Pre-Conference Workshop 4

Functional Electrical Stimulation and Restorative Neuroscience

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Presenters: (See below each session.)

Scope

For many years electrical stimulation has been applied with scant understanding of its effect on the central nervous system (CNS) and patchy evidence for its clinical effectiveness; both of which have hindered progress in developing effective systems for rehabilitation. The objective of this course is to examine the neurophysiological mechanisms that underpin the application of electrical stimulation in rehabilitation following CNS lesions.

Session 1: Manipulating Neural Plasticity in Human CNS with Electrical and Magnetic Stimulation

Transcranial magnetic and transcranial DC electrical stimulation (TMS and TDCS) are now used widely to stimulate the CNS in human studies. One of their most exciting potential new uses is as a therapy in rehabilitation. This relies on harnessing the long term effects of TMS/TDCS that occur after prolonged periods of stimulation. However, at present both methods have been reported to have efficacious effects in such a wide variety of conditions from depression, schizophrenia, Parkinson's disease, central pain, migraine, tinnitus etc, that questions have been raised about whether they ever does any more than act as an efficient placebo. I will review the possible mechanisms of action of TMS/TDCS and show how these depend on a wide variety of factors including the past history of brain activity, drug therapy and even genetic factors. This leads to a high variance in their action, which when understood may help us to target therapeutic studies much more carefully than in the past.

John Rothwell, Professor of Human Neurophysiology, Institute of Neurology, Queen Sq, London UK.

Session 2: Operant conditioning of spinal reflex pathways for restoring motor function

Spinal reflexes usually function as components of complex skills such as locomotion. Nevertheless, they are themselves simple behaviours, and operantly conditioned changes in them are simple skills. Operant conditioning of the largely monosynaptic spinal stretch reflex, or its electrical analog the H-reflex, changes both the brain and the spinal cord, and can thereby affect complex skills, such as locomotion, that involve the same neuronal pathways.

Thus, spinal reflex conditioning can be used to induce and guide plasticity so as to restore motor function after partial spinal cord injuries or in other disorders. Protocols could be designed for the particular deficits of each person. For example, up-conditioning might improve weak stance in one person, while down-conditioning might be efficacious for a person in whom extensor hyperreflexia impairs locomotion. Such protocols could be especially useful when significant regeneration becomes possible and precise methods for re-educating the regenerated spinal cord neurons and synapses are needed to restore effective function.

Jonathan R. Wolpaw, M.D., Chief, Laboratory of Nervous System Disorders, Wadsworth Center, New York State Department of Health and State University of New York, US.

Session 3: Cortical excitability following functional movements augmented with ' peripheral nerve stimulation

Electrical stimulation of peripheral nerves is used in functional rehabilitation of patients with paralysis and spasticity. The "carry-over" effects of peripheral nerve stimulation on the supraspinal structures have attracted increasing research interest. However, how a peripheral change leads to a central re-arrangement and to a consequent functional improvement is not fully understood. This session addresses how peripheral sensorimotor nerve stimulation affects the human brain. Particular the mechanisms of interaction between voluntary central motor descending commands generated based on the person's own intention, and the peripheral afferent volleys coming from the electrical nerve stimulation are investigated. Clinical evaluations of functional movements augmented with peripheral nerve stimulation in sub acute stroke patients will also be addressed.

Thomas Sinkjær, Danish National Research Foundation and Center for Sensory-Motor Interaction (SMI), Aalborg University, Denmark.

Session 4: Spinal stimulation and motor relearning

After spinal cord injury (SCI), voluntary initiation and control of stepping are lost but a large proportion of the locomotor networks that reside in the lower thoracic and lumbosacral region of the spinal cord remain largely intact. A great potential exists in harnessing the connectivity of these networks to restore locomotor capacity after SCI; however, it remains unclear which method or combination of methods could best tap into the spinally residing networks and activate them in a near normal manner. I will review the spinal and peripheral elements contributing to the generation and modulation of stepping and discuss the methods currently under investigation for reactivating the locomotor networks after SCI. I will highlight the use of spinal cord stimulation and the role it may play in modulating the aberrant firing behaviour of motoneurons following chronic SCI, and regulating the connectivity between various components of the locomotor networks.

Vivian Mushawar, PhD, Associate Professor, Dept. Cell Biology and Centre for Neuroscience, University of Alberta, Edmonton, Canada.

Session 5: Behavioural perspective of motor relearning in response to therapy and electrical stimulation

Motor learning theory and recent evidence from animal research provides convincing evidence for neuroplastic changes in the CNS associated with exposure to enriched environments. Studies of the effect of post-stroke therapy have identified that it is intensity of treatment that is critical to functional recovery. FES may be effective in two ways: appropriately timed stimulation of target muscles can enable a person with paresis to perform functional tasks that they cannot otherwise do; thus allowing the opportunity for repetitive practice. FES also provides antidromic stimulation of the anterior horn cells and may, via this mechanism, increase excitability. Conversely antidromic stimulation impulses may collide with descending voluntary-driven impulses and have been observed in the EMG signal as a silent period. Recent studies have shown that electrical stimulation can be modulated using Iterative Learning Control to reduce error when tracking an elliptical target in stroke patients with upper limb hemiplegia. Combining electrical stimulation with therapies such as Constraint Induced Movement therapy (CIMT) or robot therapy may provide an enriched environment to optimise recovery.

Jane Burridge, Professor of Restorative Neuroscience, School of Health Sciences, University of Southampton, UK.

Discussion

In the final session there will be an open discussion of how current knowledge of restorative neuroscience can be used to develop and evaluate rehabilitation technologies and in particular the use of FES.