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Effects of Selective Posterior Rhizotomy on Motor Control and Gait in Children with Cerebral Palsy

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This study evaluates how selective posterior rhizotomy (SPR) affects the motor control pattern of children diagnosed with cerebral palsy (CP) by using polyelectromyography and gait performance. Twenty-four spastic children diagnosed with CP aged 3 to 16 years old were included in this study. Another twenty children diagnosed with CP who had only undergone rehabilitation were selected as the control group. The children diagnosed with CP received polyelectromyography and gait analysis within one month before treatment (SPR or only rehabilitation) and 9 months to 1 year after treatment. Gait analysis included gait patterns and kinematic parameters. The gait patterns were scored by the shapes of their gaitline and cyclogram. The motor control patterns were scored by their temporal and spatial features using polyelectromyography. The cerebral palsy patients were divided into independent, dependent, and non-ambulators groups. Motor control and gait patterns significantly improved after SPR than when only rehabilitation was performed; positive changes were also observed in kinematic parameters before and after SPR. In addition, although motor control after surgery significantly improved in the independent and dependent ambulator groups ($p<0.01$), the non-ambulator group did not. Closely examining the changes in their gaitlines and cyclograms revealed that the independent and dependent ambulators significantly improved as well. Results in this study suggested that motor control and gait patterns improved after SPR at around 1 year among the independent and dependent ambulators groups. However, these progressions were insignificant in the non-ambulators group. (J Rehab Med Assoc ROC 1999; 27(3): 103 – 115)

Key words: Cerebral palsy, selective posterior rhizotomy, motor control, gait analysis

INTRODUCTION

Cerebral palsy (CP) refers to a group of disorders characterized by abnormal control of movement or posture, and is due to damage to the immature brain before, at or shortly after birth [1]. Upper motor neuron syndrome usually results in paresis, loss of dexterity, or spasticity due to velocity-dependent disinhibition of tonic stretch reflexes and lack of selective motor and postural control. The types of CP are defined according to neuromotor deficits, including spastic, dyskinetic, ataxic,

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or mixed CP. Among them, the spastic form has received the majority of attention.

Some degree of spasticity can be useful, particularly in the lower limb, making it possible for the CP child to transfer. However, in its advanced stages, spasticity impedes residual muscular strength and functionally disables the CP child. Moreover, clonus may intefere with the individual's ability to walk or even rest. Treatment alternatives for spasticity include physical therapy, orthosis, medication, and surgery, including selective posterior rhizotomy (SPR). Fasano et al. [2] and Laitinen, et al., [3] performed SPR to pick up and section of the abnormal firing rootlets by intra-operative stimulation of the individual rootlets. The abnormal firing roots were determined by the abnormal electromyographic (EMG) response, such as through tetanic contraction or overflow patterns. This procedure gained widespread acceptance after Peacock and Arens [4] moved the site of operation into the lumbosacral canal (L2 to L5 laminectomy) to ensure that the lower sacral nerve roots involved in bowel and bladder control would be preserved. That investigation achieved dramatic success in relieving spasticity. Numerous investigations having adopted this procedure conferred that spasticity was significantly reduced and mobility and self-care were improved [4-9].

A related study has proposed that the afferent input from the posterior nerve root ascends and synapses with anterior horn cells at many levels of the brainstem nuclei, thus providing a theoretical basis for the suprasegmental reduction in spasticity observed following SPR [9]. Another investigation reported on loss or diminution of H-reflexes in most patients with a reduction in tendon reflexes postoperatively [10].

However, as generally accepted that spasticity and impaired motor control in CP children are separate and distinct components of the upper motor neuron syndrome. Extensive research on locomotor control in vertebrates [11] has led to the conjecture that central pattern generators (CPGs) interacting with sensory mechanisms generate the basic rhythm of human locomotion [12-14]. The immature locomotor pattern of newborn infants mainly reflects the expression of these spinal mechanisms [14]. Supraspinal control over these basic neural mechanisms increases with age, enabling the development of a plantigrade gait with significant modifications of the muscle activation pattern in non-disabled children, whereas children with CP retain the immature pattern. Thus, the movement dyscoordina- tion during locomotion and postural adjustments found in children with spastic CP appears to be partially attributed to an injury of the supraspinal motor systems influencing the later development and refinement of motor patterns produced mainly at a lower level in the motor system. Some studies have concluded that the muscle activation patterns (EMG phasing) during walking remained unchanged after SPR [5,15].

This study compares the motor pattern of the CP children pre-and postoperatively in the supine position rather than walking to minimize the influence of weakness or poor endurance of the leg muscles. Gait parameters are obtained for comparison through simplified analysis using the Computer DynoGraphy (CDG) system.

METHODS

Subjects

The study group consisted of twenty-four children diagnosed with spastic CP (16 boys and 8 girls), ranging from between 3 and 16 years old. Twenty patients were diagnosed with spastic diplegia and four were diagnosed with spastic quadriplegia. Those patients were divided into three groups: independent ambulators (n=10), dependent ambulators (n=10) (requiring a walker, rollator or crutches for assistance in walking), and non-ambulators (n=4). The three non-ambulators had a significant degree of spasticity in lower extremities, and the motor abilities of those patients did not improve for 12 months even under rehabilitation program. After SPR, all patients were involved in a rehabilitation program of different intensities for about 9 months to 1 year. Another twenty children diagnosed with CP who had only rehabilitation (11 boys and 9 girls) were selected as the control group; in addition, the content of therapy was similar to that of the SPR group. Each child underwent motor control assessment and gait analysis within 1 month before and 9 months to 1 year after treatment (SPR or only rehabilitation).

Instrumentation

Myosystem 2000 (Noraxon Inc, Arizona, USA) was utilized to acquire signals from nine channels, of which, eight signals were from surface EMG on bilateral lower limbs. The last channel was used to record the maneuvers undertaken (event marker). The raw EMG electrical signals were band-pass filtered (20-200Hz) and sampled at 1000Hz. The signals were rectified and low-pass filtered (with a cutoff frequency of 6 Hz). A computer-assisted gait analysis system, CDG (Infotronic, Netherlands) was used to assess the gait in all children. This system consisted of a pair of instrumented shoes, a portable data logger and a analysis computer. Each shoe was instrumented with eight force sensors distributed over the shoes as shown in Figure 2a. The forces exerted on each sensor , as sampled at a rate of 50 Hz, were recorded by a portable data logger over 20 seconds of the recording period. Finally, the data logger was connected to the analysis computer for data transmission and analysis.

Procedure for Brain Motor Control Assessment (BMCA)

PEMG recordings were used to document volitional maneuvers during a standardized protocol for BMCA as described elsewhere [16,17]. Recordings were made using pairs of Ag/AgCl surface electrodes 3 cm apart over the midline of muscle bellies of the quadriceps, hamstring, tibialis anterior, and triceps surae muscles of each leg. While lying comfortably in the supine position on a firm bed, the children were asked to do multi-joint movement: hip and knee flexion and extension of each leg alternately with an event marker for three times. Weight support of the leg by the examiner was allowed in some dependent CP children.

Firing of muscles of the lower limbs (temporal features) and the amplitudes of EMG activities (spatial features) were analyzed. The temporal features included co-activation of ipsilateral, contralateral, or bilateral muscles during agonistic muscle firing. The EMG activities was classified into appropriate and reduced according to a 5-point quantification scale by Perry (4/4 is maximal, 3/4 is moderate, 2/4 is minimal, 1/4 is trace, and 0/4 is no activity) [18]. The EMG activities were considered as appropriate if amplitudes were larger than minimal activities, or as reduced if not. PEMG patterns were scored into seven patterns according to the temporal and spatial features of EMG activities. Figure 1 shows the temporal and spatial features of seven PEMG patterns: 1. appropriate agonist (quadriceps) activities with significant reciprocal inhibition of the antagonist (hamstring); 2. appropriate agonist activities with co-contraction in the distal muscles (tibialis and triceps surae); 3. appropriate agonist activities with co-contraction in the distal muscles and co-activation of bilateral muscles; 4. appropriate agonist activities with co-contraction in both proximal (quadriceps and hamstring) and distal muscles; 5. appropriate agonist activities with co-contraction in both proximal and distal muscles and co-activation of bilateral muscles; 6. diffuse co-contraction and co-activation of all muscles; and 7. reduced agonist activities with co-contraction or co- activation of other muscles.

Procedure of Gait Analysis

CDG can provide the following gait parameters: duration of the gait cycle (s), velocity (km/h) step length (cm), cadence (steps/min), and double and single support time (s). Using a tape measure, a staff member measured the walking distance of a subject during a recording period. These data were then input into analysis software to calculate the average step length and walking speed of the subject.

A CDG scoring system was also developed through foot pattern recognition, as classified into four categories. The gaitline patterns from fast enrollment were classified into four scores: 1. normal (the gaitline from hindfoot to forefoot with an adequate length of the gaitline); 2. calcaneal gait (the gaitline from hindfoot to forefoot, but shorter in length than normal); 3. midfoot gait (the gaitline from the midfoot to forefoot, and remarkably shorter than normal); and 4. tip-toe gait (only forefoot contact) (Fig. 3). The cyclogram patterns from the bipedal phases were also graded into four scores: 1. normal (the symmetric butterfly shape, the center located at midpoint or less than 2 squares to the midpoint); 2. mild abnormal (the cyclogram in an asymmetric butterfly shape, and the center located more than 2 squares to the midpoint); 3. moderate abnormal (the cyclogram in a triangular or rectangular shape); and 4. severe abnormal (the cyclogram in an irregular shape) (Fig.4). While using the foot pattern classification of children inflicted with CP, our previous study proved that these four different patterns in both gaitline and cyclogram were parallel to the clinical evaluation by Minear's Classification [19].

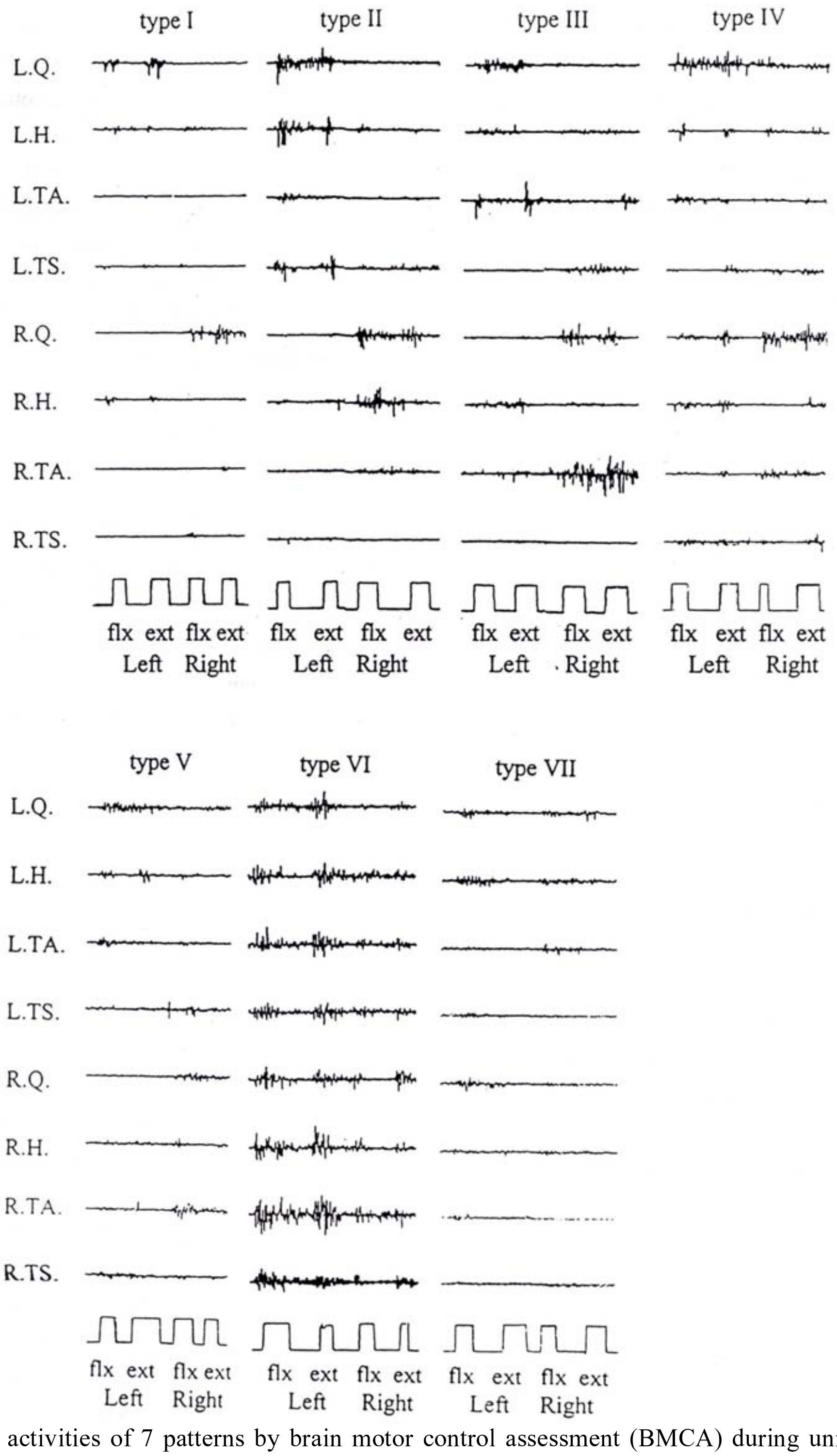


Figure 1. The EMG activities of 7 patterns by brain motor control assessment (BMCA) during unilateral hip and knee flexion and extension: (1) The normal EMG activities over ipsilateral proximal leg muscles; (2) the EMG activities over ipsilateral proximal and distal muscles in reciprocal pattern (agonist > antagonist); (3) the EMG activities over bilateral legs muscles, but more in proximal part in reciprocal pattern (agonist > antagonist, ipsilateral > contralateral); (4) the EMG activities over both proximal & distal muscles of bilateral legs (agonist > antagonist, proximal >distal); (5) the EMG activities increased in both proximmal & distal muscles of bilateral legs (agonist > antagonist); (6) the EMG activities in both agonist and antagonist of muscles of bilateral legs; (7) generalized decrease of EMG activities in all muscles.

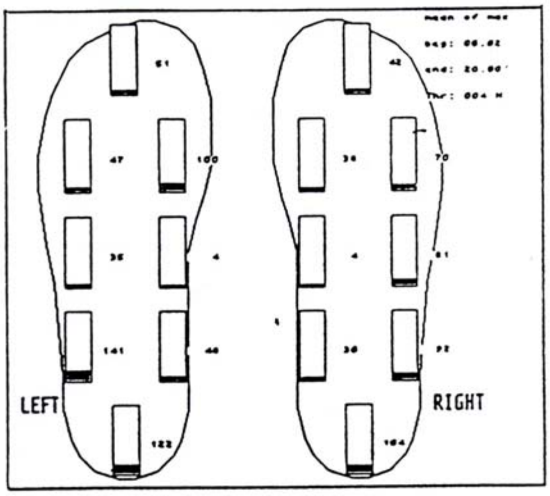


Figure 2. The position of the 8 load sensors on left and right shoes of CDG system.

Data Analysis

Velocity and step length were normalized by the subject's body height. Double and single support time were expressed as the percentage of the duration of the gait cycle. Differences in the age, body height and body weight between CP children with SPR and only rehabilitation were compared with a Student's t-test. A paired t test was used to test the changes for velocity, cadence, step length, double and single support time. In addition, a non-parametric Wilcoxon signed rank test was used to test the changes in gaitline, cyclogram, and BMCA scores between, before and after treatment (with SPR or only rehabilitation). Data were considered statistically significant at a level of $p<0.05$.

RESULTS

CP children with SPR and those who only had rehabilitation did not significantly differ in terms of age, body height and body weight (Table 1).

The changes in BMCA, gaitline, and cyclogram patterns between two treatment strategies. are listed in Tables 2 and 3. The BMCA, cyclogram and gaitline patterns revealed that although CP children with SPR ($p<0.01$) significantly improved, no significant improvement was made except for the cyclogram in CP children with rehabilitation. The walking velocity, cadence, step length increased significantly after SPR ($p<0.05$), but did not significantly change except for cadence before and after only rehabilitation (Table 4).

Table 1. The comparison in the age, body height and body weight between CP children with SPR and only rehabilitation

Parameters \ groups	CP Children		P value
	Patients with SPR (n=24)	Patients with rehabilitation (n=20)	
Age (years)	6.4 ± 3.7	5.1 ± 1.8	0.158
Body height (cm)	107.3 ± 19.5	101.4 ± 13.9	0.257
Body weight (kg)	20.4 ± 12.0	16.2 ± 5.2	0.135

Table 2. The changes in BMCA patterns between two treatment strategies

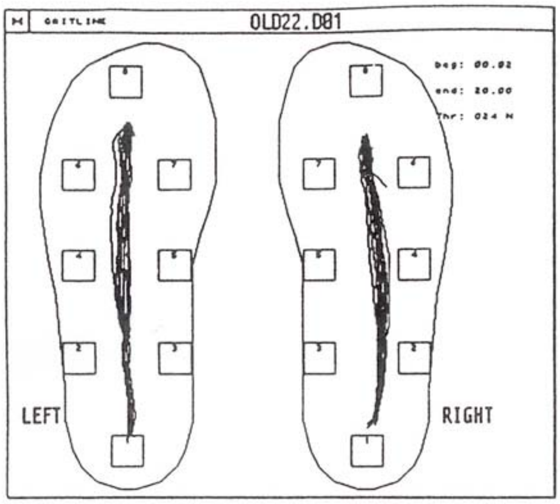
Categories of Improvement (before→after)	BMCA	
	Numbers of patients with SPR (n=24)	Numbers of patients with rehabilitation (n=20)
7→6	2 (8.3%)	
6→6	5 (20.8%)	1 (5%)
5→5	5 (25.0%)	4 (20%)
5→4	2 (4.2%)	
5→3	7 (29.2%)	2 (10%)
4→4		3 (15%)
3→3	3 (12.5%)	5 (25%)
3→2		2 (10%)
2→2		3 (15%)
P value	0.002*	0.063

*: $p<0.01$; (before→after): the scores from before SPR or rehabilitation to after SPR or rehabilitation

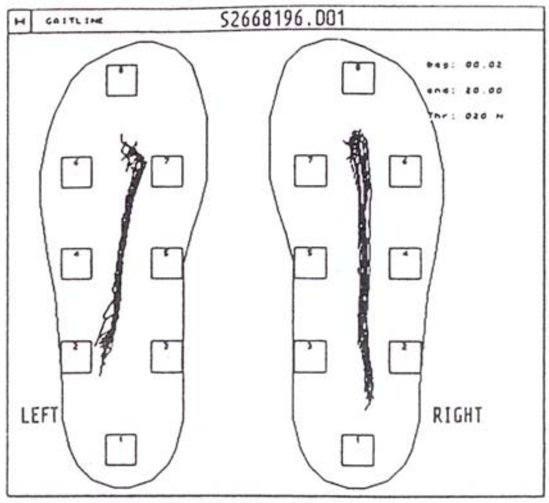
Table 5 lists the BMCA, cyclogram and gaitline patterns compared between before and after SPR in CP children. Although the independent and dependent ambulator groups ($p<0.05$) significantly improved in terms of motor control after surgery, the non-ambulator group did not. According to the changes of cyclogram and gaitline pattern in ambulatory children before and after SPR, both the independent and dependent ambulators groups ($p<0.05$) significantly improved. The walking velocity, cadence, and step length significantly increased in the dependent ambulators group after SPR (p<0.05), while the independent ambulators group increased only in step length (p<0.05) (Table 6).

DISCUSSION

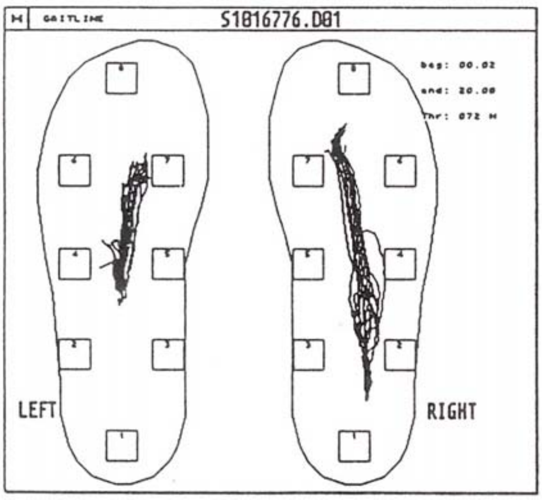
This study has demonstrated that, although children inflicted with SPR significantly improved in terms of the BMCA and gaitline, CP children who had only undergone rehabilitation did not. McLaughlin et al (1994) observed mean improvements post-SPR in muscle tone on the modified Ashworth Scale in the lower extremities of children inflicted with spastic diplegia and decreased significantly in toe-walking gait [20]. Our previous study reported a significant reduction in muscle tone in CP children with SPR than in CP children who had only rehabilitation [21]. In this study, our finding that gait



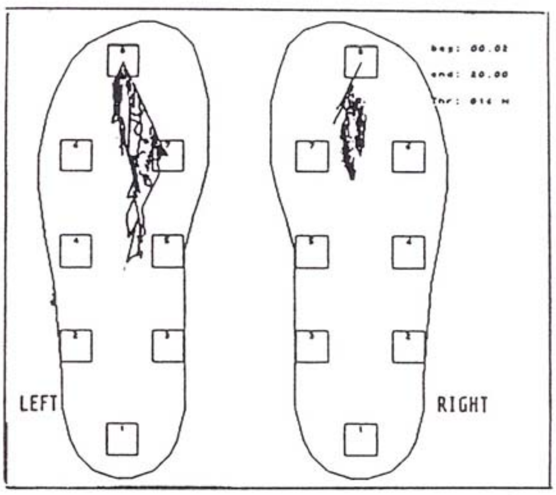
1. Normal



2. Mild abnormal

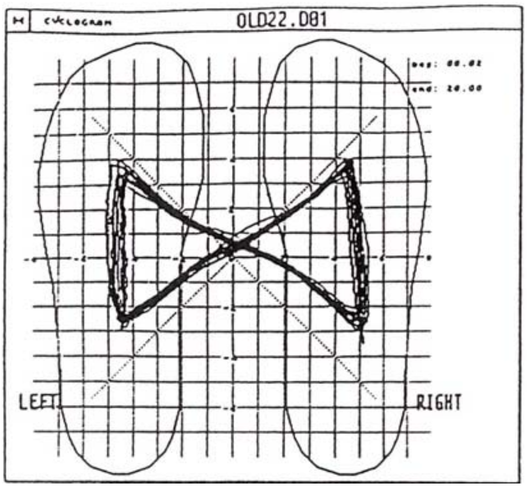


3. Remarkable abnormal

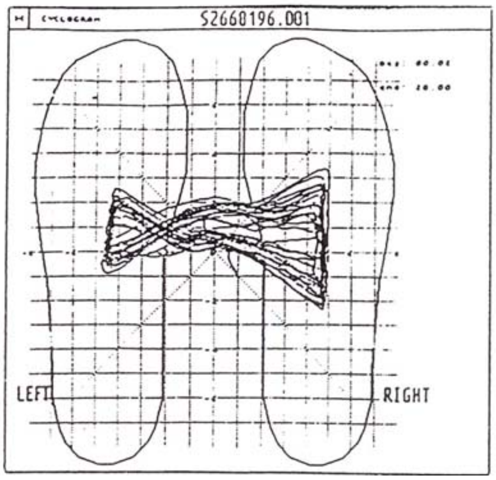


4. Severe abnormal

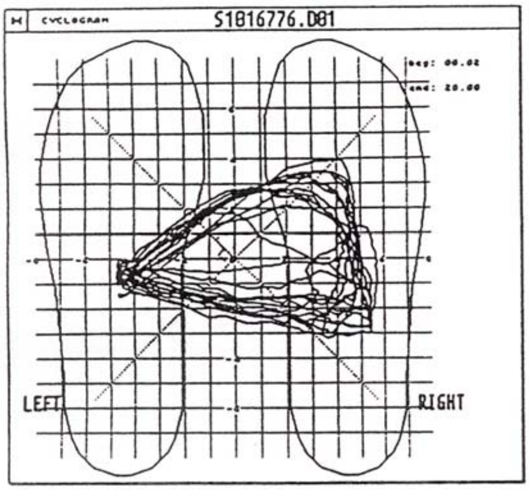
Figure 3. The gaitline patterns from the foot enrollment by computer DynoGraphy (CDG) were classified into 4 scores. 1. normal (the gaitline from the hindfoot to the forefoot with an adequate length of the gaitline); 2. calcaneal gait (the gaitline from the hindfoot to the forefoot, but shorter in length than normal); 3. midfoot gait (the gaitline from the midfoot to the forefoot, and remarkably shorter than normal); and 4. tip-toe gait (only forefoot contact).



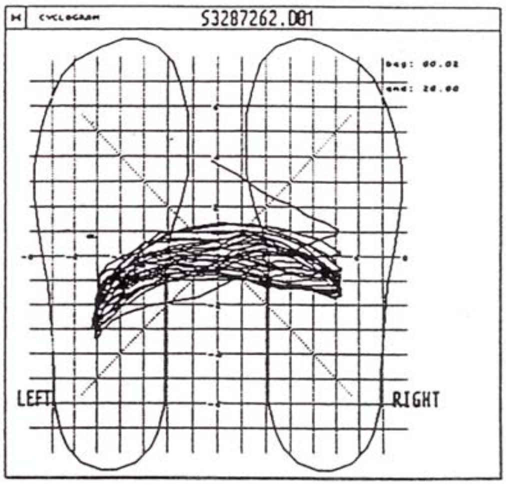
1. Normal



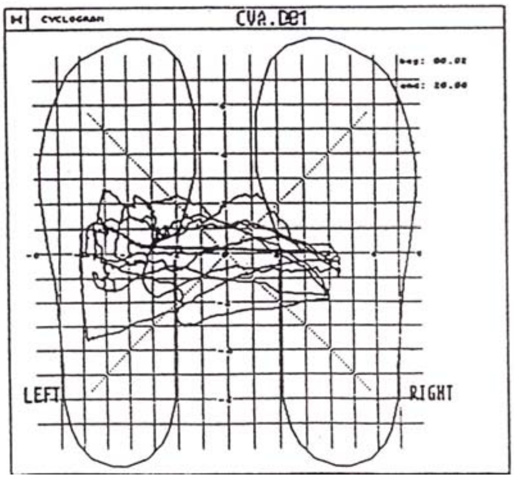
2. Mild abnormal



3. Moderate abnormal (I)



3. Moderate abnormal (II)



4. Severe abnormal

Figure 4. The cyclogram patterns from the bipedal phases by computer DynoGraphy (CDG) were graded into 4 scores. 1. normal (the symmetric butterfly shape, the center located at midpoint or less than 2 squares to the midpoint) ; 2. mild abnormal (the cyclogram in an asymmetric butterfly shape, and the center located more than 2 squares to the midpoint); 3. moderate abnormal (the cyclogram in a triangular or rectangular shape); and 4. severe abnormal (the cyclogram in an irregular shape).

Table 3. The changes in gaitline and cyclogram patterns between two treatment strategies

Categories of Improvement (before→after)	Gaitline		cyclogram	
	Number of patients with SPR (n=20)	Number of patients with rehabilitation (n=20)	Number of patients with SPR (n=20)	Number of patients with rehabilitation (n=20)
4→4	1 (5%)	2(10%)	1 (5%)	2 (10%)
4→3	8 (40%)		2 (10%)	
3→4		2(10%)		
4→2			2 (10%)	
3→3	7 (35%)	11(55%)	4 (20%)	5 (25%)
3→2	3 (15%)	2(10%)	5 (25%)	4 (20%)
3→1			1 (5%)	
2→2	1 (5%)	1(5%)	2 (10%)	7 (35%)
2→1			3 (15%)	2 (10%)
1→1		2(10%)		
P value	0.001*	0.655	0.001*	0.014**

*: p<0.01; **: p<0.05; (before→after): the scores from before SPR or rehabilitation to after SPR or rehabilitation.

Table 4. The parameters of gait analysis by CDG compared between before and after treatment (SPR or only rehabilitation) in CP children

Parameters	CP Children	
	Patients with SPR (n=20)	Patients without SRP (n=20)
Velocity (%BH/sec)		
Pre	33.2±17.1	48.3±26.9
Post	44.2±17.1	50.3±24.6
p value	0.007*	0.223
Cadence (steps/min)		
Pre	83.3±26.1	105.5±27.4
Post	98.3±21.3	110.4±24.2
p value	0.013**	0.065
Step length (%BH)		
Pre	21.0±7.0	26.4±9.0
Post	30.5±13.5	24.7±7.4
p value	0.011**	0.204
Single support (%GC)		
Pre	36.9±8.7	41.1±14.7
Post	34.3±6.9	36.8±8.0
p value	0.192	0.257
Double support (%GC)		
Pre	35.4±15.9	31.7±13.7
Post	34.9±13.3	34.0±11.7
p value	0.897	0.505

**: p<0.05; *: p<0.01; pre: before of SPR (or only rehabilitation); post: after of SPR (or only rehabilitation); BH: body height; GC: gait cycle

Table 5. The BMCA, gaitline and cyclogram patterns compared between before and after SPR in CP children

	CP Children		
	Independent ambulators (N=10)	Dependent ambulators (N=10)	Non-ambulators (N=4)
BMCA			
Improved	6	5	
Non-improved	4	5	4
p value	0.02**	0.038**	1.0
Gaitline			
Improved	6	7	NA
Non-improved	4	3	
p value	0.023**	0.011**	
Cyclogram			
Improved	5	6	NA
Non-improved	5	4	
p value	0.025**	0.014**	

**: p<0.05; *: p<0.01; A Wilcoxon signed rank test was used to compare between before and after SPR.

Table 6. The parameters of gait analysis by CDG compared between before and after treatment SPR in CP children.

Parameters	CP Children	
	Independent ambulators (n=10)	Dependent ambulators (n=10)
Velocity (%BH/sec)		
Preoperative	38.1±15.7	28.0±18.0
Postoperative	49.0±10.5	39.3±20.7
p value	0.088	0.044**
Cadence (steps/min)		
Preoperative	92.8±22.2	74.5±28.0
Postoperative	99.8±19.1	94.0±26.1
p value	0.368	0.023**
Step length (%BH)		
Preoperative	22.9±7.7	18.0±5.1
Postoperative	30.0±4.0	30.2±9.0
p value	0.041**	0.025**
Single support (%GC)		
Preoperative	36.9±11.3	33.8±20.2
Postoperative	32.3±7.3	37.5±17.5
p value	0.172	0.552
Double support (%GC)		
Preoperative	35.0±6.9	38.9±10.1
Postoperative	35.6±4.1	33.1±8.9
p value	0.812	0.056

**: p<0.05; BH: body height; GC: gait cycle

pattern associated with clinical ambulatory capability suggests that differences in the motor control could determine the gait performance. Winters TF et. al also classified the patients into the four groups and assessed association with the usage of the orthosis by analyzing kinematics data in the sagittal plane and EMG data in hemiplegic CP with walking independently [22]. SPR can improve gait performance in CP children with ambulatory abilities. Our results also indicated that gaitline and cyclogram patterns were improved after SPR in both dependent and independent ambulators groups. Other studies also revealed that SPR could significantly improve foot contact patterns [23] and ankle joint angles during walking in children inflicted with CP [19, 24, 25]. Thus, SPR can facilitate a better gait pattern by decreasing the plantar flexor spasticity and improving motor control capacity.

According to our results, the BMCA of the lower limbs of children inflicted with CP in a supine position can be analyzed as seven different patterns which resemble the findings of Tang [17] involving patients with incomplete spinal cord injuries. Only one BMCA pattern (pattern 1) was obtained in normal children, while six BMCA patterns (patterns 2-7) were identified in all CP children. Patterns 2 and 3 might be due to a lower threshold for stretch reflex activation with premature activities in distal muscles. Patterns 4 and 5 might be due to a lower threshold for stretch reflex activation in both proximal and distal muscles. Motor control disorganization, characterized by disruption of the normal sequential firing of leg muscles, was found in patterns 6. Reduced EMG activity on volitional movement in pattern 7 was observed. Co-contraction of antagonist muscles in both proximal and distal muscles (patterns 4 and 5) interferes with the independent ambulatory capability. In addition, diffuse co-contraction and co-activation of bilateral muscles (pattern 6) with disruption of the normal sequential firing of leg muscles interfere with both the independent and dependent ambulatory capabilities. Prominent weakness due to decreased EMG activities (pattern 7) necessitates that the CP children use assisted devices or braces to walk.

CP children with patterns 2 to 5 had better results, in which patterns 6, 7 were difficult to find any improvement after SPR. This is an important finding because PEMG patterns may allow the physician to select the appropriate spastic CP children to receive SPR with satisfactory results. Our results indicate that SPR improved the BMCA patterns both in the independent and dependent ambulators groups, but not in the non-ambulators group. This finding suggests that SPR improved motor control for spastic CP children with better motor control and ambulatory capability, but not for those with poor motor control and ambulatory capability. Most CP children with pattern 6 still required a long leg brace or rigid AFO with walker to assist walking even 2 to 3 years after surgery. Most children with pattern 7 can not walk due to prominent weakness following SPR 6 months later. They still walk depending on a long leg brace or rigid AFO with walker three years after SPR. A related investigation has suggested that the afferent input from the posterior nerve root ascends and synapses with anterior horn cells at many levels of the spinal cord, including the brainstem nuclei, thus providing a theoretical basis for the reduction in spasticity following SPR [9]. Thus, SPR improved motor control only for CP children with more selective control by reducing segmental and suprasegmental afferent inputs [9]. Some studies also reported that spasticity improved [4,6,9, 26-32] after SPR, while e other studies indicated that the muscle activation patterns (EMG phasing) during walking remained unchanged after SPR [15].

In this study, the walking velocity, cadence, and step length were increased significantly in the dependent ambulators group after SPR, and only step length was increased in the independent ambulator group. This occurrence may be attributed to that five of the ten children in the dependent ambulator group were promoted to walk independently after SPR, contributing to a significant increase in walking velocity, cadence, and step length if still under the supporting walking condition. Boscarino et al found that both the independent and dependent ambulators groups significantly increased in terms of stride length and reduction in cadence; however, velocity did not significantly change [15]. Vaughan et al found a significant improvement in stride length at 1 year postoperatively; velocity was not significantly increased until 3 years after SPR, did not change significantly in cadence [33]. Our parameters were normalized by body height, Boscarino's data were normalized by leg length, and Vaughan's data were not normalized. In addition, the different normalization techniques were difficult to compare the effect of SPR on gait parameters among studies. This finding might be attributed to the diverse gait patterns noted preoperatively. Some spastic diplegic CP children walk very fast with a tip-toe gait, while some are rather slow in velocity with a crouching gait.

Above results might present functional changes of CP children that are not easily defined. Pries applied the CDG system that was also used in this study for gait analysis in children between one and five years old [34]. According to their results, this simple foot pressure system can make a rapid and accurate quantitative analysis of the major changes in gait organization. Our previous study simplified the analysis of kinetic gait data for CP children by using CDG. Based on the foot pattern recognition, the gait patterns of the subjects can be classified into four different patterns in both gaitline and cyclogram which were parallel to the clinical evaluation of CP on Minear's classification of daily activities. The correlation between gaitline and cyclogram pattern was also significant [19]. However, according to pattern recognition scores, improvements in gait postoperatively became significant in terms of increase of foot contact area and bipedal alternating patterns. Parents have observed a post-SPR increase in their child's endurance during walking, which might be helpful in confirming these findings objectively.

In conclusion, both the independent and dependent ambulators groups significantly improved in terms of the motor control and gait patterns in CP children one year after SPR surgery. However, these progressions were insignificant in the non-ambulators group.

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選擇性背神經根切除術對腦性麻痺患者運動控制及步態之影響

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本研究主要針對腦性麻痺兒童在施行選擇性背側神經根切除術前後的運動控制和步態模式的評估。研究中共收錄 24 名接受選擇性背側神經根切除術的痙攣性腦性麻痺兒童，年齡分佈由 3 歲至 16 歲，並選擇 20 名單純接受保守復健治療的腦性麻痺兒童當做控制組。全部病童在治療前 1 個月和之後 9 個月至 1 年間皆施以步態分析及運動控制評估。將接受選擇性背側神經根切除術的病童依行動之能力區分爲三組：(1)獨立行走組(independent ambulators)；(2)需輔具行走組(dependent ambulators)； (3)無法行走組(non-ambulators) 予以比較。結果顯示接受選擇性背側神經根切除術的病童在步態、作用力線及運動控制模式皆比僅接受保守復健治療的病童有顯著的改善($p<0.05$)。而在選擇性背側神經根切除術三組病人當中，獨立行走組和需輔具行走組之病童，手術後在運動控制模式和步態分析方面都有所進步($P<0.05$)，然而在無法行走組則無明顯之進步。此研究結果將有助於在術前利用運動模式的篩選，以選擇適於施行選擇性背側神經根切除術的腦性麻痺病童。（中華復健醫誌 1999; 27(3): 103 - 115）

關鍵詞：腦性麻痺(cerebral palsy)，選擇性背神經根切除術(selective posterior rhizotomy)，
運動控制(motor control)，步態分析(gait analysis)

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