

Gait Neurorehabilitation: Algorithms for gait recovery in Neurological and Neurosurgical clinical practice

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Neurorehabilitation (NR) is an interdisciplinary thematic field between neurology, neurosurgery, physical and rehabilitation medicine. According to the World Disability Report: Rehabilitation is a functional therapy, based on a detailed functional assessment. In everyday clinical practice of neurological and neurosurgical departments, we can observe patients with somato-sensory and motor dysfunctions and deficits, cognitive difficulties; speech problems; altered autonomy in activities of everyday life. Our patients suffer from problems in: motor planning, motor learning ability, voluntary movements, neuro-muscular coordination, functional ability; postural adaptation; strength and endurance; in some cases – in visual-perceptual performance and emotional adjustment. Gait is an important element of the everyday functionality of NR-patients, and is crucial for their independence in activities of daily living, respectively for their autonomy. Mobility is vital for the quality of life of everyone.

Impact of Brain Plasticity in Neurorehabilitation: The physiological basis of NR is the neuroplasticity - use-induced and activity-dependent. According to medical definitions: "neuroplasticity is the brain's ability to reorganize itself by forming new neural connections throughout life". Neuroplasticity allows the neurons to compensate for injury and disease and to adjust their activities in response to new situations or to changes in their environment. Principal mechanisms of brain repair are based on brain plasticity (spontaneous recovery, input of "axonal sprouting" and "mirror-neurons", use-dependent plasticity, synaptic or grey matter plasticity, white matter plasticity). For patient adaptation to the "new" situation (of neuronal alteration), we use two types of modulation techniques: stimulation of some functions (e.g. motor and sensory functions) and inhibition of other (e.g. pain reduction). For stimulation, we apply training of the altered motor function (through movements and activities - use-dependent plasticity) and some compensatory mechanisms (bypass strategies, replacement of functions by aiding devices, adaptation of the environment to patient's needs). For inhibition, we apply pain management mechanisms: blocking the nociception and the neurotransmission, peripheral sympaticolysis, input of the gate-control, peripheral and central desensitization, influence on the descending systems for pain control and activation of the encephalic blocking system of the central nervous system, activation of reflectory connections.

The "aim" of neuroplasticity is to optimize neural networks during phylogenesis, ontogenesis and physiological learning, and after a brain injury. Our goal is to emphasize the potential of some traditional and modern physical modalities for balance training and gait recovery for patients with typical neurological conditions, and to propose complex gait NR-algorithms; established on the base of best practices and evidence-based research. We were oriented to gait abnormalities, consequence of frequent and disabling diseases of the central and peripheral nervous system (CNS & PNS): stroke, Parkinsonism (Prk), multiple sclerosis (MS); after neurosurgical interventions for brain tumours or cerebral aneurysm; traumatic brain and spinal cord injuries; peripheral paresis in

diabetic polyneuropathy or after operations for a discal hernia, traumatic lesions of peripheral nerves. **Gait NR-Algorithm:** The general schema of every NR-processus is a combination of functional assessment and functional therapy.

Functional assessment: For functional evaluation in NR we apply clinical and instrumental assessment methods, specific neurological scales and the International Classification of Functioning (ICF). In Bulgarian neurorehabilitation practice we apply traditionally some functional scales: for post-stroke hemiparesis – scale of Brunnstrom and Barthel-index, for multiple sclerosis (MS) – the Expanded Disability Status Scale (EDSS – Kurtzke), for Parkinsonism – Hoehn and Yahr scale and the Unified Rating scale of Parkinsonic disease (URSPD), for diabetic polyneuropathy – Dick scale. According to ICF principles the complex functional assessment must include: body functions (pain, range of motion, muscle force or motor deficiency, alterations of coordination – ataxia, tremor, spasticity or rigidity); activities (verticalization, mobility, grasp, standing up, balance, gait, activities of daily living (ADL), transport); participation (family relationship, relaxing activities, social life, political activity); environmental factors (conditions of life and work, transport, family and friends, health insurance, social relationship); personal factors (life style, co-morbidities, age, sex).

During clinical assessment we accentuate on some analyses: pain (localization, type, intensity – verbal or visual analogue scale; modifying pain activities); joint stability (including joint position sense) and range of motion (active and passive); presence of oedema, muscle or joint contractures; evaluation of the muscle force / muscle insufficiency, motor deficit; analysis of the grasp and gait; mobility (necessity of technical aids - canes, walking sticks, crutches, walkers, wheelchairs and other devices); fatigue (physical endurance, necessity of rest during the examination or the functional activity); autonomy in everyday activities (bathing, dressing, eating, putting shoes on, personal hygiene, need of help in ADL). Evaluation of problems must be qualitative and quantitative, including: fatigue, motor deficiency, coordination problems (body position, gait, grasp); pain; conscience for the necessity of technical aids; difficulties in ADL; limitations in functional mobility.

We evaluate the correspondent gait: spastic-hemiparetic gait type Wernicke-Mann in stroke, Parkinsonian gait, spastic-paraparetic and ataxic gait in MS; steppage in cases of peroneal paresis.

For balance and gait assessment we can apply stabilometry with platform and motion capture.

The World Report on Disability defines the goals of rehabilitation: prevention of the loss of function; slowing the rate of loss of function; improvement or restoration of function; compensation for lost function; maintenance of current function. Rehabilitation complex:

For treatment, we use the "rehabilitation puzzle"- a synergic combination

of different physical factors (natural and pre-formed).

Many NR tools have the potential to rewire cerebral functions and to excite the formation of new connections and pathways, respectively to stimulate the brain reorganization and adaptation to the 'new' situation (appearance of a damaged locus in the cerebral tissue), in other terms - to help functional recovery through potentiation of use-induced and use-dependent neuroplasticity. We apply the "rehabilitation puzzle"- a synergic combination of different physical modalities (electric currents, magnetic field, movement, activities, temperature, etc.).

From the group of physiotherapy and ergotherapy we apply: proprioceptive neuro-muscular facilitation (PNF) methods; vestibular training; balance and gait training; bimanual and bipedal exercises, analytic exercises, soft-tissue techniques (massage, post-isometric relaxation, stretching); manual therapy techniques (tractions, mobilizations, manipulations); mirror-therapy; device-assisted mechanotherapy, etc.

From the group of preformed physical modalities: functional electrical stimulations (with low and middle frequency electric currents); transcutaneous electro-neuro-stimulation (TENS); deep oscillation; magnetic fields, LASER, ultra-sound, etc.;

From the group of cryo / thermo-therapy and balneo-/peloido-therapy: ice, mineral waters, therapeutic muds, paraffin; parafango;

We paid special attention to some modern methods: functional electrical stimulations; deep oscillation; LASER; manual therapy; PNF and analytic exercises, mechano-therapy, underwater exercises; mirror therapy, etc.

We insist on the importance of technical aids (wheelchairs, walkers, rollators, canes, walking sticks) and environment adaptations (home and labour reworking).

In our clinical practice we apply a synergic combination) of two (or three) procedures with pre-formed modalities (electro- and photo-therapy, LASER; magnetic field; ultra-sound, etc.); one (or two) cryo-/ hydro- / balneo- / thermo-therapeutic procedure with three (or four) kinesi-therapeutic methods and one (or two) ergo-therapeutic activity.

The diet of patients must be adapted to their necessities (proteins, hypolipidic, hypoglycemic diet). The patients' education (and education of co-therapists – family, friends) is important: medicaments, diet, basic physical activity, weight control, etc.

Periodical functional evaluation: The control before and after rehabilitation is obligatory. At the end of every course we realize a detailed clinical, para-clinical and functional (including instrumental) revision of the obtained results, and we prescribe a periodical control and periodical PRM courses. We consider that the functional evaluation is very important not only for control of the quality of rehabilitation, but too for amelioration of independence in everyday activities and of health-related quality of life of patients.

Our own results in Neurological and Neurosurgical patients: We applied these NR-algorithms in patients with: post stroke hemiparesis, multiple sclerosis, Parkinsonism, traumatic brain injury (TBI), after neurosurgical interventions for brain tumours or ruptured cerebral aneurysm; spinal cord injuries (SCI) with paraplegia; lumbosacral radiculopathy and diabetic polyneuropathy (DPNP) with femoral, peroneal or / and tibial paresis; radiculopathies and peripheral paresis after neurosurgical intervention (for spinal trauma and discal hernia). During

our modest clinical experience (of 30+ years), we observed significant functional recovery in patients with spastic hemiparetic and paraparetic gait, festinating gait, ataxia, steppage, etc.

Future of Gait: We consider that the future of NR is in the combination of some traditional and some modern methods for assessment and therapy. For balance evaluation and treatment: stabilometry and Hubert system; for gait assessment and training: motion capture technologies (with sensors and platform); exoskeletons, robotic rehabilitation (Locomat), virtual reality.

Keywords — Balance, Gait, Neurorehabilitation algorithms, Quality of life.