no significant weakness in antigravity muscle groups of the trunk and lower extremities. Individuals with contractures and deformities were recommended for orthopedic surgery alone or in combination with rhizotomy. Surgical reduction of spasticity was not performed if the patient appeared to be dependent on spasticity for standing and walking. Goals of either improving existing function or easing daily care were established. Preoperative physical therapy was recommended at a frequency of three to five times per week and children were scheduled for surgery approximately 6 months from the initial evaluation. This allowed time for repeated evaluation and preoperative strengthening.

Operative Technique

Selective division of posterior nerve rootlets from L-2 to S-2 was performed bilaterally at the level of the cauda equina, as previously described.¹⁰ The intraoperative electromyographic (EMG) recording technique was expanded to monitor responses from 10 muscle groups simultaneously. Needle electrodes were used to record activity in the hip adductor, quadriceps, tibialis anterior, hamstrings, and gastrocnemius muscles of both lower extremities. Those rootlets associated with gradually decreasing or steady squared-off responses during electrical stimulation at a threshold voltage were spared. Electromyographic responses were classified as abnormal if they were incremental, clonic, multiphasic, or sustained. Rootlets associated with these responses were divided. Responses that spread to inappropriate or contralateral muscle groups were also considered abnormal and used as the basis for rootlet section. The patient's clinical condition, the number and distribution of rootlets being divided, and observable muscle reactions were also taken into account when EMG responses were equivocal. Approximately 60 to 70 rootlets were tested in each patient and about 25% to 50% were sacrificed.

Patients were discharged home after 8 days. Outpatient physical therapy was prescribed at a frequency of 3 to 5 days per week for the first 6 to 12 months.

Patient Sample

All 42 patients who underwent selective posterior rhizotomy between May, 1987, and December, 1988, were entered into the study. Fifteen individuals were unable to return for follow-up evaluation due to the need to travel long distances, but the postoperative course of these patients was monitored by telephone.

TABLE 1
*Scale for grading spasticity**

Score	Definition
0	hypotonic: less than normal muscle tone, floppy
1	normal: no increase in muscle tone
2	mild: slight increase in tone, "catch" in limb movement or minimal resistance to movement through less than half of the range
3	moderate: more marked increase in tone through most of the range of motion but affected part is easily moved
4	severe: considerable increase in tone, passive movement difficult
5	extreme: affected part rigid in flexion or extension

*Scale modified from those of Ashworth³ and Bohannon and Smith.⁵

The 27 individuals who returned for follow-up study included 15 boys and 12 girls with cerebral palsy. Of these 27 children, eight were spastic diplegic patients who walked independently without assistive devices but with abnormal posture; 14 were spastic diplegic or quadriplegic patients who could walk with assistive devices or support; two had spastic quadriplegia and were nonambulatory but could creep on the floor; and three were severely affected, with total body involvement. Only one of these three severely affected patients was included in the study as it was impossible to obtain accurate measurements on the other two children. This child's disability was the result of a severe head injury and he lacked functional independent movement. The mean age at surgery for the 25 patients studied was 5.9 years (range 3.25 to 10.25 years). Additionally, a group of 12 patients (six of whom were also in the group of 25 who returned for follow-up review) underwent both a baseline evaluation (several months before surgery) and a preoperative evaluation (1 day before surgery), which allowed comparison of status over time prior to any surgical intervention.

Evaluation Procedures

One of the authors (a physical therapist with experience in evaluation of children with cerebral palsy) performed the assessments. Preoperative evaluations were made within 1 week prior to surgery, usually 1 day prior to the procedure. Postoperative examinations occurred between 5 and 14 months postoperatively (mean 8.9 months). Baseline evaluations on 12 patients were made between 2 and 7 months prior to surgery (mean 4.6 months). Assessments of muscle tone, range of motion, gross motor skills, and (in ambulatory patients) gait were performed. Some children did not undergo all tests due to either the unavailability of equipment or lack of patient cooperation.

Muscle Tone

Clinical assessment of muscle tone at rest was performed using a variation of the modified Ashworth scale^{3,5} (Table 1). Resistance to passive movement of hip abduction and ankle dorsiflexion was measured

with a hand-held force transducer* as a further indication of muscle tone in hip adductor and ankle plantar-flexor muscle groups. Five myometer measurements were made within the passive range for each motion on the right and left sides. An assistant recorded the digital readout which was not visible to the examiner. Myometer measurements were obtained for 20 of the 25 patients in the study while seven of the 12 patients in the baseline group underwent complete myometer studies.

Range of Motion

Passive range of motion was measured with a plastic manual goniometer. Children were examined in the supine position using standard anatomical landmarks and an assistant stabilized the child in each test position. Two measurements of the following were taken on the left and the right: Thomas test (for hip flexor tightness), popliteal angle (knee extension with the hip flexed to 90°), hip abduction (from midline), ankle dorsiflexion (with the knee extended and foot and ankle supinated), and elbow extension (with the forearm in mid-position).

Function

A videotape recording of each child was made documenting clinical examination of muscle tone and reflexes as well as a functional developmental movement sequence. Sixteen patients were scored on their independence and postural quality during sitting, standing, crawling, and walking. The remaining nine children were scored on their ability to maintain six functional postures and to make five transitional movements between these postures. This was an attempt to rate independence in motor skill without regard to the more subjective attributes of posture and movement quality.

Eighteen ambulatory patients underwent two-dimensional kinematic analysis of gait. The motion analysis system† included a digital camera and microcomputer which sampled up to 50 frames of two-dimensional movement data at a rate of 12 to 15 frames/sec. Retro-reflective markers were placed over the greater trochanter, lateral femoral epicondyle, and lateral malleolus. Children were then asked to walk barefooted across a 5.7-m walkway and a 3- to 4-sec sample of gait data was obtained for the left and right sides. Stick figure diagrams were constructed from the motion data and enabled measurement of thigh motion (vs. the vertical) and knee motion in the sagittal plane.

The mean myometer readings, range of motion measurements, and gait range of motion values were analyzed using paired *t*-tests. A nonparametric test (Wilcoxon signed rank test) was used to analyze the preoperative and postoperative spasticity scale scores.

* Hand-held force transducer (myometer) manufactured by Penny and Giles Transducers Ltd, Christchurch, Dorset, England.

† Motion analysis system manufactured by Microneye Motion Monitor, Boise, Idaho.

TABLE 2
Preoperative and postoperative range of motion (°)*

Test	Preoperative	Postoperative	Difference
lt Thomas test (hip flexor tightness)	-5.6 ± 6.9	-1.4 ± 2.6	4.2 ± 5.4†
rt Thomas test (hip flexor tightness)	-6.3 ± 6.1	-0.7 ± 1.9	5.6 ± 5.3†
lt popliteal angle (hamstrings)	128.7 ± 8.8	144.0 ± 10.7	15.3 ± 12.3†
rt popliteal angle (hamstrings)	125.3 ± 9.0	142.0 ± 11.0	16.5 ± 9.2†
lt hip abduction	24.9 ± 7.8	36.9 ± 7.7	12.0 ± 10.2†
rt hip abduction	25.3 ± 6.5	37.6 ± 10.0	12.3 ± 9.2†
left ankle dorsiflexion	-8.3 ± 9.1	4.8 ± 9.9	13.1 ± 6.4†
rt ankle dorsiflexion	-6.8 ± 8.0	5.9 ± 10.3	12.7 ± 8.1†
lt elbow extension	-1.8 ± 5.2	-1.2 ± 4.0	0.6 ± 2.2
rt elbow extension	-2.4 ± 8.0	3.0 ± 7.9	1.4 ± 4.4

* Values are means ± standard deviation.

† Statistically significant difference, *p* < 0.001 (25 children tested).

Descriptive methods were used to examine the remaining findings. An alpha level of 0.05 was set for statistical significance.

Results

Muscle Tone

No differences were found between baseline and preoperative scores of muscle tone using the spasticity scale. Postoperative values of muscle tone, however, were significantly less than the preoperative values for all lower-extremity muscle groups examined (Fig. 1). Deep-tendon reflexes were absent or diminished and clonus was no longer elicited postoperatively. The mean myometer scores for hip abduction and ankle dorsiflexion for both left and right sides showed no statistically significant change in baseline versus preoperative measurements. Postoperative myometer scores were significantly lower than preoperative readings (Fig. 2).

Range of Motion

Range of motion values for the lower extremities were significantly increased postoperatively but there was little difference in the upper-extremity measurements (Table 2). There were no significant differences detected between the baseline and preoperative measurements of range of motion.

Function

With ordinal scales used for physical therapy assessment of motor function, the evaluation of sitting, standing, and walking ability revealed improvements in several of the 16 patients tested in this way. Nine children scored higher in sitting, seven in standing, two in crawling, and seven in walking. One child had a lower grade in standing and walking and one had a lower grade in crawling due to weakness; however, longer follow-up monitoring revealed that these patients later regained their preoperative functional status. Evaluation of static postures and transitional movement skills in the re-

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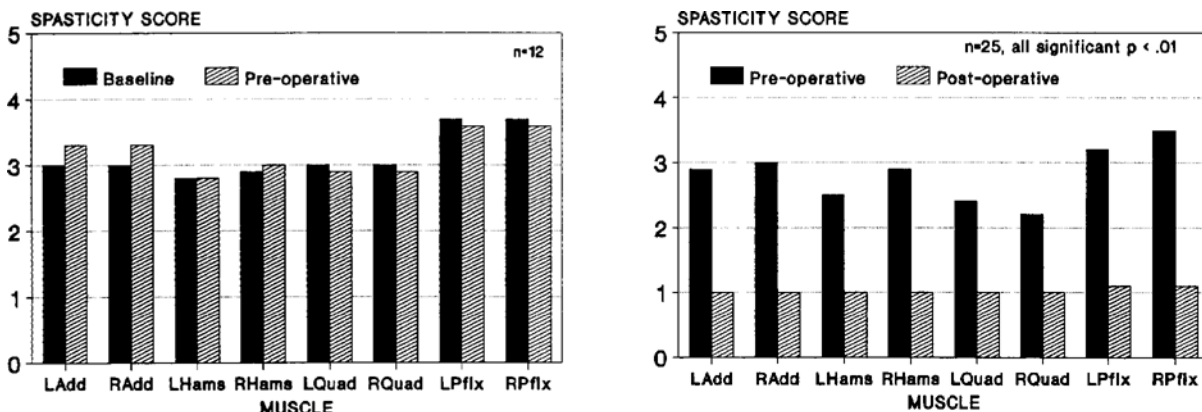


FIG. 1. Spasticity scores as defined in Table 1. Muscles: Add = hip adductor; Hams = hamstrings; Quad = quadriceps; Pflx = plantarflexor. *Left:* Comparison of mean baseline and preoperative spasticity scores in 12 rhizotomy candidates. *Right:* Preoperative versus postoperative mean spasticity scores for 25 patients showing significant differences in all lower-extremity muscle groups tested.

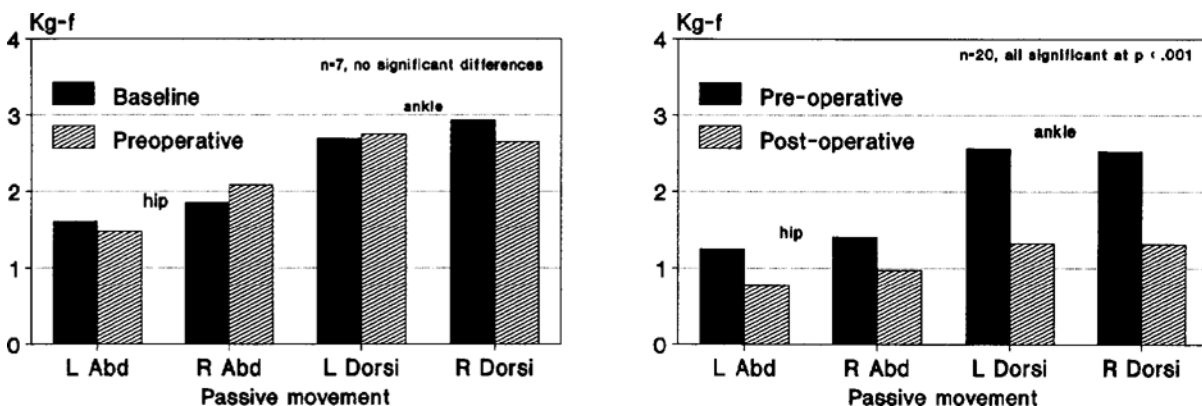


FIG. 2. Myometer results expressed in kg/force; n = number of patients tested. *Left:* Comparison of baseline and preoperative measures of resistance to passive hip abduction (Abd) and ankle dorsiflexion (Dorsi) revealed no change in mean values. *Right:* Preoperative versus postoperative measurements revealing significant reduction in passive force measured.

maintaining nine patients revealed that, postoperatively, five children required less support to maintain a half-kneeling posture, six improved in the transition between kneeling and half kneeling, and four improved in rising to stand from sitting.

Gait analysis revealed an increase in mean thigh and knee motion (Fig. 3). Changes in the total number of degrees of motion, the ranges through which the limbs moved, and the relationship between thigh and knee motion can be observed in the angle/angle plots of individual patients (Fig. 4).

Orthopedic Surgery

Two patients underwent orthopedic procedures approximately 1 year after rhizotomy; preexisting contractures were released in one child, while the other had a tendon transfer for a varus ankle deformity.

Complications

There have been no surgical complications such as wound infection, dural leak, hemorrhage, or sphincter disturbance in this series. Two female patients developed postcatheterization cystitis which was successfully treated with antibiotics.

Discussion

Although postrhizotomy reduction in muscle tone and subsequent improvement in motor function have been noted previously,^{1,10} the outcomes of this study help to confirm these clinical findings with more quantitative methods. Reduction of spasticity is the primary goal of the selective posterior rhizotomy procedure. Our findings of reduced resistance to passive range of motion along with disappearance of tendon reflexes and clonus are believed to be indicative of successful surgi-

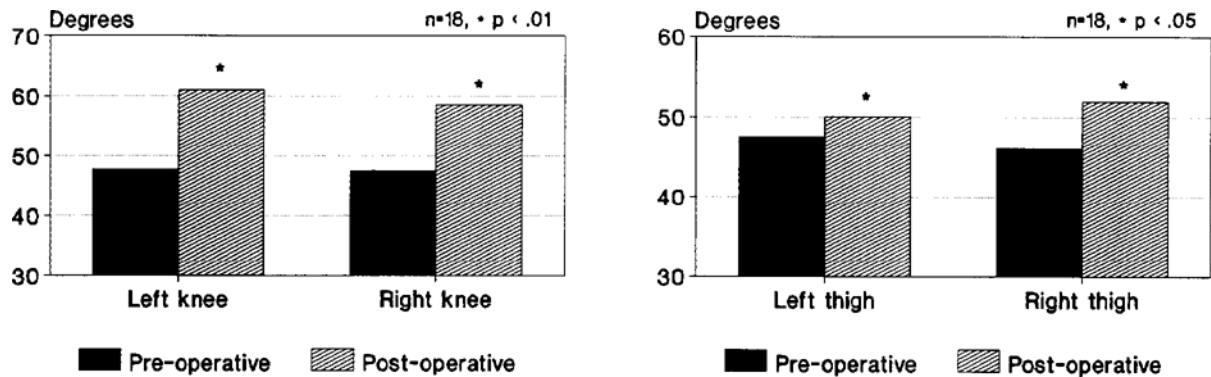


FIG. 3. *Left:* Postoperative improvements in mean knee range of motion measured during gait using the computerized two-dimensional motion analysis for 18 ambulatory patients. *Right:* Postoperative improvements in mean thigh range of motion during gait for the same patients.

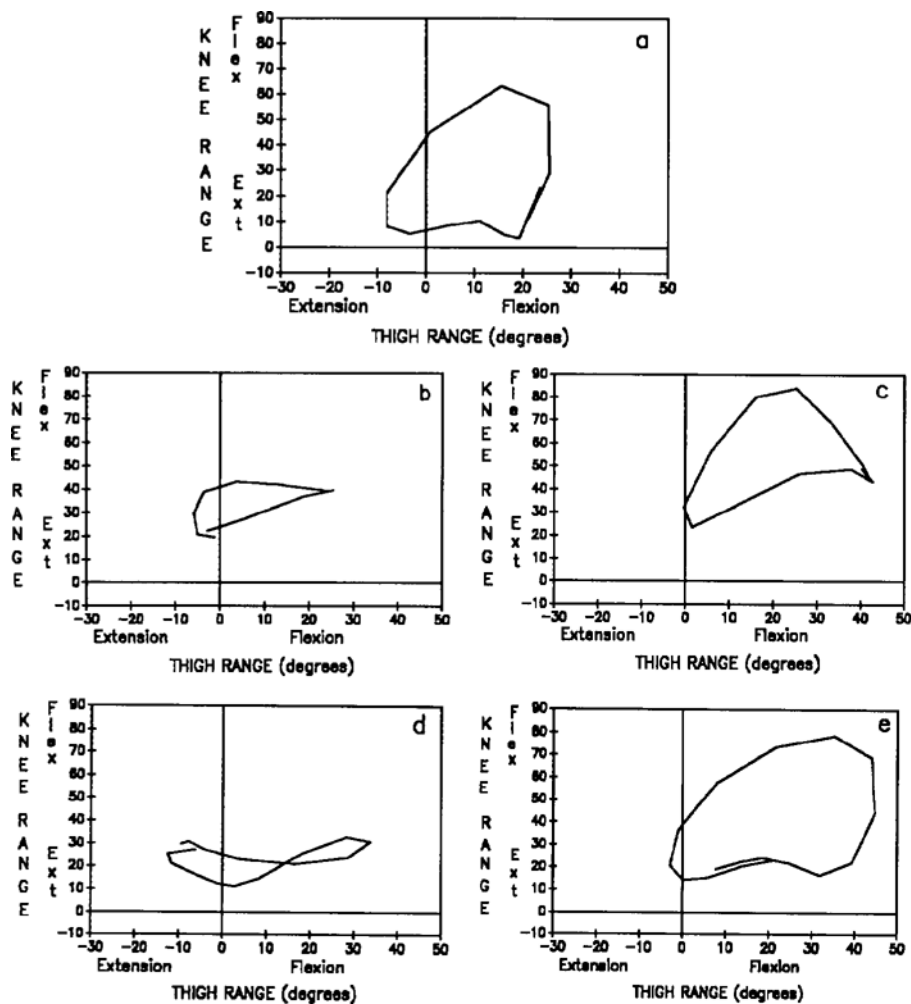


FIG. 4. Normal and abnormal motion diagrams (in degrees). a: Pattern of a normal angle-angle diagram for an unimpaired 5-year-old girl showing the relationships between the thigh and knee angles during one gait cycle. b: Preoperative angle-angle diagram for a 7-year-old girl with spastic diplegia showing limited range of motion. c: Postoperative angle-angle diagram for the same child (see b). Note improvements in range of motion for both thigh and knee. d: Angle-angle diagram for an 8-year-old girl with spastic diplegia obtained before selective posterior rhizotomy. e: Postoperative angle-angle diagram for the same child (see d). Both the range of movement and the relationship between knee and thigh motion appear more normal following surgery.

cal reduction of spasticity. Others have reached the same conclusion based on neurophysiological testing (H reflex)⁷ and EMG recordings in response to quick stretch.⁶ This effect is apparently a lasting one as evidenced by the work of both Fasano and Broggi⁸ and Arens, *et al.*¹ Reduction of spasticity, however, is only valuable if it can increase range of motion and thereby improve patient care and/or function.

Statistically significant improvements of passive range of motion were found at lower-extremity joints. These were also considered to be clinically significant, especially in the popliteal angle, hip abduction, and ankle dorsiflexion which all had mean increases of 12° or more. Although previously published studies on the manual goniometric range of motion of upper extremities and hip motion in spastic children revealed variability in repeated measurements, especially when different testers were used,^{2,4,9} no significant differences were found between our baseline and preoperative range of motion measurements in this patient group.

Previous work has shown that children with spastic cerebral palsy show improvement in motor function which is maintained over time up to 7 years after selective posterior rhizotomy.¹ Our functional assessment of patients also indicated improvement in many patients. Although all children progressed or maintained their motor skills, two had weakness which postponed their functional recovery. This emphasizes the need for careful patient selection and consistent post-operative therapy. A more objective measure of function, namely computerized gait analysis, revealed that children were able to use their increased range of motion during walking. Other instrument-based gait studies have also found increased range of movement accompanied by improvements in stride length and speed of walking.^{6,11} As indicated by our phase diagrams (Fig. 4), the relationship between thigh and knee motion appeared more normal after surgery in individual patients. Thus, improvements in active functional mobility accompanied decreased tone and increased passive range of motion.

Conclusions

In our analysis of a group of spastic children with cerebral palsy who underwent selective posterior rhizotomy, we have concluded that spasticity was reduced as indicated by decreased resistance to passive movement. Range of motion was consequently increased in patients without fixed contractures and this in turn led to improvements in function. The selection of patients

is of primary importance for successful surgical outcome when functional improvement is the goal. Objective analysis of patients in this population continues to be a challenge because cerebral palsy is a multifaceted disorder requiring coordinated management by a team of medical professionals. Selective posterior rhizotomy is an important procedure to consider in the treatment plan for any spastic child, although the benefit of the procedure will be limited by the degree of the child's overall handicap. Fixed deformities of muscle, bone, and joint which are secondary to the increased muscle tone require orthopedic management. Further study of cerebral palsy and the role of selective posterior rhizotomy should lead to improvements in the neurosurgical management of these patients.

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Manuscript received March 15, 1990.

Accepted in final form September 12, 1990.

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