ELECTRODIAGNOSTIC EVALUATION IN CHILDHOOD NEUROMUSCULAR DISEASES*

Evaluación Electrodiagnóstica en Alteraciones Neuromusculares en el niño

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Abstract

An investigation into several electrodiagnostic tests has been carried out in children 5–13 years of age, presenting with various neuromuscular diseases, to assess the validity of these procedures in the characterization of these disorders. A. slight increase in excitability was found in children with upper motor neuron diseases. Myopathics had significant perturbations in strength–duration curves, accommodation indexes and nerve stimulation studies. Changes in action potential characteristics were more marked in progressive muscular dystrophy patients than in other myopathics. These results are compatible with a neurogenic basis for muscle diseases. In peripheral nerve injuries and neuropathies these changes were more highly significant and reflect proportionately greater nerve and muscle damage.

Resumen

Se efectuaron estudios electrodiagnósticos en niños entre 5–13 años, quienes presentaban diversas alteraciones neuromusculares, para evaluar su validez en la caracterización de estas enfermedades. Se encontró un aumento leve de la excitabilidad en niños con enfermedades de neurona motora superior, en contraste con pacientes que presentaban lesiones de neurona inferior. Los pacientes miopáticos presentaban alteraciones significativas en las curvas de intensidad–duración, índice de acomodación y estudios de estimulación nerviosa, resultados que son compatibles con daño neurógeno. Las alteraciones en las características del potencial de acción fueron más marcadas en los niños con distrofía muscular progresiva que en los demás miopáticos. En pacientes con lesión traumática de mediano y en las neuropatías estas alteraciones eran más altamente significativas y reflejaban daño neuromuscular proporcionalmente mayor.

Keywords: Children. Neuromuscular diseases. Electrodiagnostic tests. Myopathies and neuropathies. Motoneuron dysfunction.

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INTRODUCTION

Electrodiagnostic studies play a prominent role in the assessment of the complex neuromuscular disorders of childhood (Dyck, 1968; Swaiman and Wright, 1979). To evaluate their advantages in the confirmation of clinical diagnosis and in the characterization of myopathies and neuropathies, these tests were made on children presenting with different pathological disorders of the lower motor neuron. Since no single criterion is sufficient for accurate evaluation, a composite of electrophysiological tests was found necessary; thus, the chronaxie, the strength–duration curve and the accommodation index in traumatic nerve injury helped to determine the degree of innervation (Gilliatt, 1962), to differentiate upper from lower motor neuron disease (Wynn Parry, 1971), and to distinguish "neurogenic" from "myogenic" disease processes. In patients with a peripheral neuropathy, all these studies yielded significant information. In addition, these methods also revealed differences between congenital myopathies which are often non–progressive, and progressive muscular dystrophies (Swaiman and Wright, 1979).

METHODS

Patients. Forty–nine children (ages 5–13 years) with various pathological states of muscle and nerve were examined. Six children presenting with upper motor neuron lesions were also included in the study.

Controls. Twenty healthy children (4–13 years) with no history of neuromuscular disease served as control subjects. All children were supplied by the Department of Paediatrics of the "Guillermo Grant Benavente" Hospital in Concepción, Chile, from January 1977 to December 1980.

Electrophysiological techniques. The following investigations were performed on the right or left flexor digitorum sublimis and tibialis anterior muscles: strength–duration curves, chronaxie, accommodation index, and motor nerve stimulation studies in the median and deep peroneal nerves.

Stimulation. Square wave pulses delivered through a pair of electrodes were used to determine rheobase, chronaxie and strength–duration curves. Exponentially rising currents with different RC constants were applied to measure the accommodative reactions (Norris et al., 1981). The active electrode was a Nº 40048 Alvar stainless steel ball 1 cm in diameter, covered by a lint pad soaked in 10% sodium chloride solution, positioned on the skin over the motor point of the muscle and connected to the negative pole of the stimulator. The reference electrode was a lead plate (surface 35 cm^2), coated with electrode jelly, and held in position on the skin with a rubber band at a distance of 10 cm from the stimulation electrode. The combined dc resistance when placed in contact with the skin was 10–30 kilo ohm. The stimuli were obtained from a Grass S_{44} stimulator through a SIU5 isolation unit.

Procedure. The strength–duration curves, chronaxie and motor nerve conduction velocity were measured according to the methods described by Cohen and Brumlik (1976) and Delisa and Mackenzie (1982). To determine the accommodation index, the threshold stimulus for each of 5 RC constants was divided by the excitation threshold for a square wave stimulus and the accommodation index (AI) was calculated according to the equation: $AI = I/I_0$, where I = exponential and I_0 = square wave current.

Motor nerve conduction velocity was measured in the median and deep peroneal nerves by means of percutaneous stimulation. The stimulus was a square wave pulse of 0.5–1 ms duration delivered through a Nº 40048 Alvar electrode at a frequency of 1–3 Hz. The cathode was placed on the skin over the nerve in the antecubital space and at the wrist for the median, in the popliteal fossa and at the lateral malleolus for the deep peroneal. A thin, flat lead plate ground was placed between the stimulation and recording electrodes. The evoked compound muscle action potentials were picked up by a fixed pair of Nº 41208 Alvar electrodes placed over the abductor pollicis brevis for the median and over the extensor digitorum brevis for the peroneal, led to a Grass $5P_3$ EMG preamplifier and displayed on a Tektronik 502A dual beam oscilloscope. The latency time was measured from the onset of the stimulus artifact to the start of the action potential. Conduction velocity of the most rapidly conducting fibres was determined by dividing the distance beween the proximal and distal stimulation points by the difference in latency of the action potential recorded on stimulation at these points.

Throughout the work values refer to the mean ± SEM. Student's *t* test was used for analysis of statistical data. $P < 0.05$ was considered significantly different from control values.

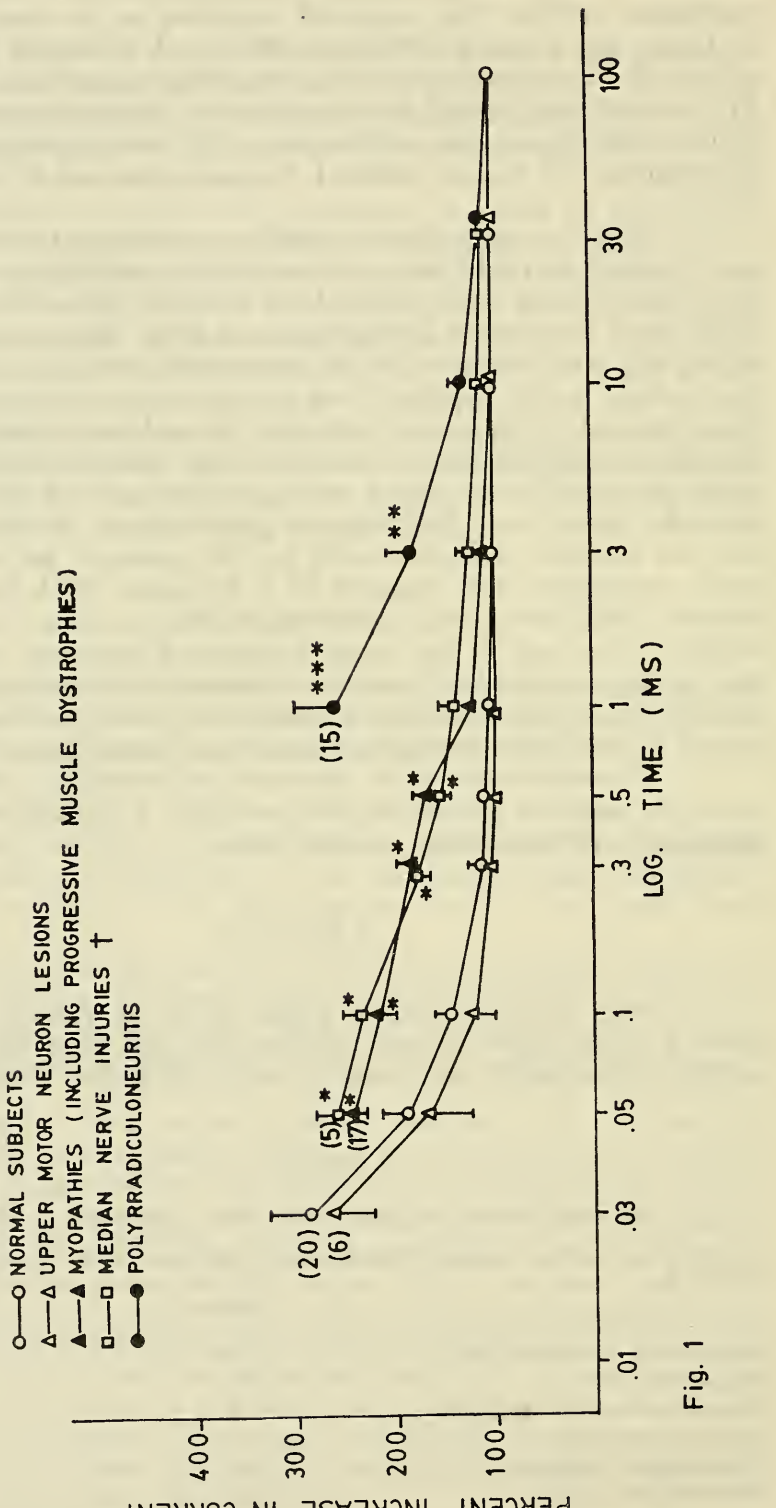
RESULTS

The clinical conditions found in the 55 patients are listed in Table I. Upper motor neuron disorders included were cerebral vascular accidents (hemiplegia) and cerebral palsy; myopathies included patients

TABLE I

Diagnosis, number of patients and time if evolution of disease.

DIAGNOSIS	Nº of patients	Time from onset of disease (months)
Upper motor neuron lesions	6	2– 5
Myopathies	11	4–18
Progressive muscular dystrophy	6	4– 9
Median nerve injury	6	3– 7
Deep peroneal neuritis	6	6– 8
Polyrradiculo - neuritis	20	1– 4


A
NORMAL SUBJECTS
UPPER MOTOR NEURON LESIONS
MYOPATHIES (INCLUDING PROGRESSIVE MUSCLE DYSTROPHIES)
MEDIAN NERVE INJURIES †
POLYRRADICULONEURITIS
PERCENT INCREASE IN CURRENT
100
200
300
400
LOG. TIME (MS)
.01
.03
.05
.1
.3
.5
1
3
10
30
100
(20)
(6)
(5)
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(15)
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Fig. 1

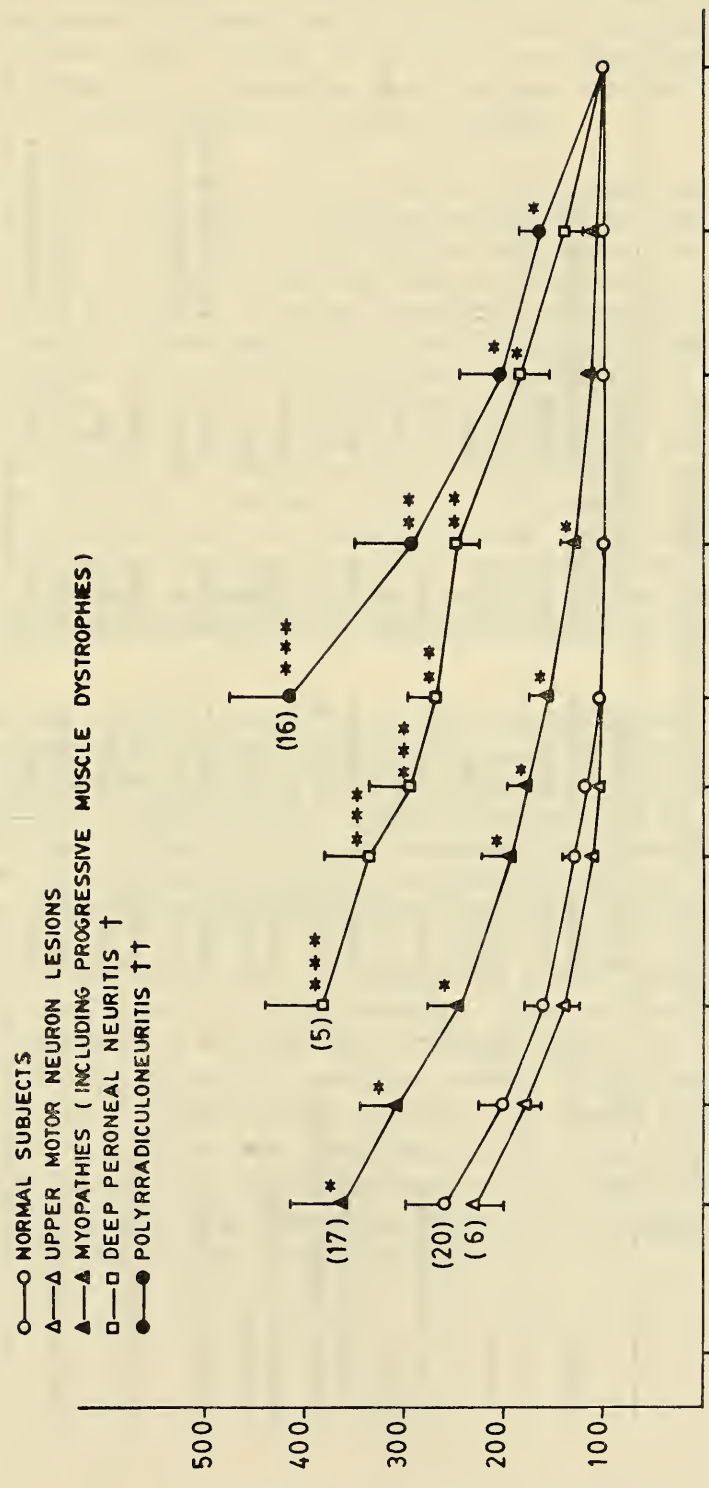

Fig. 1.- Strength–duration curves in children with neuromuscular diseases. A) right flexor digitorum and B) right tibialis anterior muscles. Values are means ± SEM. Statistical differences from control values: P $<$ *0.05; **0.01; ***0.001 Figures in parentheses indicate number of patients examined. †No response in 2; ††no response in 4 patients.

TABLE II

Rheobase and chronaxie for right flexor digitorum sublimis anl tibialis anterior muscles in children with neuromuscular diseases.

GROUPS	Nº OF SUBJECTS	FLEXOR DIG. SUBLIMIS		TIBIALIS ANTERIOR		OBSERVATIONS
		RHEOBASE (VOLTS)	CHRONAXIE (MSEC)	RHEOBASE (VOLTS)	CHRONAXIE (MSEC)	
Normal	20	41.00 ±2.77	0.08 ±0.06	38.00 ±4.85	0.25 ±0.04	
Upper motor neuron lesion	7	35.80* ±4.29	0.21**** ±0.02	27.50* ±2.20	0.11* ±0.02	
Myopathies (Walton's Disease, congenital myotonia)	13	41.69^{NS} ±4.63	0.22**** ±0.03	51.40^{NS} ±6.80	0.30^{NS} ±0.03	
Progressive muscular dystrophy	6	45.16^{NS} ±4.49	0.37** ±0.15	51.80^{NS} ±7.70	0.37^{NS} ±0.03	
Median nerve injury	5	58.00** ±3.90	0.54**** ±0.18	42.70^{NS} ±3.85	0.29^{NS} ±0.07	Flexor dig. sublimis No response in 2
Deep peroneal neuritis	5	43.50^{NS} ±4.26	0.12^{NS} ±0.09	46.00^{NS} ±5.50	6.80*** ±1.39	
Polyrradiculoneuritis	16	46.11^{NS} ±6.70	4.37*** ±0.92	57.80* ±6.95	11.00**** ±1.76	Tibialis anterior No response in 4

Values are means ± SEM. In contrast with normal subjects, P: < *0.05, **0.01, ***0.001, ****0.0001. NS = not significant.

diagnosed as benign hypotonia (Walton's disease) and congenital myotonia. Dystrophies were Duchenne, limb–girdle and facio–scapulohumeral dystrophy. Median nerve injuries were due to supracondylar or slightly higher fractures of the humerus. Deep peroneal neuritis was due to diabetic neuropathy or was of unknown aetiology.

Strength–duration curves. The six patients with upper motor neuron lesions showed a tendency to increased excitability in the muscles of upper and lower extremities, although the displacement was not significantly different from the values for normal children (Fig. 1A and 1B, $P < 0.8$). In myopathic (including dystrophic) and median nerve injury patients, partial denervation for the flexor digitorum sublimis (Fig. 1A) was evident for stimuli with pulse durations shorter than 1 ms; no response could be obtained at pulse durations shorter than 0.05 ms. Both myopathics and progressive muscular dystrophy patients also showed a significant decrease in tibialis anterior excitability for pulses shorter than 3 ms (Fig. 1B). In patients suffering from peroneal nerve neuritis and polyrradiculoneuritis, the strength–duration curve profiles showed partial and nearly complete denervation respectively. No response was obtained for pulses shorter than .1 ms in children with peroneal neuritis, and for pulses shorter than 1 ms in children suffering from polyrradiculoneuritis.

Rheobase and Chronaxie. Table 2 shows that the values for both parameters were increased in all patients, except those presenting with upper motor neuron lesions. The increase in rheobase values was not significant except in median nerve injuries, where a higher threshold may be expected in an early stage of recovery or in a compression syndrome. The rise in chronaxie for myopathies, although not significant for the tibialis anterior, was an unexpected finding, and was greater in dystrophic children.

Accommodation index curves. In upper motor neuron lesions the upper extremity muscles had normal accommodative reactions; the lower extremlty muscles showed a slight increase in accommodation (Fig. 2A and 2B). In the remaining groups the index was reduced. The decrease in accommodation for the tibialis anterior muscles in myopathic patients, including dystrophic children, was significant for RC constants greater than 40 ms. The reduction was highly significant in nerve injuries and peroneal neuritis for RC constants greater than 20 ms, and accommodation was practically abolished in polyrradiculoneuritis.

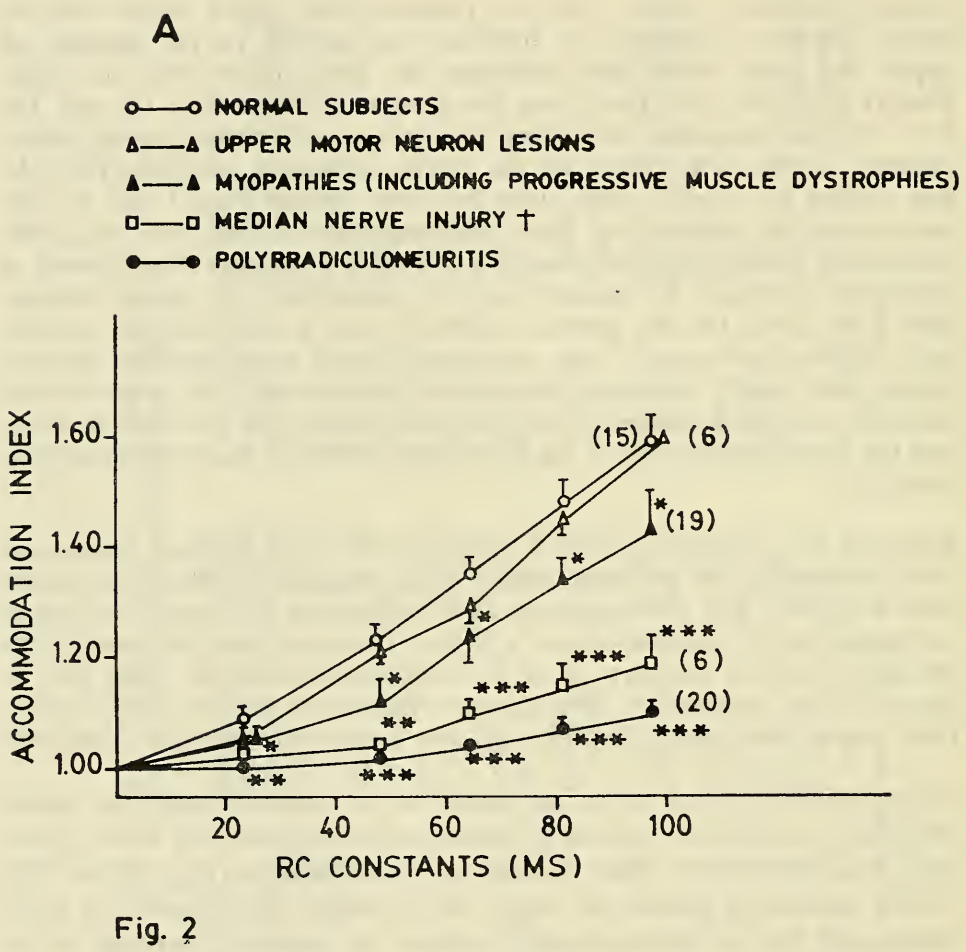

Fig. 2

Fig. 2.- Accommodation index curves in children with neuromuscular diseases. A) right flexor digitorum sublimis and B) right tibialis anterior muscles. Values are means ± SEM. Statistical differences from control values: P $<$ *0.01; **0.001; ***0.0001. Figures in parentheses indicate number of patients examined. +No response in 2; ++no response in 4 patients.

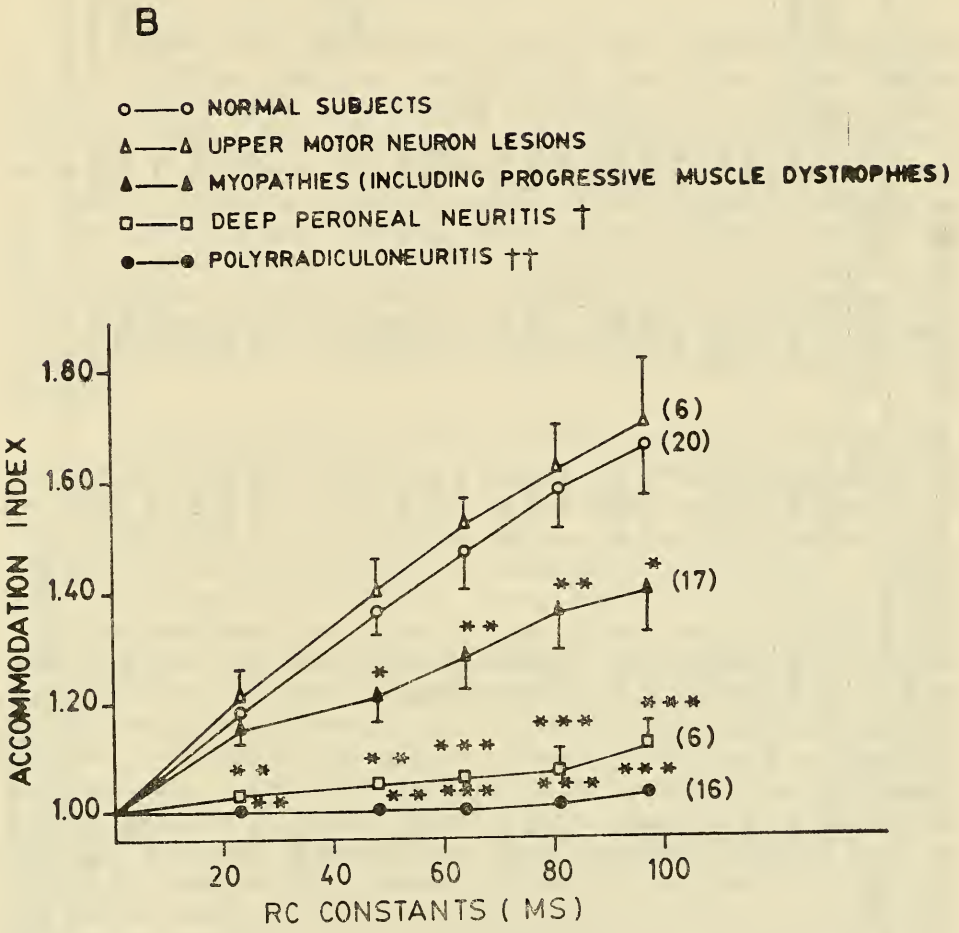

Fig. 2

Motor nerve stimulation studies. Motor nerve conduction velocity was significantly reduced in polyrradiculoneuritis and median nerve injuries, and slightly reduced in the deep peroneal nerves of progressive muscular dystrophy patients (Table 3). More striking than the slowing in conduc tion was a highly significant reduction in amplitude of the compound muscle action potential of median and deep peroneal nerves, in all groups presenting with lower motor neuron pathology. The increase in distal latency of the action potentials, although less marked, was also significant as can be seen from the examination of Table 3.

TABLE III Action potential amplitude, distal latency and motor conduction velocity in children with neuromuscular diseases.

GROUPS	Nº OF SUBJECTS	MEDIAN NERVE AMPLITUDE (mV)	MEDIAN NERVE LATENCY (ms)	MEDIAN NERVE COND. VEL. (ms-1)	DEEP PERONEAL NERVE AMPLITUDE (mV)	DEEP PERONEAL NERVE LATENCY (ms)	DEEP PERONEAL NERVE COND. VEL. (ms-1)	OTHER OBSERVATIONS
Normal	20	4.62 ±0.25	2.39 ±0.11	56.25 ±7.00	4.42 ±0.21	3.14 ±0.13	46.25 ±1.70	
			NS	NS		NS	NS	
Upper motor neuron lesion	6	4.58 ±0.83	2.60 ±0.63	61.30 ±6.50	4.49 ±0.93	3.52 ±0.80	52.00 ±7.80	
		****	*	NS	****	*	NS	
Myopathies (Walton's disease, congenital myotonia)	11		2.94 ±0.20	57.00 ±3.80	1.81 0.28	4.06 ±0.31	44.80 ±3.60	
		****	*	NS	****	*	NS	
Progressive muscular dystrophy	6	2.23 ±0.24	3.20 ±0.46	54.14 ±3.85	1.48 ±0.41	4.84 ±0.67	42.05 ±3.43	
		****	*	*	ND	ND	ND	Median nerve:
Median nerve injury	4	1.26 ±0.29	4.00 ±0.63	30.94 ±6.80				no response in 2
		ND	ND	ND	****	*	NS	
Deep peroneal neuritis	5				1.33 ±0.18	3.94 ±0.37	38.14 ±3.36	
		***	**	**	****	****	**	Deep peroneal
Polyrradiculoneuritis	16	1.78 ±0.53	8.38 ±1.48	34.00 ±2.10	0.95 ±0.14	9.28 ±0.93	29.50 ±4.00	nerve no response in 4

Values are means ± SEM. In contrast with normal subjects, P <* 0.05, ** 0.01, ***0.001, ****0.0001. NS = not significant. ND = not determined.

DISCUSSION

Although the abnormalities found in upper motor neuron lesions are not significant, they have been included since these minor changes reflect a slight increase in excitability as monitored by the strength–duration curve (Wynn Parry, 1971) and by the decrease in tibialis anterior chronaxie. The increase in motor nerve conduction velocity might be due to reduced internal or external resistance of lower motor neuron axons as a consequence of after discharges, often found in spastic disorders. The rise in accommodation index might be explained if after discharges reduce membrane potential; sodium inactivation will then increase and accommodation will also tend to increase (Quevedo et al., 1978). These changes contrast with those found in children with lower motor neuron disorders.

Since myopathies have been considered diseases in which no disturbance of lower motor neurons is present, the strength–duration curve should be normal unless late stage fibrosis induces muscle degeneration. The curves found in 17 myopathic patients, including dystrophies, thirteen of whom were in the fourth to ninth month of the disease, are significantly abnormal for all muscles tested. Harris (cited by Wynn Parry, 1971) has described these curves in one patient with progressive dystrophy; we have seen no further reference to this finding, which Harris explains as due to constriction of nerve fibres by fibrotic muscle. Our patients were at an early stage of their disease and this explanation cannot, therefore, be considered satisfactory. Lambert (1960) found evidence for a neural basis of dystrophy; Fenichel (1975) concluded that the neuromuscular junction was a focal point in the consideration of the pathogenesis of Duchenne dystrophy; and McComas (1977) reported losses of functioning units, probably present at birth, in this disorder. In central core disease increased motor unit fibre density similar to the density described in moderately severe axonal neuropathies has been found (Cruz Martinez et al., 1979).

The decrease in accommodation, which was more marked than the only just significant shift of the stength–duration curve in myopathic tibialis muscles, shows that this test is a sensitive index of neuromuscular damage in agreement with previous findings (Norris et al., 1979; Norris et al., 1981; Concha, 1982).

Nerve stimulation studies have shown changes in the amplitude, shape, distal latency of the compound muscle action potential, and of motor nerve conduction velocity in several types of neuropathies (Kaeser, 1975) and in some myopathies (Cohen and Brumyik, 1976). The non–significant decrease in conduction velocity in our patients might argue against a neural basis for these diseases, or alternately, this technique may be inadequate to assess motoneuron involvement in myopathic muscle except in disease of long standing. The finding that conduction velocity is slightly lower in dystrophic children than in other myopathic patients seems to imply extensive neurogenic dysfunction in the former. The de-

crease in muscle action potential amplitude and increase in distal latency is significant in both groups, particulary in dystrophic children. These characteristics are therefore more important than the measurement of conduction velocity, in the evaluation of neuron function in neuromuscular diseases.

These findings, taken in conjunction, implicate a defect in motor neuron–muscle fibre relationship in myopathies, and furnish additional evidence for a neurogenic origin of disorders according to the hypothesis proposed by Rowland (1974) and McComas et al. (1974).

The significantly altered strength–duration curves for the muscles of median nerve injury patients, together with the prolonged chronaxie, point to neurapraxia since the muscles responded to short duration pulses (Brooks, 1976) and therefore a favourable prognosis might be expected. However, the marked decrease in the slope of the accommodative index in these patients revealed moderate nerve pathology and is in accordance with the previously discussed sensitivity of this test. The considerable decrease in action potential amplitude, increase in distal latency, and reduction in conduction velocity can be ascribed to the reduced diameters of the regenerating nerve fibres.

The magnitude of nerve damage is reflected in the marked displacement of the strength–duration curves and prolonged chronaxies for peroneal neuritis, in contrast to the slight changes in recovering median injuries. Conduction velocity was less affected in peroneal neuritis; it is well known that pathogenetic agents induce a variety of histological alterations according to the severity and length of action of the agent, and these pathological states may be more accurately monitored by tests such as the strength–duration curves and accommodation.

In this series of patients, the most crippling disease was polyrradiculoneuritis and the tests were indicative of severe denervation; the strength–duration curve profiles were those found in almost denervated muscle fibres, chronaxies were greatly prolonged, and accommodation was almost abolished. Axonal degeneration interferes with inactivation of the sodium carrying mechanism (Hodgkin and Huxley, 1952) and thus decreases accommodation (Saez, 1982; Concha, 1982). The extensive damage revealed by nerve stimulation studies is probably due to both demyelination and axonal degeneration (Raine, 1978; Kaeser, 1975).

These tests showed slight increases in neuromuscular excitability in children presenting with upper motor neuron diseases and significant perturbations of strength–duration curves, chronaxie, accommodation indexes, and of nerve stimulation studies in non progressive myopathies. The changes in action potential characteristics were more marked in progressive muscular dystrophy patients than in myopathics; in both groups, these results support a neurogenic basis for muscle disease. Peripheral *nerve* injuries and neuropathies revealed values consistently different from myopathies, and the most pathological values were found in polyrradiculoneuritis patients.

This work furnishes further evidence that disorders previously considered due to structural or metabolic defects of muscle, show neuronal muscle fibre dysfunction.

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