

# Selective Posterior Rhizotomy for Treatment of Spastic Cerebral Palsy

Loretta A. Staudt, MS, PT and Warwick J. Peacock, MD

UCLA Division of Neurosurgery

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Selective posterior rhizotomy is a neurosurgical procedure for reduction of spasticity that has been used successfully for highly selected patients with cerebral palsy. An improved surgical technique was developed in 1981 that is now used at several major medical centers throughout the United States. Physical therapists have a major role in management, including patient referral, preoperative assessment, postoperative treatment, and follow-up. Careful patient selection and intensive postoperative physical therapy are believed essential for optimal outcome. Continued research should lead to refinement of selection and treatment protocols and improved understanding of functional outcome of this neurosurgical procedure.

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Management of cerebral palsy is generally aimed at preventing and reducing deformities, maximizing development of functional skills, and providing appropriate services, equipment, and environment for optimal function. Spasticity is one of the primary features of cerebral palsy that causes deformity and functional impairment. Selective posterior rhizotomy is a neurosurgical procedure currently used for reduction of spasticity in highly selected patients with cerebral palsy. An improved surgical technique for selective posterior rhizotomy, developed in 1981 and introduced to the United States in 1986, is now performed at several major medical centers. Physical therapists have an important role in this form of management. This role includes appropriate patient evaluation and patient referral, pre- and postoperative treatment, and evaluation of outcome. This article will address the rationale of the procedure, patient selection, postoperative clinical findings, and recommendations for the postoperative physical therapy treatment of patients undergoing selective posterior rhizotomy.

## HISTORY

In 1898, Sherrington discovered that hypertonus could be eliminated in decerebrate cats by sectioning

posterior rootlets of the spinal cord.<sup>1</sup> Fifteen years later, Foerster described reduction in muscle tone and improvement in posture and function in patients with "congenital spastic paraplegia" after division of whole posterior nerve roots.<sup>2</sup> They recommended sparing the L4 root to aid in knee extension for standing. In 1967, Gros et al. reported good results using a modification of Foerster's procedure.<sup>3</sup> He resected four-fifths of the rootlets comprising the posterior lumbosacral nerve roots. In 1978, Fasano et al. described a method of selective division of posterior spinal nerve rootlets.<sup>4</sup> Electrical stimulation was used to determine which rootlets were associated with abnormal responses. Peacock et al. modified this surgical technique by changing the site of surgery from the conus medullaris to the cauda equina.<sup>5</sup> This allowed identification and preservation of sacral nerve roots innervating the bowel and bladder. This procedure was found to benefit selected patients with spastic cerebral palsy.<sup>5,6</sup>

## RATIONALE

Cerebral palsy is a multifaceted disorder that varies in severity. One dominant feature of cerebral palsy is spasticity, which is defined as "a velocity-dependent increase in tonic stretch reflexes (muscle tone) with exaggerated tendon jerks, resulting from hyperexcitability of the stretch reflex."<sup>7</sup> Delayed and abnormal movement patterns, contractures, and joint deformities and dislocations are frequently seen in spastic cerebral palsy.<sup>8</sup> The hyperreflexia associated with spasticity is due to a disturbance of spinal cord reflexes from damage to corticospinal pathways, which ultimately results in overactivity of alpha motor neurons.<sup>9</sup> The facilitatory influences of muscle spindle

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Address correspondence to: L. Staudt, MS, PT, UCLA Division of Neurosurgery, 74-137 CHS, Los Angeles, CA 90024.

afferents in the posterior spinal roots remain relatively unopposed. The goal of selective posterior rhizotomy is to reduce spasticity by dividing certain posterior (sensory) rootlets of the second lumbar to the second sacral spinal nerves. Only those rootlets associated with an abnormal electromyographic response to electrical stimulation are divided. The remaining rootlets are left intact to preserve sensation. The procedure reduces segmental level excitation of the alpha motor neuron, counteracting the disturbance in supraspinal inhibitory control. The reduction of spasticity is expected to diminish the threat of complications, such as joint contracture. For severely involved patients without independent motor function, reduction in spasticity is aimed at allowing ease in positioning, patient comfort, and daily care. For individuals who have independent motor function, increased passive and active range of motion and improvement in motor skills including gait are anticipated.

## PATIENT SELECTION

Appropriate patient selection is vital to the success of selective posterior rhizotomy. Concurrent evaluation by the neurosurgeon, physical therapist, orthopedic surgeon, and other specialists in pediatric rehabilitation facilitates this process. Explanation of the benefits and limitations of the procedure and establishment of realistic goals for each child are essential when recommending surgical intervention. Guidelines for selection have been based on a 1 to 5 year clinical follow-up of 60 patients who underwent selective posterior rhizotomy.<sup>5</sup> Those with the most dramatic functional improvements had spastic diplegia, no athetosis, some mode of independent locomotion, and independent side sitting ability. The best candidates for selective posterior rhizotomy are children who have spasticity without dyskinesia, no fixed contractures or deformities, no previous orthopedic surgery, and who display evidence of voluntary strength and selective motor control.<sup>5</sup>

The first step in patient selection is to make a definitive diagnosis of cerebral palsy excluding progressive degenerative disorders of the central nervous system. A history of prenatal, perinatal, or early postnatal insult to the brain should be obtained to assist in making the diagnosis. Neonatal complications such as prematurity and intraventricular hemorrhage are frequently associated with the spastic diplegic type of cerebral palsy.<sup>10</sup> Clinical examination is used to identify the presence of spasticity and confirm the absence of other abnormalities of muscle tone and movement. Increased resistance to passive movement with a "clasp-knife" quality and hyperactive stretch reflexes with or without clonus should be present. Rigidity, dyskinesia (dystonia or athetosis) or ataxia must be ruled out. Rigidity has a quality of constant resistance to passive movement throughout the range. Dyskinesia refers to involuntary movement and fluctuation of muscle tone and ataxia is characterized by lack of postural stability.<sup>11</sup>

The distribution of spasticity is also noted. Children with primarily lower extremity involvement (spastic diplegia) are often good candidates for sur-

gery. Individuals with spastic quadriplegia may also benefit, especially when positioning problems are present. It is the authors' experience that those with spastic hemiplegia are not usually considered for surgery due to potential exaggeration of asymmetry from unmasking weakness of their involved side. They generally achieve good functional status without surgical intervention.

Sufficient underlying strength for antigravity control must be present if functional gains are anticipated. This is especially necessary in muscles used for upright stability including the neck and trunk musculature, hip extensors and abductors, quadriceps, and calf muscles. Evaluation of the ability to control body weight during standing, sitting to standing, and unilateral standing activities is performed. The tasks included on the Rancho Los Amigos Hospital evaluation of Upright Control for hemiplegic patients can be applied in assessing functional strength.<sup>12</sup> It is particularly important to recognize the need for control of the tibia in upright postures. Even children with equinus ankle postures may have insufficient calf strength. The degree to which spasticity contributes to antigravity support should be estimated. Asking the child to stop and start motion on verbal command while performing a slow, graded muscle contraction is helpful in judging voluntary control. Although no formal evaluation of endurance has been performed, the ability to repeat test maneuvers and maintain postures is noted. Selective control is assessed by asking the child to perform isolated motions at the hip, knee, and ankle in various combinations which are not part of total limb synergies. For example, the child is asked to perform knee extension with the hip flexed and ankle dorsiflexion with the knee extended.

It is our opinion that the ideal candidate has no history of orthopedic surgical procedures and no severe contractures or bony abnormalities. Although previous orthopedic surgery does not automatically rule out rhizotomy, surgical reduction of spasticity is not recommended when neurectomies have been performed or when tendons have been over-lengthened. Fixed contractures and spinal deformities are relative contraindications for rhizotomy. Evaluation by the orthopedic surgeon is particularly important in these situations. Orthopedic surgery may be required after rhizotomy if there are pre-existing structural deformities.

Rhizotomy only reduces spasticity. It does not improve the negative features of the upper motor neuron lesion such as weakness and loss of dexterity. Although reduction in spasticity can be very helpful, other aspects of cerebral palsy, such as contractures, weakness, influence of tonic reflexes, poor selective muscle control, and elements of ataxia or athetosis, when present, will continue to affect the functional ability of the child. This makes selection of patients and determination of realistic goals extremely important. Children who display intact trunk righting responses, evidence of underlying equilibrium reactions, and evidence of antigravity and selective motor control are expected to demonstrate optimal functional outcome.

## OPERATIVE TECHNIQUE

Under general endotracheal anesthesia, the child is positioned prone with a bolster under the chest and pelvis. Limited laminectomies are performed from L2 to L5. The spinous process and a small portion of the lamina medial to the facet joints on each side is removed at each level. The dura is opened and the cauda equina is exposed. Two microneurosurgical electrodes are used to stimulate the posterior root and rootlets of each spinal nerve from L2 through S2. The response to electrical stimulation at threshold voltage is monitored by recording electromyographic (EMG) responses from major muscle groups of the lower extremities and by visually observing the legs. A localized nonsustained contraction is considered to be normal. Responses which spread to inappropriate muscle groups or continue beyond the duration of stimulation are considered to be abnormal. EMG responses are analyzed for evidence of irregular reactions to the steady stimulus, such as an incremental or clonic pattern. Rootlets associated with normal responses are spared, while those associated with abnormal responses are divided.<sup>5</sup>

## POSTOPERATIVE CLINICAL FINDINGS

Reduction of spasticity can be appreciated on clinical examination immediately following surgery.<sup>13</sup> Few clinically detectable signs of either cutaneous or proprioceptive sensory losses have been reported postoperatively.<sup>5,14</sup> Hypersensitivity of the feet or legs may be present in the early period following the procedure. This, however, resolves spontaneously within a few weeks.<sup>5</sup> Minor sensory changes have been noted in only 3 out of 52 cases studied in a 3 to 7 year follow-up.<sup>15</sup>

Cahan et al. have reported their findings from electrophysiological studies on 20 patients with spastic cerebral palsy aged 2.5 to 9.8 years who underwent selective posterior rhizotomy.<sup>14</sup> Results of H reflex and cortical somatosensory evoked potential (cSSEP) assessments performed preoperatively and 1 week postoperatively were described. In seven out of eight patients tested using the H reflex, the postoperative  $H_{max}/M_{max}$  ratios were absent or significantly decreased, confirming clinically observed reduction in muscle tone. Cortical somatosensory evoked potentials (cSSEP) of the posterior tibial nerve were abnormal preoperatively in 9 out of 20 patients. Six of these nine children had postoperative improvements in their abnormal cSSEP wave form. Of the remaining 11 patients with normal preoperative posterior tibial cSSEPs, 3 had abnormal alterations in their postoperative studies. The authors concluded that the studies suggest evidence of preoperative spinal cord dysfunction in certain patients, which improved in some after selective posterior rhizotomy. Clinically observed postoperative changes of decreased muscle tone with minimal sensory disturbances were confirmed by electrophysiologic evaluations.

No complications of lumbar laminectomy have been found in children without pre-existing spinal deformity.<sup>5</sup> Yasuoka et al. reported a zero incidence

of spinal deformity in children and young adults following multilevel lumbar laminectomies.<sup>16</sup>

Assessment of patient progress following rhizotomy has been primarily subjective. Foerster published photographs of some of his patients demonstrating improved postoperative postures.<sup>2</sup> Gros,<sup>17</sup> and Fasano et al.<sup>4</sup> also described postoperative results based on clinical evaluation. In the 3 year follow-up on 71 cases by Fasano et al., they noted that patients who could ambulate independently preoperatively continued to do so afterwards.<sup>4</sup> They described decreased adduction, improved knee motion, and a plantigrade foot position in these patients postoperatively. Patients without ambulatory function did not achieve ambulation postoperatively. Laitinen et al. used a Cybex II isokinetic dynamometer to evaluate ankle motion torque before and after selective posterior rhizotomy. In a small group of adult patients with multiple sclerosis they found improvements in plantarflexor torque.<sup>18</sup>

Peacock et al.'s series of 60 patients followed for 1 to 5 years included clinical assessment of muscle tone, power, sitting, standing, walking, upper limb function, and speech using ordinal scales.<sup>3</sup> Evaluations were performed by a neurosurgeon, a pediatric neurologist, and an occupational therapist. Film and video recordings were made of each child and the physical therapists treating the children completed preoperative and postoperative assessments. Three types of patients were identified and grouped for analysis. Negligible benefit was seen in four children with spastic athetosis. Sixteen patients had spastic quadriplegia and reduction of tone was primarily helpful for improved positioning. Forty children with spastic diplegia showed the most functional improvement. Gains were observed in sitting, crawling, standing, and walking skills. Of 14 children in this group who walked independently before surgery, 12 improved their walking pattern. Of the eight spastic diplegic children who walked with a walking aid preoperatively, five achieved independent ambulation, two continued walking with an aid and one child required above-knee braces to walk with an aid. Progression from nonambulatory status to ambulatory status was noted in younger patients, however the effects of maturation were not considered. Weakness was determined to be a contraindication, and the authors acknowledge the need for improved methods of analyzing power in spastic children. For the spastic diplegic group, improvement in upper extremity function was noted in 19 out of 28 patients with upper limb involvement. A positive effect on speech was reported in five out of nine with preoperative speech problems. One possible explanation for this may be the reduction of input in the ascending collaterals of the posterior spinal root neurons. Improvement of sitting posture through reduction of lower extremity spasticity could also contribute to this. Gros<sup>17</sup> and Fasano et al.<sup>4</sup> reported effects of lumbosacral rhizotomy on upper extremity function and speech. Gros called this a "distant effect" which he attributed to an overall reduction of stimuli in interneuronal circuits.<sup>17</sup>

In order to more objectively assess the outcome of surgery, two-dimensional analysis of movement

was used to evaluate changes in gait following selective posterior rhizotomy. Statistically significant improvements in thigh and knee range of motion and stride length were found in a group of 16 ambulatory children with spastic cerebral palsy.<sup>19</sup> We are currently using a similar two-dimensional motion analysis system (Micron Technology Inc., Boise, ID) employing a digital camera and microcomputer to collect motion data in the sagittal plane during gait before and after surgery. Retroreflective markers are placed at the patient's hip (greater trochanter of the femur), knee (lateral femoral epicondyle), and ankle (lateral malleolus). Stick figure diagrams are constructed and analysis of two angles can be made: the angle of the thigh segment versus the vertical and the angle of the knee (Fig. 1). When these angles are plotted against each other the overall range of thigh and knee motion throughout one or more gait cycles can be appreciated (Fig. 2).<sup>20</sup> Pre- and postoperative angle-angle diagrams illustrate the changes in range of motion of an 11 year old boy with spastic diplegia. (Figs. 3 and 4).

### PHYSICAL THERAPY MANAGEMENT

The physical therapist must evaluate and appropriately treat the individual problems of each child.

#### STICK FIGURES

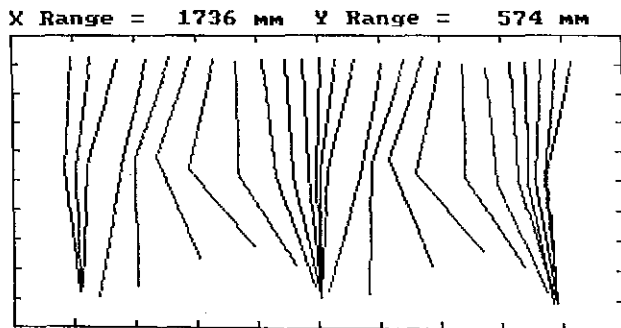


Figure 1. Stick figure diagram of the gait of a normal child from two-dimensional movement analysis.

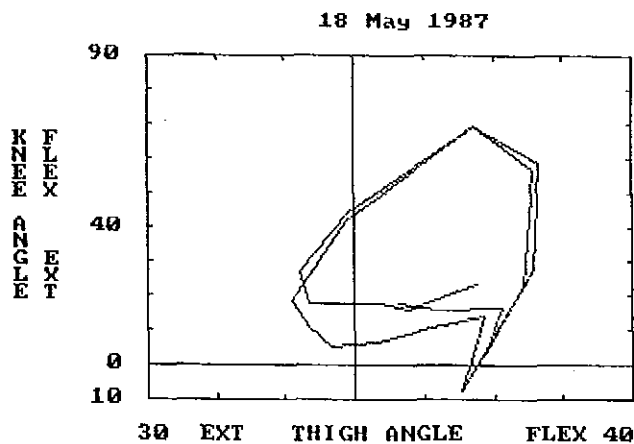


Figure 2. Angle-angle diagram of the gait sample of a normal child seen in Figure 1. The thigh angle is plotted on the x axis and the knee angle is plotted on the y axis.

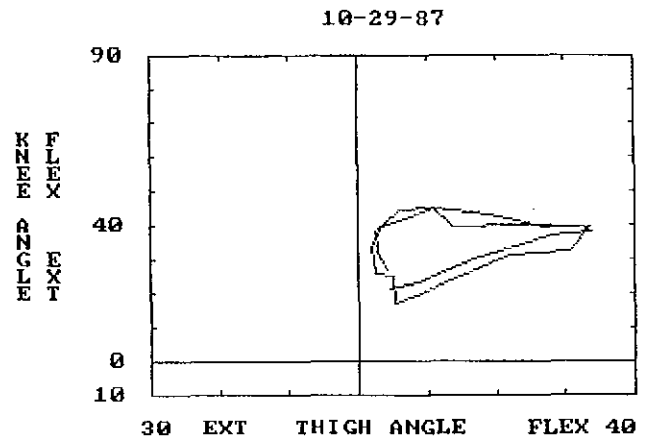


Figure 3. Angle-angle diagram from the preoperative two-dimensional gait analysis of an 11 year old boy with spastic diplegia.

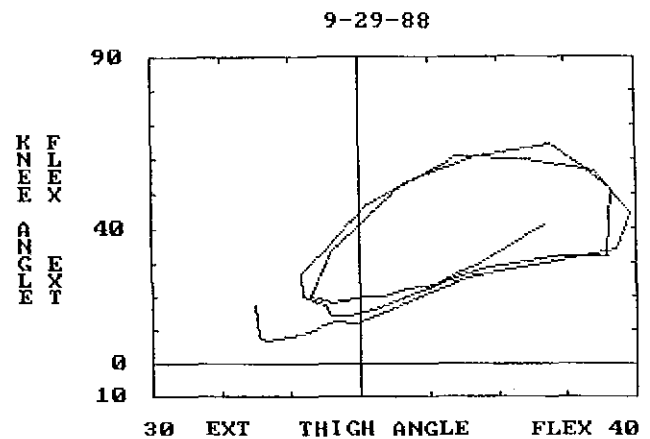


Figure 4. Angle-angle diagram from the postoperative two-dimensional gait analysis of the same child as seen in Figure 3.

Some children benefit from therapy prior to rhizotomy to emphasize strengthening of trunk and lower extremities and prevent losses in range of motion. Intensive physical therapy is recommended after surgery. Treatment should be coordinated with occupational therapy and speech therapy as appropriate to the child's needs.

At UCLA Medical Center, patients are generally hospitalized for 8 days. During the first 2 postoperative days, the emphasis is on nursing care during surgical recovery. Appropriate patient positioning and handling prevent any chance of cerebrospinal fluid leakage. Physical therapy, including positioning, bed mobility, range of motion, active exercise, and family education, begins on the third postoperative day. Patients remain flat in bed until the fifth day to prevent increases in cerebral spinal fluid (CSF) pressure. They are log rolled frequently to reduce bony pressure. Children are progressed to sitting and transfers by the sixth postoperative day. For early sitting, a slightly reclined position with a lumbar roll to maintain extension is usually most comfortable. It is desirable for ambulatory children to experience standing with support prior to discharge.

The neurosurgeon will refer the child for intensive

outpatient physical therapy during the first 6 to 12 months following surgery. Passive movement of the lumbar spine into flexion, lateral flexion, or rotation is avoided during the first 3 postoperative weeks. Lumbar extension is not restricted. Therapy activities requiring these movements may be introduced gradually as the child begins to actively move his trunk without discomfort.

Surgical reduction of muscle tone alters the focus of treatment to emphasize strengthening of muscles and development of active control rather than inhibition of hypertonicity. With reduction of spasticity, other factors that influence motor function, such as weakness, joint range limitations, and motor planning difficulties, may be more clearly seen and addressed. The persistent influence of early reflex patterns and lack of selective motor control may continue to interfere with function, although stretch reflexes are absent or diminished. Therapists must use their knowledge of normal movement, biomechanics, facilitation techniques, and therapeutic exercise to develop an appropriate program for each child. The treatment program should address protection of weak joints and muscles, improvement and maintenance of range of motion, improvement of strength and motor control, and development of functional skills.

Weakness may be observed in muscle groups that were previously spastic, such as the gastrocnemius complex. Orthoses or bivalved casts are used to help control alignment and provide stability of the foot and ankle after rhizotomy. Ongoing modification of these devices may be necessary as progress takes place. This allows the child to develop proximal control and stability while gradually introducing active control of the entire limb. Individuals with insufficient strength or motor control of hip abductors or extensors should be given a walker or crutches for support. A prone stander or child's tilt table may be helpful for early weight bearing. It is important to protect weak joints and muscles by using proper equipment. More challenging positions and activities can be introduced gradually as strength increases.

Specific stretching techniques and a home program for positioning should be used to improve and maintain functional range of motion. Some restrictions in range of motion may be beneficial for function, such as limited dorsiflexion range in an individual with weak calf muscles.

Activities to encourage proximal stability and graded, isolated control of movement are emphasized in the early postoperative period. These include bridging, hip abduction with knee extension, knee flexion with hip extension, and knee extension with the hip flexed and ankle dorsiflexed. All foot and ankle motions can be practiced with varying knee positions. Weight bearing with proper alignment and support is encouraged in the early phase of therapy along with the activation of muscles required for postural stability. If voluntary selective control is present, active and resistive exercises are used to strengthen specific muscle groups. Most children with cerebral palsy have impairment of selective control and tend to move in mass synergy patterns. Strengthening and skill development are usually addressed using neurodevelop-

mental treatment principles. Use of techniques such as proprioceptive neuromuscular facilitation, EMG biofeedback, functional electrical stimulation, and isokinetic exercise should also be considered, if appropriate to the child's needs. Treatment goals should be realistic and incorporate functional skill development.

## RESEARCH NEEDS

Objective evaluation of treatment outcome in cerebral palsy is a challenge. Although selective posterior rhizotomy is aimed at reduction of spasticity, definition and documentation of changes in spasticity is problematical. Sophisticated analysis of spasticity has been attempted by many researchers, but the complex instrumentation required has been described as clinically impractical.<sup>21</sup> Tools such as the isokinetic dynamometer are generally used in adult evaluation and treatment. For adult hemiplegics, the pendulum test for knee extensor spasticity using the Cybex isokinetic dynamometer was shown to be reliable for consecutive trials, but the value of this test for patients with cerebral palsy has not been determined.<sup>22</sup> Armstrong et al. used a myometer (hand-held force transducer) to evaluate resistance to passive motion as an indication of spasticity in individuals with cerebral palsy following treatment with intrathecal baclofen.<sup>23</sup> This tool was found to have good intratester reliability but poor intertester reliability in a study of 30 spastic adults.<sup>24</sup> Others have suggested that passive movement protocols are not valid for quantification of spasticity.<sup>25</sup> Bohannon has evaluated interrater reliability of a modified Ashworth scale with encouraging results.<sup>26</sup> Further study of various methods of evaluating spasticity in children is required to find a clinically useful, reliable, and accurate means of documenting the effects of intervention.

Increased range of motion is also an expected outcome following surgical reduction of spasticity. Standard manual goniometric evaluation has long been used for clinical evaluation and is often used in research. Validity, reliability, and normative data studies for manual goniometric range of motion evaluation of healthy adults indicate that this is a good assessment tool.<sup>27,28</sup> Unfortunately, attempts to establish reliability for these measures in spastic children have revealed variability in interrater and intrarater testing.<sup>29,30,31</sup> Large changes in range of motion would be necessary to indicate significant progress.<sup>30</sup>

Controlled replicable research is lacking for all models of cerebral palsy treatment including selective posterior rhizotomy, orthopedic surgery, and physical therapy. Evaluation of functional changes in children with cerebral palsy usually involves nonstandardized, subjective scoring of motor skills.<sup>32</sup> Recent studies designed to objectively assess the effects of neurodevelopmental therapy (NDT) have failed to demonstrate favorable outcome.<sup>33,34,35</sup> Evaluation tools included standardized tests of normal development and intelligence and rating of postures and movements by "blind" raters. The investigators of these studies reported difficulties in studying treatment effectiveness in cerebral palsy including lack of adequate controls, variability in neurological involvement, difficulty in

matching patients, elimination of examiner bias, and limitations of sample size. Control of confounding factors such as previous surgery, other forms of treatment or developmental stimulation, maturation, and variation in treatment quality and frequency were also noted to be problems.

There is a need for studies of treatment outcome in selective posterior rhizotomy as well as other forms of cerebral palsy management. Development of reliable tools that are sensitive to the expected treatment outcomes for this population would be of great benefit to cerebral palsy research. Computerized gait studies have been recommended for more objective documentation of ambulatory spastic diplegic patients following orthopedic surgery.<sup>36</sup> This may include use of dynamic electromyography (EMG), force plate studies, footswitch stride analysis, energy cost measurement, and motion analysis. Many of these techniques require large financial investment and the support of engineering staff, which limits use in the clinic.<sup>37</sup> Affordable tools such as the hand-held force transducer and two dimensional motion analysis systems can be easily introduced into a clinical setting. Use of more objective measurement methods and long term follow-up of patients after selective posterior rhizotomy will be beneficial in refining the selection process and improving the comprehensive management of children with spastic cerebral palsy.

## CONCLUSION

Selective posterior rhizotomy is a surgical procedure for reduction of spasticity that is used for selected children with cerebral palsy. Appropriate selection of patients and intensive postoperative therapy are felt to be vital to the success of the procedure. For some children, the goals of the procedure include improvement in independent function and mobility. The procedure is also recommended for severely involved children to facilitate positioning and reduce the deforming influence of spasticity.

Physical therapists play an important role in the analysis and treatment of children before and after rhizotomy. Postoperative physical therapy is an integral part of this method of intervention. It is important for therapists to understand the procedure and its goals for appropriate participation in the child's management plan. More importantly, therapists must be actively involved in continued research to improve patient selection and treatment. Although postoperative clinical findings have been encouraging, objective analysis and documentation of these findings is necessary to provide insight into the treatment of spasticity.

Issues related to the long term effects of rhizotomy, the role of postoperative therapy, the development of selection criteria and the comparison of this technique to other management strategies must be addressed. Development of reliable measurement tools are needed to evaluate children with cerebral palsy before and after all types of surgical and therapeutic intervention.

Although initial reports suggest that selective posterior rhizotomy is an effective method for reduction

of spasticity in cerebral palsy, spasticity is only one aspect of this multifaceted disorder. A comprehensive team approach is needed for appropriate management of all aspects of cerebral palsy.

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