DIAGNOSTICS OF CLINICAL NEUROPHYSIOLOGY IN ORTHOPAEDICS AND PHYSIOTHERAPY – AN OVERVIEW OF THE MOST COMMONLY USED METHODS

Juliusz Huber, Aleksandra Kulczyk, Joanna Lipiec

Department of Pathophysiology of Locomotor Organs, Poznan University of Medical Sciences, Poland

ABSTRACT

Introduction. The paper presents application of clinical neurophysiology methods for functional testing compatible with Evidence Based Medicine, which are most commonly used in orthopedics and physiotherapy to determine the source of pathology in the muscular and nervous systems and evaluation (through tests performed comparatively), the progress of surgical and conservative treatment.

Methods and observation. Application of the needle electromyography is only essential when the cause of muscle pathology (myogenic or neurogenic damage) is unclear, as well as to assess the severity of muscle's denervation which is supplied from a certain neuromer. Surface electromyography determines the degree of motor units dysfunction more in cases of neurogenic injuries origin when the test of maximal contraction is performed. This allows the estimation of proper muscle tension in terms of muscle relaxation. Electroneurography both in orthopaedics and physiotherapy plays an essential role in determining the transmission of nerve impulses in the sensory and motor fibers peripherally or at the level of the spinal nerves. Evaluation of efferent transmission from the level of motor cortex to the effector is possible by analysing the parameters of motor evoked potentials induced with the magnetic field. The study of surface electromyography recorded during maximal contraction can be related to the result of muscle strength test performed with the Lovett's scale. Electromyography recorded during "relaxation" with increased amplitude parameter may indicate for the phenomenon of increased muscle tension, and the results can be related to the examination with Ashwort's scale.

Key words: clinical neurophysiology, diagnostic methods, orthopaedics, physiotherapy

Introduction

Clinical evaluation of muscles function and transmission of impulses in the nerves and efferent and afferent pathways of the central nervous system on its different levels provides the results to some extent subjective, mainly due to the varying degree of the doctor and patient cooperation (Buckup 2004). Contemporary orthopaedics and physiotherapy are start to use more and more the clinical neurophysiology studies for direct and dynamic assessment of the results of surgical or pharmacological and conservative treatment (kinsiotherapeutic and/or physicotherapeutic). The aim of these studies is to determine the pathology source and location in muscular and nervous systems. Being functional tests with a high level of precision of obtained results, they complement neuroimaging studies which indicate the structural pathology. Plan of clinical neurophysiology diagnostic tests depends on the initial diagnosis of the attending physician, the results of additional tests (neuroimaging and laboratory), and they can be modified in the course of their conducting. The most common contraindications are implants including stabilizers, electronic devices or ferromagnets, certain pharmacological agents (used for treatment of the nervous system diseases or diseases associated with blood coagulation), advanced cardio-vascular disorders, epilepsy or pregnancy. The results of clinical neurophysiology diagnostic tests are influenced by age, temperature, constitutional type of the examined subject (Huber et al 2009; Kulczyk et al 2011; Huber 2013). Demonstration of muscle's pathology taking the origin as myogenic or pseudomyogenic (including the inflammatory reaction in the course of rheumatic diseases) or the consequences of damage to the nerve components of motor units within the central or peripheral systems (neurogenic) determines the legitimacy of the physiotherapeutic treatment use by means of the strengthening exercises, procedures aiming to decrease the effects of increased muscle tension (relaxation procedures) or the certain physiotherapeutic procedures (Lisiński et al 2008; Huber et al 2012; Huber 2013).

While in the clinical testing the Lovett's scale is still the most reliable and widely accepted test for muscle strength evaluation (Buckup 2004), the electromyography (EMG) estimates the activity of the muscle's motor units.

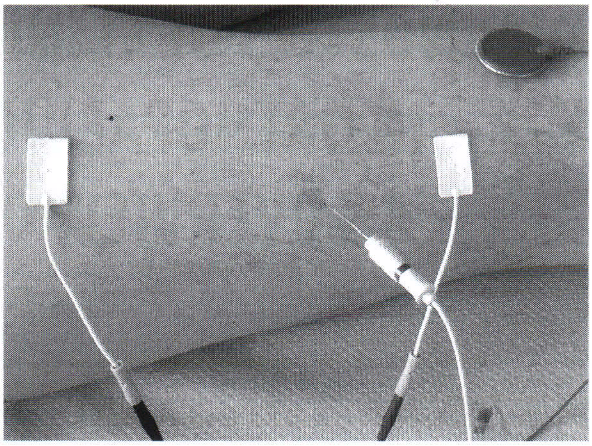

Figure 1. Photography illustrating the study design with surface and needle electromyography

Methods

Electromyography is methodically divided to needle electromyography (nEMG) and surface electromyography (sEMG) (Figure 1). Needle electromyography, which assess the parameters of single muscle motor units potentials during voluntary contraction (duration, amplitude, area), enables the differentiation of changes to the myogenic or neurogenic. Recordings carried out by nEMG during the resting state, by the presence of spontaneous discharges (fibrillations, positive sharp waves, fasciculations; Figure 2B), may suggest the source of the pathology in the nervous system at the level of the injured motor fibre, denervation at the neuromuscular synapse or the damaged cell body of motoneurone in the spinal cord. Spontaneous discharges of multiple individual potentials taking the forms called myotonic discharges or pseudomyotonic discharges confirm the primary source of the muscle injury.

Surface electromyography is particularly useful for the preliminary screening before application of nEMG and allows the best selection of muscle with symptoms of motor units dysfunction. In physiotherapy sEMG occupies a special role because of the possibility of non-invasive examination the homonymous muscle groups on both sides of the body, and to distinguish the phenomenon of asymmetric motor function (lateralization) from muscle's paralysis with a certain advancement. Practically, during EMG recording with maximal contraction lasting 5 seconds, there are evaluated the amplitude (in microvolts) and frequency (in Hz) parameters (Lisiński et al 2008; Huber et al 2011; Wytrążek et al 2011; Huber et al 2012; Huber 2013) (Figure 2A). The increase in the frequency of recorded single potentials (nEMG) or summary (sEMG) potential recordings above 100Hz confirms the myogenic pathology, while the decline in this parameter below 60Hz – 10Hz (Figure 2) describes damage to the muscle of the source of neurogenic with varying degrees of severity (Kulczyk et al 2011).

The difference in the decrease of the amplitude parameter in sEMG recordings of homonymous muscle groups >20% defines the phenomenon of paralysis. During nEMG recordings of >20 individual motor units potentials, the ascending trend in values of the amplitude, duration and area of the individual motor units potentials confirm the neurogenic damage, while the descending trend in changes of these parameters – myogenic change. Proper single motor unit potentials should not be more than three-phases, phenomenon of polyphasic potential exists in both types of muscle's injuries (Huber 2013). The clinical manifestation of increased muscle tension is tested using the Ashwort's scale (Pandyan et al 2005). sEMG amplitude with the average resting potential $\leq 25\mu V$ defines proper muscle tension in terms of clinical neurophysiology studies (Huber et al 2013) (Figure 3A).

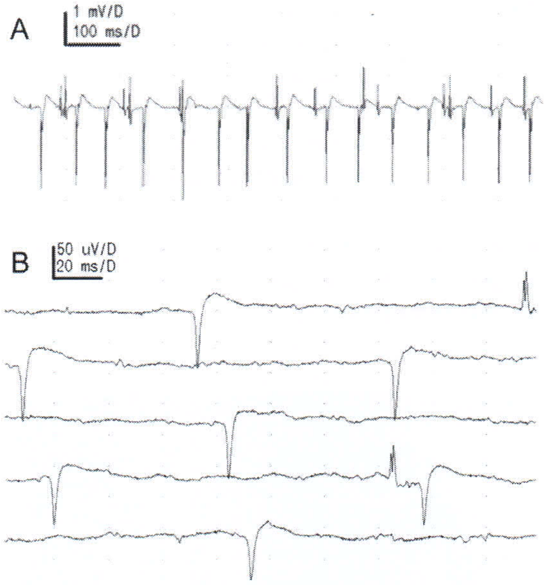

Figure 2. Examples of nEMG recording (A) during of the maximal contraction and (B) the relaxation of examined the abductor pollicis brevis muscle pointing to the advanced neurogenic changes (note the high-amplitude and low frequency recording) and denervation (with positive sharp waves).

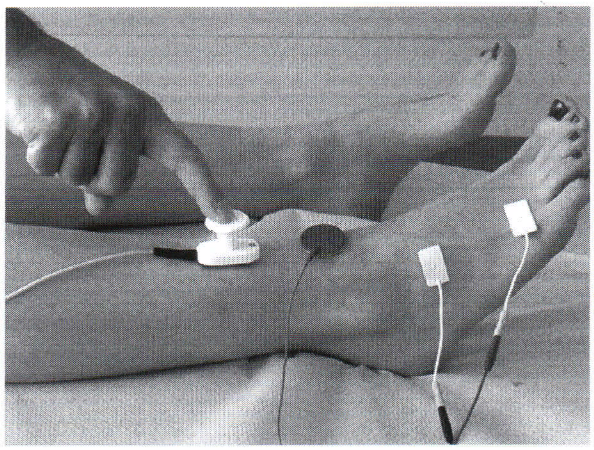

Figure 4. Photography illustrating the methodology of the electroneurographical study of peroneal nerve with the locations of stimulating, ground and recording electrodes.

Electroneurographical examinations (ENG) (Figure 4) using for excitation the nerve fibers along their course the electrical stimuli, allow specifying the abnormalities in the transmission of nerve impulses peripherally or in their proximal part.

ENG examinations make possible to diagnose mono- or polyneuropathies, which can be of the axonal type (degeneration of axons, the decrease of exclusively M-wave amplitude in the study of transmission in motor fibers or SCV – sensory potentials in the sensory nerve conduction study; orthodromically – according to the direction of the physiological impulses propagation), demyelinating type (segmental demyelination, increase only M-wave latency or SCV potential), indicate the conduction block (in the so-called segmental study) or of a mixed type. Examination of F-waves frequency recording (using antydromic transmission phenomenon- opposite to the physiological spread of nerve impulses) and interlatency of M-F waves specify the level of motor fibers injury (in proximal spinal roots or distally). In general, when during the stimulation test using 20 electrical pulses and evoking 20 ENG waves, the frequency of recorded F-waves is less than n = 14, this suggest the level of the spinal injury (Figure 5). The evaluation of nerve transmission in all parts of the monosynaptic reflex arc enables the study of H-wave recordings which belongs to the ENG tests.

The central and peripheral efferent transmission is monitored more and more using the MEP method (motor evoked potentials induced with magnetic field). The phenomenon of excitation the

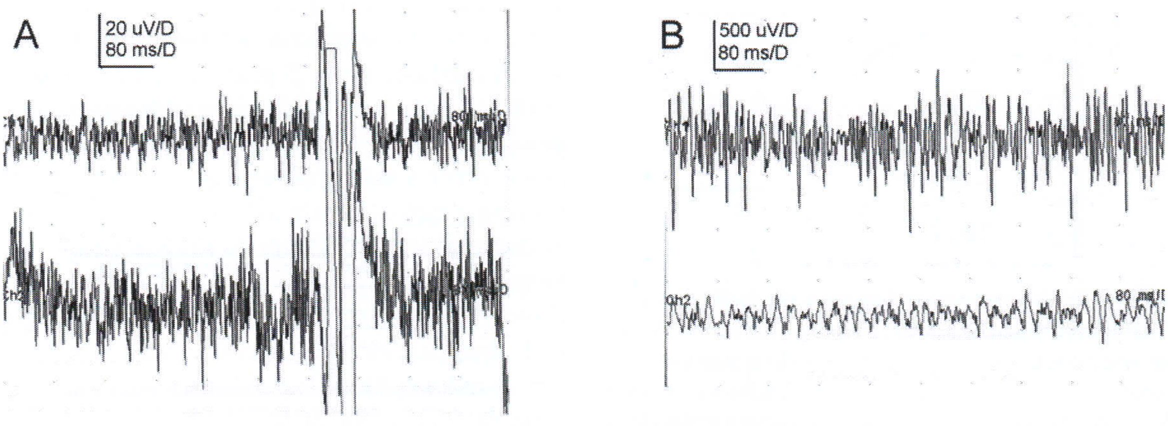

Figure 3. Examples of sEMG recordings during the maximum muscle contraction (A) and relaxation (B) of the right (upper recordings) and left (lower recordings) trapezius muscles. Note the symptom of increased muscle tone (A, lower recording), limiting the maximal muscle contraction (B, lower recording).

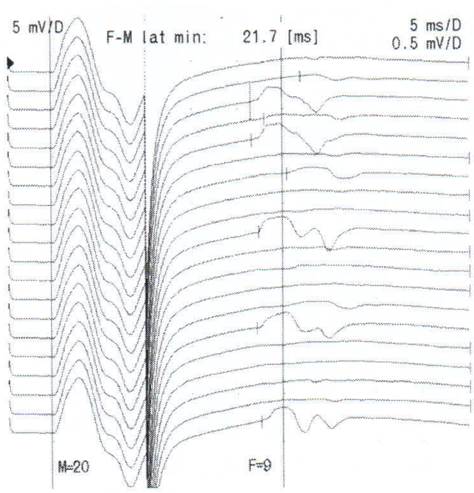

Figure 5. Example of recordings the M-waves (n=20) and F-waves (n=9) in ENG study when performed from extensor digiti minimi muscle after electrical stimulation of the peroneal nerve distally within the lower extremity. Note attention the low frequency of recorded F-waves suggesting abnormalities in the transmission within motor fibres in the ventral roots at L5-S1 level.

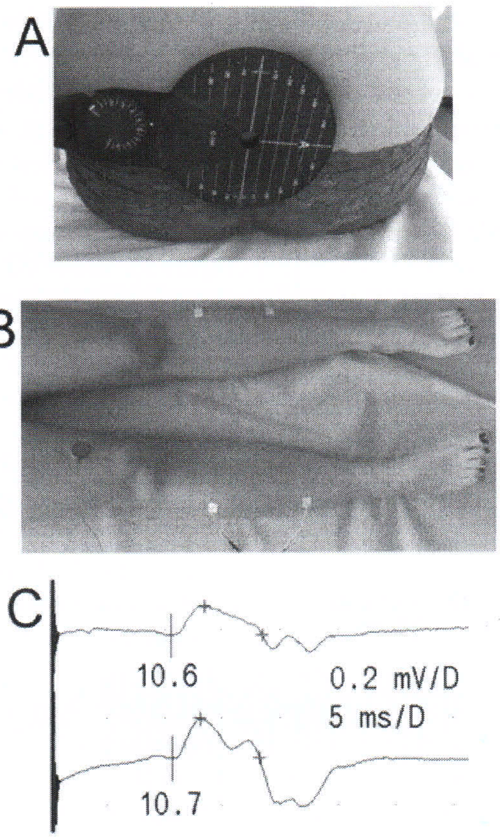

Figure 6. Photograph which illustrates the methodology of bilateral recordings the MEP potentials (C) from tibialis anterior muscle (B) following oververtebral stimulation of motor centres in the spinal cord at the lumbo-sacral levels (A). Note the reduction of evoked potential amplitude on the right side (upper recording), indicating the abnormalities of the axonal type in transmission of nerve impulses from the motor center to the muscles.

motor centres at the supraspinal or spinal levels is induced by the magnetic field stream which is applied overcranially or oververtebrally (Tabakow et al 2013) (Figure 6).

Tests with von Frey's filaments are used to assess the degree of the sensory perception and the afferent transmission from the level of receptor to the centres of the cortex. They allow a precise differentiation of hyperalgesia, normal sensation and analgesia (Huber 2013).

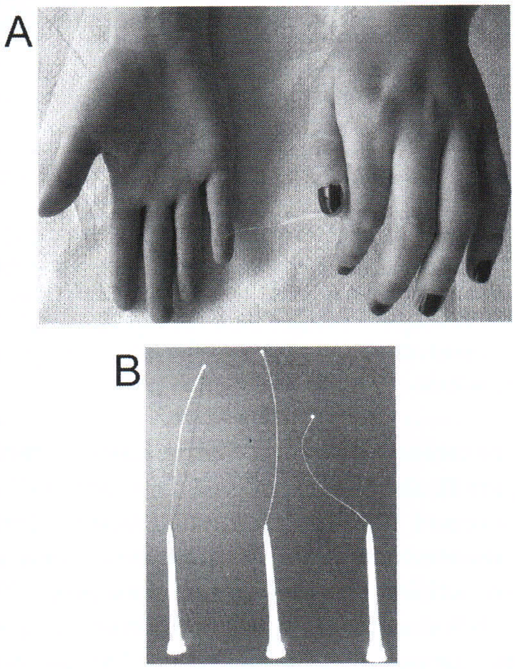

Figure 7. Photographies illustrating the methodology for the study of the sensory perception (A) with von Frey's filaments (B) of calibrated diameter for diagnostics of hyperalgesia, normal sensation and analgesia.

General consideration

The results of clinical neurophysiology are compared with the standards set for all of these research methods every 5 years, in a population of healthy volunteers of both sexes with regard to age groups. Motor units are undergo the natural aging process with a shift of parameters characterizing of the single motor units in a direction corresponding to the neurogenic damage in healthy people over forty years of age. The relationship between the clinical assessment of muscle strength in Lovett's scale and parameters of sEMG frequency (up to 90Hz) and amplitude (up to 800μV) during the increasing contraction of muscle (Figure 8, modified for Lisiński et al 2008).

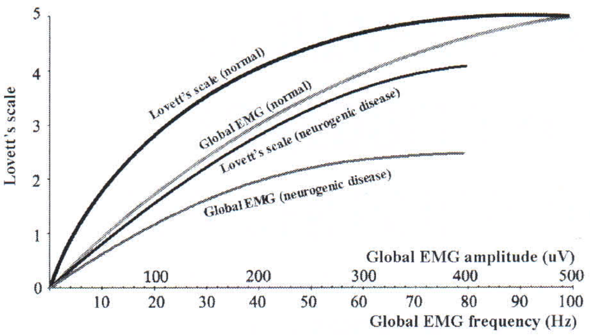

Figure 8 The relationship between the results of the muscle strength assessment with Lovett's scale and recorded sEMG parameters in healthy people and in patients with neurogenic motor units pathology.

References

Buckup K., Clinical Tests for the Musculoskeletal System, Stuttgart, New York: Thieme; 2004.

Emeryk-Szajewska M., Niewiadomska-Wolska M. (Eds.): Neurofizjologia kliniczna. Elektromiografia, elektroneurografia, Medycyna Praktyczna, Kraków 1993.

Huber J., Kulczyk A., Lisiński P., Lipiec J., The use of surface electromyography for diagnosis of muscle dysfunction with pain symptoms, Trends Sport Sci, 2013;20,3:135-139.

Huber J., Lisiński P., Samborski W. et al, The effect of early isometric exercises on clinical and neurophysiological parameters in patients with sciatica: an interventional randomized one-blinded study, Isokin Exerc Sci 2011;19: 207-214.

Huber J., Lisiński P., Polowczyk A., Reinvestigation of the dysfunction in neck and shoulder girdle muscles as the reason of cervicogenic headache among office workers, Disabil Rehabil 2012;35:793-802.

Huber J., In: Interna Szczeklika. Podręcznik chorób wewnętrznych. Chapter VII. Choroby reumatyczne, C. Badania diagnostyczne, 5. Badania neurofizjologiczne, Medycyna Praktyczna, Kraków 2013.

Huber J., Zagłoba-Kaszuba A., Kulczyk A., Lipiec A., Wytrążek M., Age and functional properties of motor units in healthy people, Medical News 2009,78,2,99-102.

Kinalski R., Neurofizjologia dla neurorehabilitacji, Med. Pharm., Wrocław Polska, 2008.

Kulczyk A., Lipiec J., Huber J., Zagłoba-Kaszuba A., Wytrążek M., Stryła W., Warzecha D., Standards of the surface electromyography examinations for assessment of muscle motor unit activity for physiotherapy purposes. W: Current Topics on Clinical Neurophysiology, Physiotherapy and Manual Therapy. Eds.: Juliusz Huber, Marcin Wytrążek, Joanna Lipiec, Aleksandra Kulczyk. Poznan, 2011, Coll. Educ. Ther. Publ. House, ISBN 978-83-927622-2-5,106-119.

Lisiński P., Huber J., Samborski W. et al, Neurophysiological assessment of the electrostimulation procedures used in stroke patients during rehabilitation, Int J Artif Organs 2008;31:76-86.

Pandyan A.D., Gregoric M., Barnes M.P., Wood D., Van Wijck F., Burridge J., Hermens H., Johnson G.R., Spasticity: clinical perceptions, neurological realities and meaningful measurement, Disabil Rehabil. 2005;7-21;27,1-2:2-6.

Wytrążek M., Huber J., Lisiński P., Changes in muscle activity determine progression of clinical symptoms in patients with chronic spine-related muscle pain. A complex clinical and neurophysiological approach, Functional Neurology, 2011;26,3,141-149.

Tabakow P., Jarmundowicz W., Czapiga B., Fortuna W., Międzybrodzki R., Czyż M., Huber J., Szarek D., Okurowski S., Szewczyk P., Górski A., Raisman G., Transplantation of autologous olfactory ensheathing cells in complete human spinal injury, Cell Transplant. 2013;22,9:1591-1612.

Author responsible for correspondence: Juliusz Huber, 28 Czerwca 1956 Street, no 135/147, 61-545 Poznań, e-mail: zpnr@wp.pl