CLINICAL NEUROPHYSIOLOGY – THERADIAGNOSTICS INTERFACE: PERSPECTIVE OF NEW PHYSIOTHERAPIST PROFESSION

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Summary

Aim: To justify the conception of utilization by physiotherapist the clinical neurophysiological diagnostic tools and procedures as the neurophysiotherapeutic tools and procedures. Objective: The countless number of the human behaviors is the expression of the nervous reflexes (ENR). The ENR development by repetitive physical factor intensify the physiologic Long Term Potentiation (LTP) phenomenon. For neurophysiologist LTP is the value of diagnosis however for the physiotherapist LTP is the effect of therapy. The ENR bioelectrical feature connect in the electrophysiological terms the conceptions of personalized medicine and theradiagnostic with the clinical neurophysiology (CNF) and physiotherapy. Method: The review of articles dealing with utilization of the tools and procedures for CNF examination as the means that intensify the post stroke and post spinal cord injuries neuroplasticity. Results: The diagnostic CNF tools and procedures are utilized as physiotherapeutic ones. This improves the quality of life of the hemiplegics and tetraplegics who become subordinated to others. Such effects are possible thanks to engineering devices produced by industry interested in collaboration between neurophysiologists and rehabilitation bioengineers. However the physiotherapist, who should fulfill the medico-legal requirements in that area, is not educated. Conclusion: Existed situation indices the need to innovate the curriculum of the physiotherapy faculties.

Key words: personalized medicine, theradiagnostics, clinical neurophysiology, bioengineering, neurophysioterapy, education.

Introduction

Each year the number of young unemployed physiotherapy graduates increases in the country. This does not change the curriculum on that faculties since 2007 [1]. At the same time one can observe a breakthrough in medicine which promotes the concept of personalized medicine. This implies a change of treatment paradigm. In the colloquial translation it means a treatment "not of the disease" but treatment "of the patient" [2]**.** It turns out that a patient treatment based on a recognized disease entity is less sufficient and more costly than the treatment based on recognized individual (personal) biological characteristics of the organism [3]. Identification of such a feature is carried out basing on the instrumental test result[1]. A model of a choice of a tool or a therapeutic procedure, based on the instrumental test result, has been named a diagnostic therapy (theradiagnostics) [4]. This new concept, known and applied in the environment of oncologists has not been disseminated in the environment of physiotherapists yet. Meanwhile, taxpayers spend their money on the disease treatment and sequels of injuries of the central nervous system (CNS). Therefore it justifies the expectations of the patient on the availability of the high-quality services provided to them.

[1] The term means carrying out the procedure with the use of engineering devices, i.e., the tool.

A person who suffers from impaired cerebral control of motor behaviours, occurring as a result of CNS damage, and who presents or is referred to physiotherapist wants to recover the ability to function independently as quickly as possible and to the largest possible extent. In order to achieve it, self-reactive processes of neuroregeneration and neuroplasticity ongoing in CNS need to be supported or provoked externally by physical factors[2]. Processes of CNS neuroplasticity, which have been the subject of preclinical instrumental scientific study since the Decade of the Brain (1990-2000), quickly became the aim of clinical instrumental studies both scientific and service. Owing to the development of new technologies, tools and procedures which have been of diagnostic nature so far, are currently used as tools and procedures supporting neuroplasticity processes. An example of such a breakthrough is clinical neurophysiology [5]. The CNF study belong to the category of instrumental electrophysiological studies carried out in patients with CNS damage. The results of these studies objectify and quantify in SI[3] units the expression of nerve reflexes induced by physical factors. The frequency (in Hz) of inducing CNS reflex response is closely related to frequency of activating neurons and/or CNS neural networks. Inducing neural reflexes with physical factors repeated with selected frequency, can lead to physiologic prolonged intensification of synaptic transmission in microstructures of CNS, called long-term potentiation (LTP) [6]**.**
In the case of instrumental inducement of LTP phenomenon with the physical factors, that in reality are basic physiotherapeutic factors instrumentally influencing CNS, the LTP phenomena should be understood not only as an objectified result of the study but also as an objectified result of the treatment.
Instrumental inducement of LTP phenomenon in hemiplegic or tetraplegic patients can have, depending on the objective of medical procedure, a two-fold meaning. For a neurophysiologist LTP is the value of diagnosis however for a physiotherapist LTP is the effect of therapy. Clinical neurophysiology and physiotherapy compiled in this light, however basing on biophysics and not on biochemistry, meet the rule of theradiagnostic concept [4].

History
The CNF diagnostic tools and procedures have been incidentally and temporary used by some for many years for instrumental physiotherapy of patients with CNS damage. An example is history of numerous intervals in a hundred-year development of transcranial stimulation of cerebral cortex with the impulses of direct current [7]. Although the technology of transcranial stimulation of cerebral cortex motoneurons was initiated in 1954 by Gualtierotti and Paterson, the dynamic development of this technology, which later contributed to a breakthrough in CNF field, took place in 1980 when Merton and Morton described a technique of Transcranial Electrical Stimulation (TES) of pyramidal motoneurons of motor cerebral cortex [8,9]**.** In 1985 Barker, Jalinous and Freeston described Transcranial Magnetic Stimulation (TMS) [10]**.** Since then, the frequency of examinations carried out by clinicians on central motor functions in patients with brain and/or spinal cord damage, has begun to increase in geometric progression. The cooperation between neurophysiologists and bioengineers has contributed into it. As a result, the ways of utilization of energy of physical factors generated with CNF diagnostic tools in physiotherapy, were successively elaborated. An example is transcranial stimulation of cerebral cortex with repetitive magnetic impulses (Repetitive Transcranial Magnetic Stimulation – rTMS). The treatment relieves the symptoms of Parkinson's disease, symptoms of dystonia, and improves the effects of post stroke physiotherapy. Transcranial Direct Current Stimulation (tDCS) has been reused in neurological patients [11**].** According to the statements of Mark Hallett[4] and John Rothwell[5],

[2] Name of physical factors, will always be used in the text as the basis for physiotherapy
[3] Lippert H.: SI unit in medicine. Introduction into the International System of Units PZWL Warszawa 1980.
[4] Human Motor Control Section, NINDS, NIH, Betesda, Maryland, USA.

tDCS procedure is more often applied therapeutic technique which influences cerebral cortex excitability and its plasticity [5]. The effect of increasingly tight cooperation between clinical neurophysiologists with neurobioengineers is a continuous improvement of Brain-Computer Interface (BCI)[6]. This technology enables hemiplegic or tetraplegic, by means of emitted energy of cortical neuron discharge activated by process of thinking, remotely and wirelessly control mobile engineering devices, which helps to function in the environment.

Review

The content below, though signalled earlier and in other context [12,13], specify the report objective e.g. the justification of using tools and procedures of clinical neurophysiology by physiotherapist as tools and procedures of neurophysiotherapy.

Classic Electrodiagnostics

The time lapse between the invention of rheobase and chronaxia in the 19th century, has not caused a negligence of study in the field of classic electrodiagnosis abroad. Its theoretical basis was created by Louis Lapicque, who proposed physiologically defined rheobase and chronaxia parameters. Values of rheobase and chronaxia and plotting a hyperbolic curve i/t (intensity/time) enable comparison of excitability of skeletal nerves and muscles in animals and people. Knowing this determines the clinical effectiveness of electrostimulation of denervated skeletal muscle with superficial electrodes. To meet these requirements, Russo at all. showed experimentally that, transcutaneous stimulation of denervated anterior tibial muscle of rat with impulses equal to chronaxia and rheobase of this muscle, reduces expression of myoD and atrogin-1 gens which are respectively responsible for hypertrophy and atrophy of muscle fibers. The result of this instrumental study gives rheobase and chronaxia the value of biophysical biomarkers, which according to authors' intention, should be used by physiotherapists for personalization of physiotherapy in patients with neurogenic skeletal muscle damage [14]**.** Although terms of chronaxia and rheobase have been known for a hundred years, their significance has not faded and is reflected also in cardiology. This applies to the findings of threshold values of rheobase and chronaxia of impulses generated by cardiac pacemakers and used during cardiac defibrillation [15].

Superficial Electromyography (sEMG)

Examination with superficial electromyography is considered noninvasive instrumental intervention for patients with damaged peripheral or central nervous system. Owing to new technologies, miniaturization of devices and their decreasing cost, sEMG has been still developing as dynamically as in the times of its formation. The results of intercentre studies carried out by the European Group SENIAM resulted in applications of sEMG tools and procedures and their usage in the engineering devices [16]. Testing the results of physiotherapy with sEMG technique cause more and more interest in the country. Basing on the outcome of the said studies, results of kinesitherapy of people with lower back pain syndrome, activity of motor units within the painful triggered points are objectified and the effectiveness of manual therapy of shoulder-neck-strain-syndrome is evaluated [17,18,19]. Although the use of sEMG diagnostic tools and procedures as means to perform neurophysioherapy has been known for a long time, the cooperation of clinical neurophysiologists with bioengineers inspired production of devices less costly than electromyographs and contributed into dissemination of this type of physiotherapy [20,21]. From the patient's mental effort, that is his free will, depends the number of activated muscle motor units and the frequency of their discharge. This basic neurophysiologic phenomenon

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[5] UCL, Institute of Neurology, Queen Square, London, United Kingom.

[6] Own translation of English name

changes into bioelectric energy, generated in volitionally exercised muscles [22]. A patient with post stroke hemipharesis, appropriately taught by a physiotherapist, can use the energy of volitionally activated motor units of his healthy skeletal muscles to induce involuntary contraction of counterpart paretic skeletal muscles located on the opposite side. This kind of neurophysioterapy, carried out for 12 weeks in accordance with a protocol of in-depth procedure, leads to control of fingers straightening in the paretic hand and the use of improved paretic hand function in hemiplegic patients in activities of daily living [23].

Superficial Polyelectropmyography (sPEMG)

Superficial polyelectropmyography is an examination of many muscles simultaneously. Such examinations objectify, controlled by human brain, muscle coordination activated during different motor behaviours [24]. Superficial polyelectropmyographic examination is applicable in instrumental verification of the degree of spinal cord damage. The results of these studies show that patients with an complete spinal cord damage (category A according to ASIA scale), diagnosed with subjective or objective clinical neurological examination, in reality and in many cases in CNF instrumental examination have incomplete damage [25]. On this basis, techniques and procedures of sPEMG examinations are currently used in order to qualify paraplegics and tetraplegics for teaching them how to use paralyzed lower extremities armed with neuroprostheses. This technique makes patient try to perform volitional movements of bending and straightening of feet and lower leg. In this way, paraplegic or tetraplegic practice voluntary activation of paralyzed skeletal muscles. The energy of volitionally induced and residually preserved functional bioelectrical potentials in these muscles, after their appropriate strengthening is sufficient to use a neurprosthese. The application of this technology by patient with clinically diagnosed complete damage of spinal cord (category A according to ASIA scale), enables significant improvement of the quality of life due to the ability of standing on two extremities [26]**.**

Somatosensory Evoked Potantials (SEP)

Examination of somatosensory evoked potentials is a procedure which imitates the procedure of pain alleviating physiotherapy treatment of transcutaneous electrical nerve stimulation (TENS). The concept of recognition of SEP test procedure as a possible physiotherapy treatment has already been described by the author in 1999 [27,28]. The concept of SEP application as a temporary post stroke neurophysiatry window was based on meta-analysis novelties (1988-1999) published in MEDLINE. It turned out that SEP examinations were carried out in patients during acute post stroke period only for diagnostic purposes [29]. It is currently known that transcutaneous electrostimulation of peripheral nerve significantly activates neurons of primary somatosensory cortex (SI) which is anatomically and functionally connected with primary ipsilateral and contralateral motor cortex (MI). Motor and somatosensory cortex show specific ability to neuroplasticity which is associated with the improvement of motor functions. Performing in a hemiparetic stroke patient on the hemiparetic side, somatosensory stimulation of nerves such as median, ulnar, radial, fibular, tibial or sural, enhances functions of upper paretic limb or gait. Application of this procedure in connection with a traditional kinezytherapeutic intervention increases the outcome of learning and memorizing motor patterns [30]**.** The competence to carry out monosynaptic Hoffmann (H) reflex test is useful, once the protocol and aim of the procedure are changed, to decrease pyramidal spasticity. The H reflex amplitude reflects condition and level of descending presynaptic inhibition of spinal motoneuron excitability. Our previous studies showed that after a 60-minute transcutenuous electrostimulation of the peroneal nerve, both H reflex amplitude and pyramidal spasticity decrease [31]. Depending on the chosen frequency of electrical afferent impulses which stimulate peripheral nerve, a function of spinal neural networks which inhibit spinal motoneurons can be enhanced. This opens up the possibility of using SEP as noninvasive method of physiotherapy which decreases pyramidal spasticity [32]**.** After somatosensory stimulation of upper paretic limb in patients after stroke, there is an enhanced motor activity, temporarily increased paretic hand grip and the scope of volitional movements connected with activities of everyday life. This category of neurophysiatric treatments is considered as safe, noninvasive and theoretically suitable to be performed by patients at home [33].

Transcranial Magnetic Stimulation (TMS)
Described above transcranial magnetic stimulation [10] is of clinical neurophysiology diagnostic procedure widely recognized as noninvasive and safe. The competency to perform this procedure enables the performer to use it also in neurorehabilitation, vs. neurophysiatry of patients after stroke or spinal cord damage. TMS procedures belong to an enormous group of various techniques of cerebral cortex stimulation which with the help of physical stimuli support neuroplasticity processes as well as renewal of motor functions in patients after stroke [34]. An example of the physiotherapeutic result of TMS procedure is to modulate interhemispheric inhibitive functions of primary motor cortex (MI), which supports the performance of volitional manipulative movements [35].

Repetitive Transcranial Magnetic Stimulation (rTMS)
The technique of transcranial stimulation of the cortical pyramidal motor neurons with the repetitive magnetic impulses is considered as painless, noninvasive and safe method of neurophysiotherapy used in patients after stroke and spinal cord damage. When using rTMS technique, it is significant to consider which cerebral hemisphere is stimulated (damaged or contralateral) and what frequency of repeated impulses, high (5, 10 and 20 Hz) or low (below 1.0 Hz) is used. In the case of intact nerve fibers running in the corpus collosum (the great commissure), unilateral damage of motor cortex MI increases the activity of motor cortex neurons MI of contralateral cerebral hemisphere. The use of a two-minute rTMS (20 Hz) of the damaged hemisphere MI area decreases activity of its neurons and increases activity of neurons of contrlateral MI area. This brings the hypothesis according to which unilateral inhibition of one MI area with rTMS increases the activity of contralateral intact MI area. As a consequence, performance of volitional paretic limb movements improves and it is easier to learn to carry them out. This suggests triggering LTP neuromechanizm. This effect, which is indicative of improvement of cortical spinal tract activity sustains after the completion of treatment. The use of a fifteen-minute rTMS (1.0 Hz) of the damaged hemisphere MI area brings the reverse effect, that is, decreases activity of cortical spinal tract. This suggests trigerring LTD neuromechanizm [6]. This effect sustains after the completion of treatment. rTMS techniques also influence modulation of neurotropic substances levels like dopamine and serotonin [34,36,37]. The technique of transcranial rTMS with high-impulse frequency (20 Hz) combined to learning to walk is also used in neurorehabilitation of adults with incomplete damage of spinal cord in a cervical and thoracic area (category D according to ASIA scale). After fifteen days of performing rTMS treatments there was an improvement of strength and decrease of spasticity of lower limbs as well as improvement of steps length and the rhythm of gait. The improvement sustained for two weeks after the last day of such neurophysiotherapy [38].

Transcranial Direct Current Stimulation (tDCS)
Technique of transcranial stimulation of cortical pyramidal motoneurons with direct current impulses was initiated in 1954 by Gualtierotti and Paterson [8]. tDCS procedure relies on transcranial electrostimulation of cerebral cortex with two superficial electrodes placed on the

scalp in distant places. These sites correspond to the anatomical lobes and cortical fields which lie under the skull and which are identified with appropriate measurements [39]**.** Such locations are determined according to the needs of stimulation of cerebral cortex with cathode or anode. tDCS treatment which lasts from ten to twenty minutes at 1-2 mA intensity impulses do not cause damage to nerve tissue, is not painful, however, it may sometimes cause temporary itching of the skin under the electrodes. Change in motor cortex activity depends on polarization. Increased activity is induced when the anode is placed over cortex. But if the cathode is placed in the same place then the activity of cortex is reduced. tDCS treatment directed at stimulation of cortex in damaged hemisphere after stroke improves activities of daily living. The hypothesis according to which, combining tDCS with kinesitherapy can be a useful complement to traditional methods was confirmed. The use of tDCS with the cathode electrode produces an effect similar to that of rTMS at a frequency of 1.0 Hz. The use of tDCS with the anode produces an effect similar to rTMS at a frequency of 20 Hz. Clinical studies showed that both procedures can influence LTP and LTD neuromechanisms, neurotropic substances, levels of dopamine and serotonin and modulate early response gene expression. The authors of many reports document that improvement of motor function, including speech, can be obtained with tDCS technique in patients after stroke. From the comparison of devices used to perform tDCS and rTMS treatment in patients, it is known that tDCS method is simpler, cheaper and theoretically could be used by patients themselves [36,37,38,40].

Medical technologies related to physiotherapy.

In the Polish healthcare system, access to medical technologies, including medical procedures and organizational systems, is regulated by the insurer, i.e. the National Health Fund (NHF). Medical technologies include tangible resources such as drugs and equipment (tools) and intangible resources such as knowledge, skills and procedures. Health technology assessment includes the analysis of the clinical effectiveness and analysis of the influence of the refund to the taxpayer and on country's NHF budget. In this situation, the translation of foreign technology into the country is not easy but possible.

Brain-Computer Interface (BCI)

Basis for Brain-Computer Interface technology is, described in 1993, magnetoencephalography (MEG) [41]**.** Bioelectrical currents, produced in the cerebral cortex during the process of thinking, generate an electromagnetic field that is transmitted wirelessly to telesensors of the computer. Programs installed on the computer are activated and consequently electromagnetic signals are wirelessly transmitted and received by antennas of satellite equipment. They are various mobile devices such as neuroprosthesis of upper limb or a wheelchair. Remote control of such equipment allows the patient to function in the environment. As a result, people with a high degree of motor disability improve the quality of their lives. They can communicate with the environment and control their mobile devices [42,43,44]. An innovative technology of forearm neuroprosthesis corresponds to the assumptions of BCI and allows a tetraplegic to open hand and to move captured items. The engine of neuroprosthesis is started wirelessly. Worldwide, this is the first wirelessly controlled neuroprosthesis out of 150 000 implanted neuroprosthesis [45].

Recapitulation

Integrating technology with biology is a social challenge to improve the quality of life for physically disabled persons with damage to the CNS, including hemiplegics and tetraplegics [46]**.** Evidence of this is the desire of industry to miniaturize the equipment and the market to lower its costs. This is a signal significant for the economy and important for the insurer.

Those refunding for patients will always require the healthcare provider to obtain the qualifications to ensure the desired effect. A real healthcare provider is not a physician but a physiotherapist who carries out treatment commissioned by a physician. Therefore a physiotherapist should mainly know not only the structure but also understand the CNS neurodysfunctions in patients with brain or spinal cord damage. To achieve such a qualification it is necessary to know the tools and procedures for testing CNF and have an competency to use them for physiotherapy purposes. The author expresses such an opinion based on personal experience with over 30-years of work[7] with physiotherapists who perform so called medical and enhancement treatments, for hemiplegics and tetraplegics, both inpatient and outpatient conditions. Meanwhile, while in the country there are fifty-eight operating wards and other organizational units named neurological rehabilitation units [47], there is no legal requirement that the healthcare provider of specialized neurophysiotherapeutic treatment, granted to the person with brain or spinal cord damage, could support CNS neuroplasticity with the selected medical technology, personalized on the basis of NFC study [48]**.** This demonstrates the non-utilization, also by NHF, the existing resources of the national infrastructure and human capital, which enable teaching of clinical neurophysiology subject on the faculty of physiotherapy [49]. Meanwhile, conducted since 1998, at several state and private universities, teaching of the NFC subject continues, and even in one university teaching of the subject has been extended to two semesters [50]. This does not change the fact that population of many thousands of unemployed young physiotherapy graduates has been increasing and as much as 80% of them are easily able to find employment in the EU countries [51].

Conclusion

The current situation shows the necessity for innovation of training curriculum for physiotherapists towards formation of new faculties of neurophysiotherapy vs. neurophysiatry.

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I state that the content of this article delivered to the Editorial Committee shall not be considered for publication in any other journal in whole or in part.

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