Spasticity of muscles: morphological and electromyographic characteristics in patients with cerebral palsy, directions for rehabilitation

G. M. Kushnir
S. V. Vlasenko

Crimean State Medical University named after S.I.Georgievsky, Simferopol, Department of the Nervous Diseases with the Course of Postgraduate Neurology; Evpatoria Central Children Sanatorium of the Ministry of Defense, Evpatoriya, Ukraine

Summary. The morphological structure of the long adductor muscle of the thigh of 73 patients with infantile cerebral palsy has been investigated, and obtained results were collated with clinical data and electromyographical investigation. Distinct dependence of clinical signs of disease on the degree of pathological changes in muscular tissue has not been revealed. Certain approaches to the choice of the program of rehabilitation were suggested, depending not only on the clinical and morphological condition of patient's muscle but also with the consideration of electromyographical investigation which reflects the state of the morphological structure of muscular tissue.

Keywords: cerebral palsy, morphology, electromyography, rehabilitation.

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INTRODUCTION

Social adaptation and self-service are the goals that are put at the head of any program of long-term rehabilitation of patients with infantile cerebral palsy (CP) [1, 2]. Violation of independent physical activity as a result of severe organic lesions of the central nervous system structures requires development of an individual complex which includes a variety of techniques. It is necessary to consider the neuro-psychological and motor status of a child, that is why in addition to clinical investigation various methods of neurophysiologic examinations are used (Doppler, EEG, EMG, etc.).

Electromyography (EMG) is a traditional method of examination which continues to remain relevant and allows to evaluate the status of muscles by recording their electrical potentials [3, 6, 7].

Adresas:
Grygory Matveevich Kushnir – M.D., Ph.D., Professor Department of the Nervous Diseases with the Course of Postgraduate Neurology, Crimean State Medical University named after S. I. Georgievsky, Simferopol Department of the Nervous Diseases with the Course of Postgraduate Neurology, CSMU after S.I.Georgievsky. 5/7, Lenin Blvd., Simferopol, 95006, Ukraine Tel.: (+38 0652) 373 590.

PURPOSE

To evaluate morphological changes in spastic muscles in patients with cerebral palsy, to compare the data with the results of the EMG study, and to develop common criteria for the diagnosis of the functional state of spasticity in cerebral palsy.

MATERIAL AND METHOD

The object of the study were 73 patients with diplegic form of cerebral palsy of the age from 4 to 30 (mean age 10.7±5.0).

A morphological study of the section of the long thigh adductor in 73 patients with cerebral palsy was conducted. The material was taken during the lengthening operation of this muscle in case of contracture. Fragments of each muscle were filled with celloidin-paraffin and stained by standard histological techniques (hematoxylin and eosin) for light microscopy, and fixed in 2.5% glutaraldehyde solution in the phosphate buffer (pH=7.2–7.4), followed by additional fixation 1% OsO4 solution. Materials were embedded in a mixture of Epon-MNN-DDS A. Ultrathin slices were produced by ultramicrotome "Reichert" (Austria) and were viewed and photographed with an electron microscope JEOL-1010 (Japan) in Neuromorphology Laboratory UCLA (USA).

All morphological signs correlated and were divided into three main groups, depending on the processes occurring in the muscle. The first group included signs of de-

struction (destruction of muscle fibers, homogenization of myoplasma, swelling, vacuolization, disintegration of muscle fibers, hemorrhagic soaking, absence of striations of myofibrils or their decay, thinning, absence or marked decline in the number of nuclei, their irregular arrangement, the absence of endo-, epi-, perimisium, destruction of the vascular wall, destruction of mitochondria, fresh post-traumatic dystrophic changes, the absence of blood vessels). The second group consisted of signs of regeneration which included accumulation of miosatellitocitis, regeneration foci (nuclei were located in groups on periphery of sarcoplasm, perimisium was not always observed), and the presence of young muscle fibers randomly arranged. Signs of degeneration of muscle tissue were referred into the third group (high prevalence of the connective tissue in the preparation, expanding perimisium and endomysium, the presence of scar tissue, destruction of muscles fibers).

Clinical severity of the disease was evaluated by the following criteria: the ability of independent travel (walks without aid, with support, does not move), the degree of muscle spasticity was assessed by Ashworth scale, severity of paresis was assessed by five-point scale. The control group included 23 children admitted to sanatorium due to frequent colds.

Total EMG was performed by a standard method using skin overlapping metal electrodes and a 4-channel digital electromyographer "Neyromian" produced by "Medic" (Russia). Sweep rate of the screen was 50 ms per division, screen sensitivity – 100 mV and 1000 mV, filter frequencies in the range of 10 to 2000 Hz. Global EMG of the long adductor of thigh was recorded at rest and when performing voluntary movements. The numerical values obtained by automatic analysis of electromyographic curve were investigated. The mean amplitude (A) of bioelectric oscillations (V), the average frequency of (P) waves (Hz), as well as an integral index of the bioelectrical activity of the muscles, defined as the area of electromyographic curve per unit time (mV × s) were analyzed. Types of EMG were also determined according to Y. S. Yusevich classification (1967).

RESULTS AND DISCUSSION

According to obtained data of morphological study all preparations were divided into three groups. The first group (with minimal changes in the structure of muscle tissue) included specimens of 19 patients (26.03%). Morphological pattern of this group was characterized by minor vascular changes (expansion of empty capillaries) and related phenomena of intracellular edema (diffuse enlightenment cytoplasm of endothelial cells, swelling and a sharp increase in the size of mitochondria, the loosening of the endothelial basal membrane). In this regard, muscle looked loose, and separate muscle fibers seemed disjointed. However, the fibers themselves preserved their characteristic structure. Constituent of their microfibrills were parallel, compact and orderly. In muscle fibers intercalated disks were clearly identified, and M-line separating anisotropic disks in sarcomers was evident. Within the disc A microfibrills clearly contoured, maintained their integrity throughout. The disks I with a winding Z-line with fairly clear outlines in high magnification were clearly defined.

The second group (with moderate pathomorphological features) was compound by preparations of 43 people (58.9%). For this group in addition to edema and vascular changes muscles showed dystrophic and destructive processes in the form of changes in the cytosol, and reduction and destruction of intracellular organelles. Most important changes in this group were changes in the mitochondria. In the vast majority vacuolization and swelling with enlightenment matrix, and also reduction, disorientation and even dislocation of cristae were observed. In marked number of mitochondria gaps and the integrity of the outer membranes, and the destruction of cristae and rupture with subsequent fragmentation were identified. However, most of the muscle fibers and myofibrils retained their structure with parallel arrangement of densely packed microfibrils and clear transverse striations due to anisotropic rotation of discs and their border lines.

The third group (with the most pronounced signs) included preparations of 11 patients (15.07%). In these observations the pathological changes were most pronounced in comparison with the previous groups and were characterized mainly by phenomena of destruction and degeneration.

Analysis of the clinical manifestations of the disease showed that 15 people could move without assistance (20.55%), 37 patients could move with assistance (50.68%), and 21 patients could not walk at all (28.77%). The degree of spasticity in average was 3.30±0.78 points, severity of paresis – 3.12±0.73 points. Thus, when considering clinical signs of cerebral palsy patients no dependence was determined between the degree of severity and the degree of pathological changes in the muscle tissue.

During the EMG study in a group of specimen with minimal pathological changes amplitude was 150.79±4.42 mV, which was significantly different from normal values (300.91±11.79 mV, $P<0.001$ (here and hereinafter compared with the control group). Frequency happened to be 159.63±5.79 Hz (190.30±6.55 Hz, $P<0.01$), and integral index – 54.63±3.04 mV×s (60.78±6.16 mV×s, $P>0.05$). EMG in this group was represented by the interference of the curve with some rare gypersinhronous fluctuations and could be regarded as the first type of EMG according to Y. S. Yusevich.

In the second group (with moderate pathological changes) the average of the bioelectric activity of the muscles was 170.97±4.58 mV ($P<0.001$), frequency – 102.61±8.17 Hz ($P<0.001$), the integral index – 75.74±3.74 mV×s ($P<0.05$). On EMG the curve was mixed, its analysis revealed signs typical for EMG both of type I and type II EMG.

In the group with the most severe morphological changes the integral index was very low – 12.18±2.48 mV×s (P<0.001). According to the main features of EMG it could be attributed to the first type, but in general myogram was presented in the form of interference curve with an amplitude of fluctuations in the level of bioelectric noise – 32.45±7.46 mV (P<0.001). Separate fluctuations that looked against this background like "gypersinhronous" (100–120 V) had frequency of – 15.91±2.98 Hz (P<0.001).

Thereby, the group with minimal morphological changes was characterized by the total decrease in the amplitude of bioelectric potentials with arbitrary motor skills on EMG, what can be explained by dysregulation of the neuromuscular system at the level of the central structures. In case of more prominent morphological changes and signs of regeneration processes, the appearance of gypersinhronous potentials against decrease in frequency of bioelectrical oscillations may be due to compensatory innervation and is regarded as an adaptation mechanism. In the most severe cases, with marked morphological changes, the emergence of extremely low bioelectrical activity with individual motor unit potentials of low amplitude and frequency was noted. In these cases we can assume a severe depletion of adaptive mechanisms reinnervation of muscle fibers which is a sign of the severity of violations of neurobiological processes in the structural units of the musculoskeletal system for this group of patients.

Thus, the formation of rehabilitation therapy programs of cerebral palsy should take into account EMG studies that may reflect the state of the morphological status of the muscles, which also allows to control treatment effectiveness. Moderate changes in the basic parameters of EMG may indicate sufficient safety of the structure of muscle, even with severe delay of motor development and contractures, which allows to continue complexes of conservative measures to reduce spasticity (injections of "Dysport" – botulinum toxin type A) [4, 6, 7], to continue developing motor skills. Significant changes in EMG-curve usually correspond with severe violation of the morphological structure of the muscle tissue, which with combination with severe contractures is a direct indication for the different methods of surgical treatment with subsequent rehabilitation aimed to improve the trophic processes in muscle.

FINDINGS

1. Morphological status of the muscles in patients with cerebral palsy is characterized by a variety of changes which allow to distribute them into three groups: those with minimal pathological changes, the moderate severity of symptoms, and gross degeneration.
2. In patients with cerebral palsy correlation of clinical signs of disease on the degree of pathological changes in the muscle tissue has not been made clear.
3. The EMG studies reflect the morphological changes in the muscle.
4. Using and comparing the data of morphological and EMG studies, we can form an individual rehabilitation tactics for each patient and monitor its efficiency.

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G. M. Kushnir, S. V. Vlasenko

RAUMENŲ SPASTIŠKUMAS: CEREBRINIU PARALYŽIUMI SERGANČIŲ PACIENTŲ MORFOLOGINĖS IR ELEKTROMIOGRAFINĖS CHARAKTERISTIKOS, NUORODOS REABILITACIJAI

Santrauka

Šiame tyrime buvo tirta 73 pacientų, sergančių cerebriniu paralyžiumi, ilgojo pritraukiamojo šlaunies raumens morfologinė struktūra. Gauti rezultatai palyginti su klinikiniais duomenimis ir elektromiografijos tyrimo rezultatais. Nebuvo nustatyta specifinių ligos klinikinių požymių priklausomybės nuo patologinių pakitimų laipsnio raumenyse. Straipsnyje pateikiami reabilitacijos programos pasirinkimo pasiūlymai, remiantis ne tik klinikine ir morfologine paciento būkle, bet ir elektromiografinio tyrimo rezultatais, kurie atspindi raumens audinio morfologinę struktūrą.

Raktažodžiai: cerebrinis paralyžius, morfologija, elektromiografija, reabilitacija.