SELECTIVE PERIPHERAL NEUROTOMY IN THE TREATMENT OF LOWER LIMB SPASTICITY IN CEREBRAL-PALSY CHILDREN

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ABSTRACT

Objective: *Spasticity represents the most handicapping sequel of cerebral palsy children. Although selective posterior rhizotomy is the most commonly performed neurosurgical procedure for reduction of diffuse spasticity in these patients, neurotomies have been used for the treatment of spasticity in certain patients with more localized form of spasticity. This prospective study was performed to evaluate the results of microsurgical selective peripheral neurotomies in the treatment of lower limb spasticity in children with cerebral palsy.* ***Methods:*** *Between January 2004 and January 2006, 18 children with cerebral palsy suffering from handicapping spasticity affecting the lower limbs were operated-upon by microsurgical selective peripheral neurotomies at Neurosurgery Department, Ain-Shams University. All patients were objectively evaluated both clinically (as regard motor power, muscle tone, joint range of motion and degree of disability) and electro-physiologically (nerve conduction and electromyografic studies). Assessment was performed a week prior to surgery and at 1, 6, 12 and 18 months post-intervention. Neurotomies done for these children were: 27 tibial, 6 sciatic and 14 obturator neurotomies. Complementary orthopedic procedures including tendons lengthening, tenotomies and derotation osteotomy of the femur were performed in 16 children.* ***Results:*** *Statistical analysis of the results showed significant improvement in all the assessment parameters including physical (motor power, muscle tone, joint range of motion), functional (degree of disability) and electro-physiological measurements with no recurrence of spasticity throughout the follow-up period which ranged from 6 to 18 months (mean: 11 months). There was transient post-operative weakness in all patients but the motor power has returned to the baseline within 6 months post-operatively. Two children had experienced transient parathesia following tibial neurotomy and one had wound infection necessitated debridement and secondary sutures.* ***Conclusion:*** *Microsurgical selective peripheral neurotomy showed good results in children with spastic diplegic cerebral palsy in both physical and functional outcomes and this was supported by the electrophysiological measurements. It carries the advantage of being simple and safe surgical technique for focal and multifocal spasticity.*

Keywords: *Neurotomy, Spasticity, Cerebral palsy.*

INTRODUCTION

Varying degrees of spasticity occur with lesions of the central nervous system that affect the upper motor neuron within the brain or spinal cord. Spasticity can be defined as a condition in which there is a velocity dependent increase in resistance of the muscle group to passive stretch with a “Clasp Knife” type component associated with hyperactive tendon reflexes. Spasticity affects both children and adults and arises from a number of neurological disorders including cerebral palsy, multiple sclerosis, cerebrovascular accidents, spinal cord injury and head trauma[32].

Neurosurgical procedures directed at relieving medically intractable spasticity were first performed during the early 20th century after Shenington's classic studies which opened the door to an understanding of the underlying neurophysiological basis of muscle tone and spasticity(32). Although selective posterior rhizotomy has evolved as the predominant neuro-surgical procedure for reduction of spasticity in children with spastic cerebral palsy, especially when it severely affects the entire lower limb(s)(2,25,34), neurotomies have been used for the successful reduction of spasticity in certain patients with more localized forms of spasticity(24,31,12,10).

The principle of peripheral neurotomies consists upon partial transection of motor collaterals of muscles causing sever spasticity, this partial transection involves the afferent fibers of the spinal cord mainly Ia and Ib whose transection cause disappearances of spasticity. On the other hand, transection involves as well motor neurons axons causing partial denervation(13,3,8). Within several months, two types of regeneration occur; the first is motor regeneration by sprouting of the remaining motor axons or enlargement of the already existing endplates to involve more muscle fibres. Being well organized allows motor strength to recover to a level almost equivalent to the patient's preoperative strength. The second is sensory regeneration of the afferent proprioceptive fibers from the muscle spindle which is disorganized allows long term control of spasticity. Microsurgical techniques and the use of intraoperative electrical stimulation offer high selectivity to help in disappearance of spasticity without causing excessive paralysis(15,18,27).

The objective of this prospective study is to evaluate the results of microsurgical selective peripheral neurotomies (MSPN) in children with lower limb spasticity due to cerebral palsy.

PATIENTS & METHODS

This prospective study concerns 18 children with cerebral palsy suffering from segmental handicapping spasticity affecting the lower limbs (spastic diplegia) with no or minor motor deficits in the upper limbs. They were operated upon by microsurgical selective peripheral neurotomies in the period between January 2004 and January 2006 at Neurosurgery Department, Ain-Shams University. The general indications for surgery were functional improvement, joint protection and promotion of normal growth of lower limbs. The 18 children were 12 males and 6 females. Their mean age was 8.8 years (range: 5-15 years).

Selection of patients and timing of surgery were done according to the criteria proposed by Decq et al.(10) and Msaddi et al.(24) :

1. Spasticity is more predominant than contracture and is confined to a specific muscle group with Hmax/Mmax > 0.5 i.e. more than half of the motor pool of a certain muscle is excited by the stimulation of afferent Ia fibres of this muscle.
2. Good function of antagonistic group as residual spasticity, even minimal, gradually returns the limb segment to its initial position because of the absence of antagonist function.
3. Neurotomy is indicated when no other treatment option is available; after the child has completed a well conducted rehabilitation program.
4. Neurotomy is restricted to children above the age of three years when the gait is expected to be relatively mature and not too late where the patient makes no further progress.

5. In case of excessive contracture of spastic muscles, an orthopedic procedure combining tendon lengthening and/or transfer and arthrodesis would be preferable either simultaneously with or soon after neurosurgical intervention.
6. The child cognitive abilities, social skills and the availability of family support are important factors since cooperation with the physiotherapist is very important to achieve good results.

Assessment of the patients was performed a week prior to surgery and subsequently at 1, 6, 12 and 18 months post-intervention.

Physical assessment:

The muscles were inspected to detect the presence of atrophy or contracture. The muscle power was assessed using the Medical Research Council Scale (MRCS) which is a scale from 0 to 5 for power grading[(19)]. The Modified Ashworth Scale (MAS), a scale from 0 to 4, was used for assessment of muscle tone[(5)]. Muscle power and tone were graded for each muscle group and the mean was taken for the whole limb. The joint range of motion (ROM) was measured using a plastic manual goniometer as described by Merchese et al.[(21)]. Results were interpreted according to the standard ranges. For statistical analysis purpose, the patient joint range of motion was calculated as a percentage of the reference range for this joint. The sum of all joints percentages were divided by the number of listed joints to find the mean value. Detection of improvement or deterioration was done by detection of difference between baseline and follow up mean values.

Functional assessment:

Assessment of disability in children was performed using the Static Postures and Transitional Movement Scale. Children were scored based on their need for assistance while trying to maintain six static postures and perform five transitional movements[(33)]. All patients were video-tapped before surgery and during the follow up visits for documentation and evaluation of response to treatment.

Motor nerve block:

This test was done for patients in whom the passive joint range of motion (ROM) was limited, to confirm the presence or absence of muscle contracture necessitating a lengthening procedure. It also allows both the surgeon and the family to predict the impact of tone reduction on function. Blocks were performed by injection of anesthetic agent near the motor point. The motor points are well defined areas of the muscle that produce maximum contraction when the motor nerve is stimulated. Lidocaine injection into the muscle is performed with a special electrode needle through which low grade stimulation and recording can be performed. The proximity to the motor point was assessed if stimulation causes contraction with intensity equal to or less than 0.3 mA[(32)]. Five children underwent nerve block test, while in 4 other uncooperative children assessment of passive joint range of motion was done by examination under general anesthesia in the operative theatre just before surgical intervention in the presence of an orthopedic surgeon.

Electrophysiological assessment:

It was done for all patients at presentation and for most of those who attended the follow up assessment schedule. Patients who did not undergo the electrophysiological assessment post-operatively were excluded from the statistical analysis of the results. The tests include:

1. *Nerve conduction studies:* These include:
   a. Hmax/Mmax (for soleus muscle): The maximum H reflex

amplitude is compared to the maximum CMAP (compound motor action potential) response obtained by direct excitation of the peripheral nerve to estimate the percentage of the motor neuron pool activated through the reflex response. Hmax/Mmax is increased in chronic spasticity. Ratio >0.5 is an indication for surgery[9,10].

b. F/M ratio: The ratio of F wave to that of the corresponding CMAP is calculated in an attempt to measure the amount of the motor neuron pool activated. In patients with chronic spasticity, F wave persistence and magnitude are increased commensurate with the elevated excitability of the motor neuron pool[9].

2. *Electromyographic studies (EMG):* where each muscle was examined for spontaneous activity, minimum and maximum voluntary activity. Patients with fixed contractures of certain muscle group(s) and silent EMG recording of activity at rest were excluded from the study and referred for orthopedic treatment.

All children were subjected to brain CT, routine lab investigations and X-ray of concerned joints. This preoperative evaluation was followed by a careful discussion and explanation with the patient's family about the goals and limitations of the procedure.

Surgical procedure:

All procedures were done under general anesthesia without long acting muscle relaxant as described by Decq et al.[10,14]. Intraoperative nerve stimulation was used in all patients for identification of motor branches. A stimulus intensity ranged from 0.2-2 mA was used, the extent of fascicular resection was monitored by intra-operative assessment of clonus in tibial neurotomies and by physical observation of pattern of muscle contraction in other types of neurotomies.

Tibial neurotomy was the most common in this series because of the prevalence of spastic talipes equines deformity in children with spastic diplegia due to cerebral palsy. In this case, a vertical incision is made starting at the transverse popliteal line extending 5 cm down. Neurotomy of the obturator nerve below the obturator foramen was performed for spastic hip adductors while for spastic knee flexion, neurotomy of the branches of the sciatic nerve at the buttock serving the hamstrings was done when indicated.

Equines and ankle clonus necessitates sectioning of the soleus and/or the medial and lateral gastrocnemius nerves. The following maneuver allows a clinical estimation of the extent to which each of the two muscular groups, belonging to the triceps surae, are implicated: when equines and/or ankle clonus are significantly decreased by flexing the knee which reduces the gastrocnemius tension, it may be assumed that this muscle plays an important role in the abnormal posture. If this maneuver is negative, spasticity may be considered predominant in the soleus muscle. Varus essentially depends on the tibialis posterior muscle while tonic flexion of the toes depends mainly upon the flexor hallucis and the flexor digitorum communes. It requires identification and sectioning of the corresponding motor fascicles inside the tibial trunk at the level of the soleus muscular arch (fig. I).

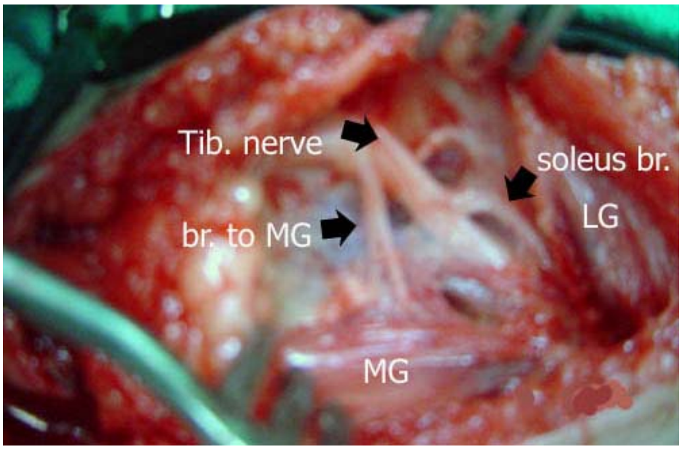

Fig. (1): Intraoperative photograph (microscopic view) showing exposure of right tibial nerve and its branches. (MG:Medial head of gastrocnemius.LG:Lateral head of gastrocnemius.)

The technique of selective neurotomy is as follows: after exposure of the nerve, the branches are individualized and identified one by one using the operating microscope and nerve stimulation. Each branch (or fascicle) considered as supporting harmful spasticity on the basis of stimulation and preoperative assessment is then partially resected with microscissors over 5mm length to prevent regeneration. Ends are coagulated to prevent neuroma formation. Preservation of one-fourth to half of the fibres of each branch is sufficient to avoid loss of motor function. Comparing the results of stimulation of the distal and proximal parts of the resected fibres proved useful in controlling the effect of the operation on muscular contraction.

All children underwent selective peripheral neurotomies in lower limbs ± complementary orthopedic procedures. Thirteen of them (72.2%) had both procedures in the same session. Two children had Botulinum toxin (BTX-A) injection for localized upper limb spasticity plus selective neurotomies and orthopedic procedures in the lower limbs. Seven children (38.9%) underwent single event multi-level approach (multi-level neurotomies and orthopedic procedures at the same time). Fifteen children (83.3%) underwent bilateral procedures. Selective peripheral neurotomies done for these children were 27 times tibial neurotomies, 6 times sciatic neurotomies and 14 times obturator neurotomies. Orthopedic procedures were done for 16 children including 18 Achilles tendon lengthening, 14 fractional lengthening of hamstrings, 10 adductor tenotomies and one derotation osteotomy of the femur. All orthopedic procedures were performed in cooperation with the Orthopedic Department in Ain-Shams University Hospitals.

Post-operative program:

The child was discharged home between the 3rd and 7th day after surgery and followed regularly in the outpatient clinic. Physiotherapy was started two weeks after surgery with an electrical stimulation program, standing and gait training, passive stretching and strengthening exercise for at least six months. For those children who underwent simultaneous orthopedic procedures, physiotherapy was delayed until the cast was removed (usually after 2-4 weeks).

Statistical methodology:

Statistical analysis was performed by SPSS (statistical program of social signs) version 8.0.

The various parameters were compared preoperatively and after 1, 6, 12 and 18 months post-intervention by use of: a paired t-test (at one month) and r-test (correlation coefficient) at 6, 12 and 18 months. The r-test was used due to variability in numbers and data of patients throughout the follow-up schedule. The improvement or deterioration was detected by calculating the difference between baseline mean value and follow-up mean value for each variable. The symbol (–) means decrease in mean value in comparison to baseline value. The difference in means was considered in statistical analysis. Results of comparison were considered significant if P≤0.05, highly significant if P≤0.01 and very highly significant if P≤0.001.

RESULTS

All children attended the follow-up assessment at one and 6 months post- intervention but only 11 children attended and were assessed at 12 months and only 4 children were assessed at 18 months. The mean follow-up period was 11 months (range: 6-18 months).

I- Physical measurements:

1. Motor power: Immediate post-operative lower limb weakness was observed in all patients and was statistically significant (P=0.02) as compared to the baseline at one month after surgery. There was gradual increase in the mean of MRCS which exceeded the baseline at 6, 12 and 18 months. For all patients, this improvement was statistically significant at 6 months (P=0.05) (table 1).

Table (1): Assessment of motor power using Medical Research Council Scale (MRCS), baseline values and changes in follow-up records at 1, 6, 12 and 18 months post-operatively.

Statistical values	Baseline values	Changes in post-operative values			
		1 m	6 m	12 m	18 m
Number of patients	18	18	18	11	4
Mean values	3.24	- 0.29	0.35	0.62	0.5
Standard deviation (SD)	0.83	0.47	0.49	0.74	0.7
P-value	–	0.02	0.05	0.18	–

2. Muscle tone: Muscle tone was decreased immediately post-operatively and the changes in the mean of MAS at one month were statistically very highly significant (P<0.001). Means of MAS measured at 6, 12 and 18 months following surgery remained below the baseline and changes were non-significant as compared to those of the first month post-operatively (table 2). The relation between changes in muscle tone as measured by MAS and power as measured by MRCS is shown in figure (2).

Table (2): Assessment of muscle tone using Modified Ashworth Scale (MAS), baseline values and changes in follow-up records at 1, 6, 12 and 18 months post-operatively.

Statistical values	Baseline values	Changes in post-operative values			
		1 m	6 m	12 m	18 m
Number of patients	18	18	18	11	4
Mean values	4.5	- 3.59	- 3.52	- 3.62	- 3.5
Standard deviation (SD)	0.61	1.12	0.87	0.74	0.7
P-value	–	< 0.001	0.51	0.8	–
Significance		V.H.sig.	Non-sig.	Non-sig.	–

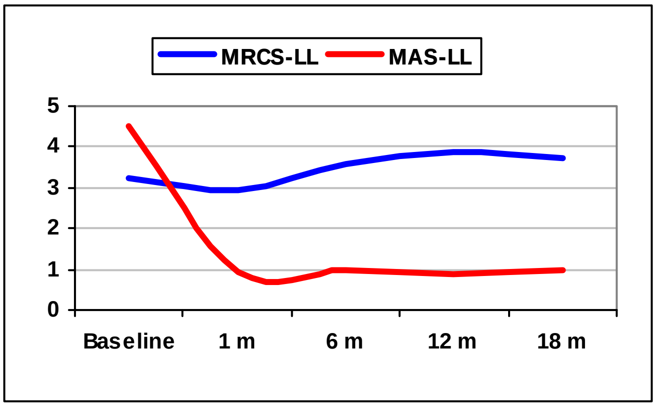

Fig. (2): Line chart showing the relation between changes in tone (MAS) and motor power (MRCS) in the operated lower limbs in cerebral-palsy children.

3. Joint range of motion (ROM): Increased ROM was highly significant (P = 0.002) at one month post-operatively. The means of joints ROM were gradually increased at 6 and 12 months in comparison to previous measurements, but this improvement was only significant at 6 months (table 3).

Table (3): Assessment of joint range of motion (ROM), baseline values and changes in follow-up records at 1, 6, 12 and 18 months post-operatively.

Statistical values	Baseline values	Changes in post-operative values			
		1 m	6 m	12 m	18 m
Number of patients	18	18	18	11	4
Mean values	57.86	36.42	42.14	56.25	37.5
Standard deviation (SD)	31.6	27.27	31.6	29.12	17.67
P-value	–	0.002	0.05	0.07	0.1

II- Functional measurements:

There was significant (P < 0.02) improvement in static and transitional posture scale values at one month following surgery. The increase in scale values was very highly significant (P < 0.001) at 6 months and significant (P = 0.01) at 12 months post-operatively (table 4, fig. 3).

Table (4): Assessment of disability using the Static Posture and Transitional Movement Scale, baseline values and changes in follow up records at 1, 6, 12 and 18 months post-operatively.

Statistical values	Baseline values	Changes in post-operative values			
		1 m	6 m	12 m	18 m
Number of patients	18	18	18	11	4
Mean values	34.53	2	3.64	4.87	1
Standard deviation (SD)	15.17	3.29	4.31	4.58	1.41
P-value	–	0.02	< 0.001	0.01	–
Significance		Sig.	V.H.Sig.	Sig.	–

Fig. (3): Photograph for an 8 years-old boy with spastic diplegic cerebral palsy. (1) Pre-operative joint-fixed deformities in the form of scissoring and talipes equino-varus. (2) Six months following single-event multilevel surgery with bilateral obturator and tibial neurotomies + adductors tenotomies and Achilles lengthening. The child showed marked functional improvement and ability to walk with minimal support.

III- Electrophysiolgoic measure-ements:

1. Nerve conduction studies:

a. Assessment of stretch reflex activity (Hmax/Mmax ratio): The stretch reflex activity was reduced at one month post-operatively and this reduction was highly significant (P = 0.003). The ratio was maintained below baseline values at 6, 12 and 18 months and changes were non-significant (table 5).

Table (5): Assessment of stretch reflex activity (Hmax/Mmax ratio), baseline values and changes in follow-up records at 1, 6, 12 and 18 months post-operatively.

Statistical values	Baseline values	Changes in post-operative values			
		1 m	6 m	12 m	18 m
Number of patients	18	9	14	7	2
Mean values	0.7	- 0.61	- 0.57	- 0.66	- 0.51
Standard deviation (SD)	0.42	0.42	0.33	0.46	0.16
P-value	–	0.003	0.1	0.02	–
Significance		H.Sig.	Non-sig.	Sig.	–

b. Assessment of spinal neuronal activity (F/M ratio): There was significant decrease (P = 0.03) in the mean ratio after one month. The progressive increase in the mean ratio at 6 and 12 months was very highly significant (P < 0.001) but was still below the baseline (table 6).

Table (6): Assessment of spinal neuronal activity (F/M ratio), baseline values and changes in follow-up records at 1, 6, 12 and 18 months post-operatively.

Statistical values	Baseline values	Changes in post-operative values			
		1 m	6 m	12 m	18 m
Number of patients	18	12	13	7	1
Mean values	0.23	- 0.17	- 0.15	- 0.11	- 0.1
Standard deviation (SD)	0.24	0.23	0.22	0.3	–
P-value	–	0.03	< 0.001	< 0.001	–
Significance		Sig.	V.H.Sig.	V.H.Sig	–

2. Electromyography (EMG):

There was significant reduction (P < 0.001) in spontaneous motor unit activity recorded at one month post-operatively. There was a very highly significant increase (P < 0.001) in spontaneous activity at 6, 12 and 18 months post-operatively, but it was still below the baseline spontaneous activity by a wide range (table 7).

Table (7): Assessment of spontaneous motor unit activity, baseline values and changes in follow-up records at 1, 6, 12 and 18 months post-operatively.

Statistical values	Baseline values	Changes in post-operative values			
		1 m	6 m	12 m	18 m
Number of patients	18	16	16	7	2
Mean values	11.25	- 11.12	- 10.93	- 10.14	- 8
Standard deviation (SD)	9.79	9.81	9.78	13.75	8.48
P-value	–	< 0.001	< 0.001	< 0 .001	–
Significance		V.H.Sig.	V.H.Sig.	V.H.Sig.	–

DISCUSSION

Although many etiologic factors share in the development of spasticity in pediatric age group, cerebral palsy remains the most common cause of spasticity in children[29]. Based on the predominant clinical features of the motor disorder, cerebral palsy can be classified as spastic, dystonic, ataxic and mixed types[35]. Spastic diplegia is the most common pattern of spastic cerebral palsy with involvement of both lower limbs. Despite the term "diplegia", there is no complete paralysis of the lower limbs. Spastic dipelgia is particularly associated with a preterm delivery and there is often some involvement of the upper limbs[35]. Spasticity is predominant in ankle flexors, hip adductors and knee flexors. Weakness is dominant in the antagonist muscle groups; triceps surae, glutei and quadriceps femoris. Children stand up with slight bent knees and legs held closely together. In sever cases, the legs are crossed giving a scissor type gait. With ankle equines internally rotated feet and partial contact of the sole and toes on the ground, the gait becomes digitigrades[1,20].

Excessive (diffuse) spasticity in children is usually treated in the majority of cases by posterior rhizotomy. In certain cases, spasticity predominates in certain muscle groups. These cases particularly are treated with single and sometimes multilevel peripheral neurotomies with minimization of functional risk for the child[13]. Selective peripheral neurotomy (SPN) provides a very precise degree of spasticity release on specific muscle groups. It is highly selective since it involves the fascicles much closer to innervated muscle to avoid excessive manipulation of sensory fascicles with possible painful and trophic side effects[24].

In the present study, microsurgical selective peripheral neurotomies in the lower limbs were performed in 18 children with handicapping spastic diplegia due to cerebral palsy. Almost all children were referred to the spasticity outpatient clinic in Ain Shams University Hospitals. This clinic was organized specifically where the spasticity patients undergo full assessment by a multidisciplinary team including a neurosurgeon, an orthopedic surgeon and a neurologist.

Pre-operative assessment concerning the physical, functional and electrophysiological status was performed for all patients for evaluation and treatment decision. Assessment was also directed to settle a baseline data about the status of the patient to be ready for post-treatment outcome evaluation. There is no evidence in the literatures for a standard follow-up strategy and the functional parameters used vary widely making comparison difficult[7,37].

The 18 children underwent 27 times posterior tibial neurotomies for spastic foot deformity, 14 times obturator neurotomies for spastic adductors and 6 times sciatic neurotomies for spastic knee flexion. In addition, complementary orthopedic procedures including 18 Achilles tendon lengthening, 14 fractional lengthening of hamstrings, 10 adductor tenotomies and one derotation osteotomy of the femur were performed in 16 patients either in the same session with the neurosurgical procedure or shortly after. Performing neurotomy in a patient with excessive retraction will never ameliorate the patient's condition. In contrary, the tendon lengthening does not help in disappearance of spasticity; it helps only in displacement of muscular contraction. However, the persistence of spasticity will expose to the risk of recurrence. Perfect cooperation between these two techniques is desired to give the patient the best adaptable treatment[10].

Msaddi et al.[24] performed 28 posterior tibial, 3 obturtor and 2 sciatic neurotomies in addition to 3 ulnar and median neurotomies in a series of 28 children with spastic cerebral palsy. Their ages ranged between 3 and 15 years (mean: 6.5 years). They found that the best results were obtained in children operated upon between the age of 3 and 6 years. Russman et al.[28] reported that surgery of lower limb spasticity in cerebral palsy is not recommended until after the gait has matured but should not delayed especially if spasticity is rapidly impairing the patient function. In the present series, the age of the children ranged from 5 to 15 years with a mean age of 8.8 years. This relatively old age at the time of presentation might explain the large number of children who required multilevel neurotomies and complementary orthopedic procedures in this series.

Tibial nerve is the most encountered among peripheral nerves in spasticity surgeries and topography of its fascicles is well known following the functional study of Taira and Hori[36] and was discussed intensively in most of published related articles. In the present study, dissection was directed towards motor branches after their emergence from the parent trunk to avoid sensory complications. Branches to medial head of gastrocnemius, not less than two branches in all cases, were found to emerge at higher level from the nerve trunk in popliteal fossa. Branches to lateral head, one or more, were found thinner and emerge at lower level than those to the medial head. The superior solial branch was found to be situated postero-laterally in relation to the nerve trunk after its emergence in the popliteal fossa. In 50% of cases, it consisted of more than one branch ensheathed together and could be dissected separately. In all patients, varus deformity was present for which the motor branch of the tibialis posterior muscle was dissected. In El Mahdy study[16], dissection of tibial motor branches to soleus and gastrocnemius were done for all cases and tibialis posterior branches in17.3% of cases. From 2 to 3 soleal branches and from 4 to 6 branches to gastrocnemius with an average of 2 branches to each head were noticed.

In this study, sectioning was guided with intra-operative examination of clonus and observation of physical muscle contraction in response to stimulation of each individual motor fascicle in the motor nerve was considered. Disappearance of clonus with preservation of muscular flickers upon stimulation was the limit to stop sectioning. Accordingly, it was found that sectioning did not exceed 50% of fascicles in each branch in all cases. In El Mahdy study[16], sectioning was done for 75% of branch thickness in 85% of cases and 50% of thickness in 15% of cases according to the pre-operative degree of spasticity. In Roujeau et al. series[27], resection was also based on intra-operative resolution of clonus and sectioning was up to 80% in 83% of cases of soleus branch only and tibialis posterior branch was included in 66% of cases. For selective neurotomies other than tibial neurotomy, where there is no rule for intra-operative assessment of clonus, the degree of resection was guided by observation of physical muscle contraction. Fascicles which give powerful contraction were considered for resection. Accordingly, not more than 50% of fascicles were resected. Purohit et al.[26] followed the same technique and less than 50% of the fascicles were resected.

In this study, the power was significantly decreased in most of patients post- operatively (P = 0.02). However, significant improvement exceeding the baseline mean was found at 6 months post-operatively. Transient post-operative weakness was also reported by El Mahdy[16]. Both muscle tone and joint ROM were significantly improved (P<0.001 and P = 0.002, respectively) in all patients at one month post-operatively and this improvement continued throughout the follow-up period. This is mostly due to regular exercising and similar findings which were reported in other series[22,24].

Hmax/Mmax >0.5, i.e. more than half of the motor neuron pool of a certain muscle is excited by the stimulation of afferent Ia fibers of this muscle, is considered an indication for surgery by Decq et al.[10]. In the current study, the mean ratio was 0.7. Four patients (22.2%) had ratio less than 0.5 in one or both lower limbs associated with spontaneous motor unit firing at high rate and all of them were operated upon for spasticity and fixed contractures. Post-operatively, the Hmax/Mmax ratio showed marked reduction and long term stability below the baseline value for 18 months (P = 0.003). In Féve et al.[17] series on selective tibial neurotomy, the Hmax/Mmax ratio was found to be significantly reduced (P < 0.01) at one month post-operatively. Roujeau et al.[27] found that significant reduction in this ratio was maintained for two years post-operatively. Changes in F/M ratio in the present series were found to be significant almost all through the follow-up assessment. Although there was highly significant increase in the ratio at 6 and 12 month post-operatively, it remained lower than the baseline ratio. This could be confirmed by the significant improvement in power (MRCS) at 6 and 12 months as compared to the early post-operative assessment.

It should be emphasized that the most important element in this type of management is not only the quality of the analytical results obtained, but also the patient’s functional improvement and satisfaction[6]. In this study, significant improvement (P = 0.04) in function associated with either neurotomy alone or with complementary orthopedic surgery was noted. Moreover, a decrease in spasticity in the entire lower limbs was observed even in some children who underwent tibial neurotomy alone. This distant effect, previously described by Sindou et al.[31] as well as the reduction of the abnormal posture of the foot had beneficial consequences on the static and biomechanical condition of the whole locomotion apparatus including the spine[30]. However, the present study was limited to a relatively short follow up period. The 6 to 18 months post-operative limit isolates the effects of surgical intervention without the subsequent impact of growth and development and thus represents the primary response to treatment. It will be equally important to evaluate whether this treatment philosophy ameliorates the gait deterioration at maturity and in adulthood noted in other reports.

Recurrence of spasticity is a major problem and some published studies reported high incidence of recurrence following tibial neurotomies. The highest recurrence rate was reported by Berard et al.[4] where 65.5% of patients showed recurrence of equines deformity. They did 70-80% resection of the nerve fibres. Recurrence was also occurred in 33% of the patients in Roujeau et al. series[27] where they did 80% resection of soleus branch only. The current study, however, demonstrated that functional and electrophysiological improvement remained stable all through the follow-up period and other studies have confirmed the persistence of this improvement after several years[11,23,31]. The difference in recurrence rates may be attributed to the difference in the degree of resection of the nerve fibres. In this series, sectioning did not exceed 50% of the fascicles in each branch in all cases. Berard et al.[4] concluded that the greater the neurotomy, the larger the motor unit reinnervated by the surviving motor neurons, the higher the recurrence.

Regarding complications, immediate post-operative transient weakness (MRCS decreased by 1 or 2 grades in the operated limb) was found in all cases. This might be related to the surgical manipulation of the nerves or to the pre-existing weakness (due to UMNL), which became unmasked after resolving of spasticity. This observation was not clarified in most of the published series. Two old children (aged 12 and 13 years) experienced transient parathesia (11.1%) following tibial neurotomies and one case (5.6%) had a wound infection necessitated debridement and secondary sutures. Buffenoir et al.[6] reported transient parathesia in 4.45% of cases and superficial wound infection in 1.8% of cases.

CONCLUSION

This study demonstrated that microsurgical selective peripheral neurotomy is effective in the treatment of focal and multifocal lower limb spasticity in cerebral palsy children and this was evidenced by the post-operative improvement of both clinical and electrophysiological spastic indices. Peripheral neurotomies help in amelioration of function. Even if the benefit is modest, it provides considerable benefit for patients. Rehabilitation plays a fundamental role in the management of these patients. In its absence, the benefit of surgery would remain limited.

Electrophysiological assessment (including Hmax/Mmax ratio, F/M ratio, spontaneous activity recording) as a quantitative approaches together with physical evaluation are essential for surgical decision making as well as objective evaluation of the obtained results.

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