INTRODUCTION TO NEUROREHABILITATION AND RESTORATIVE NEUROLOGY

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Neurorehabilitation is complementary to Restorative Neurology and they share many common goals. The differences are present in clinical practice. The Neurorehabilitation goal is defined toward the repair of the function of the nervous system and to improve function in order to advance the accomplishments of clinical rehabilitation programs. This main thrust of the repair is described as *neuroplasticity*, a term that it is used to describe the ability of neurons and neuron aggregates to adjust their activity and even their morphology to changes in their pattern of use. Neuroplasticity encompass biological processes ranging from learning and memory to the dendritic pruning and axonal sprouting in response to injury. It has gained currency of or coaxed functional recovery after neuronal injury and can be studied in human through imaging techniques, that include MRI, fMRI, and PET and neurophysiological methods including SSEP, MEG, and TMC,SCS, BMCA (Brain Motor Control) (1 - 3).

In the second half of the 1980's, clinical neurological practice advanced in the control and treatment of medical complications that typically occurred during the acute and chronic phases of neurological injury and diseases. Morbidity was reduced in people who experienced injuries to the CNS due to trauma or stroke and disorders as multiple sclerosis, Parkinson and neuromuscular disorders. Therefore, it become more important than ever that medical and neurological protocols for rehabilitation medicine be expanded for the treatment of chronic neurological conditions. This led to the development of new clinical subspecialty. The Neurorehabilitation, "devoted to the restoration and maximization of function lost due to impairment caused by injury or disease of the nervous system (3).The American Academy of Neurology formed a section on neurorehabilitation was established in 2003, the American Society for Neurorehabilitation (ASN) and other national societies confederated officially into in to World Federation.

Restorative neurology is defined as the branch of neurological sciences which applies active procedures to improve functions of the impaired nervous system through selective structural and functional modification of altered neurocontrol according to underlying mechanisms (4). Restorative Neurology details the clinical neurophysiological assessment process and methods developed throughout the past half century by basic and clinical scientist. Then through the use of specialized clinical and neurophysiological testing methods, conduction and processing performed within the surviving neural circuitry is examined and characterized in detail. Based on the results of each assessment, treatment strategies are applied to augmented rather then replace the performance of surviving and improve the capacity of upper motor neuron functions.

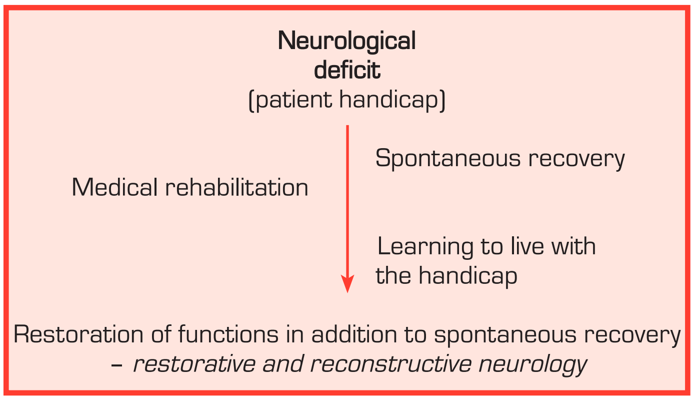

Fig. 1: *The place of restorative and reconstructive neurology after neurological deficit.*

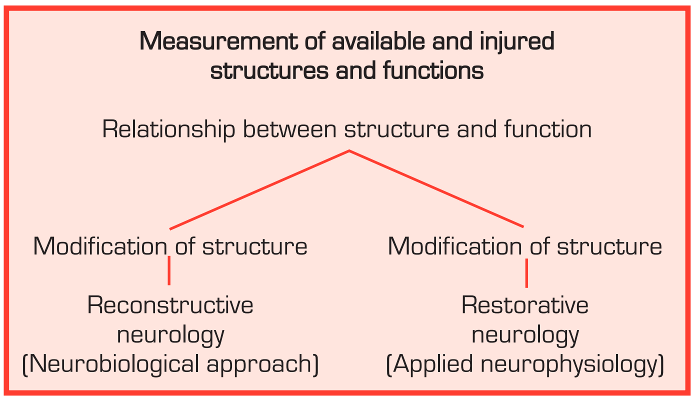

Fig. 2: *Relationship bet6ween reconstructive and restorative neurology.*

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The human CNS has the ability to conduct neural impulses as spikes carrying information from inside and outside the body, to from and between hierarchically placed nuclei of the brain and spinal cord, and then to process this information in one or more nuclei into appropriate sensory perception and motor output. The conducting pathways are made up of multi-parallel axons of different diameters and lengths providing connections between brain and spinal cord processors.

These neural processors are of different sizes and shapes, located within the gray matter and constructed from a population of interneuron's, with short axons. There are also longer myelinated axons, white matter, conducting impulses between processors, from receptors to processors and to effectors from the processors. **These two basic functional features of the CNS, to *conduct* and to *process*, provide sensory perception, cognition and a wide variety of movements;** from locomotion and skilful volitional , automatic, reflex movement as well as movement involved in speech performance.

Injury or neurological disease can impair conducting or processing or both of these CNS functions leading to so-called positive and negative deficits. The development of human neurophysiology and methods for the noninvasive examination of motor and sensory functions within the brain, spinal cord and peripheral nerves allow to study and to characterize the altered structure and function after damage caused by injury or disease.

Advances in human neurophysiological assessment methods to measure ***upper motor neuron function and dysfunction after lesion onset*** (4) to practice Restorative Neurology of the spinal cord injury (1) head injury, stroke and ***intact upper motor neuron function altered in response to neuromuscular weaknesses due to degenerative diseases*** , in order to practice Restorative Neurology of the progressive neuromuscular disorders (5) have lead to the development of the clinical practice of restorative neurology of upper motor neuron functions and dysfunctions. It has become possible to study and to modify the neural control of long loop reflexes, automatic movements, patterned movements, isolated skillful movements and their interactions.

Rather than focusing on the deficits and lost function caused by upper motor neuron lesions or disorders, it is more advantageous to elucidate, in each individual, the specific neural functions that remain available, and then, to build upon them by designing a treatment protocol to optimize their effectiveness and thus improve recovery.

To modify neural processing and restore upper motor neuron functions, there are two possibilities: **[A]** ***Morphological restoration***, reconstructive neurology or **[B]**. ***Functional Restoration***, restorative neurology. Both of these approaches are applied in the contemporary practice of restorative neurology using intervention modalities from ***physical therapy, neurophysiology pharmacology, functional neurosurgery and neurobiology***.

Morphological restoration are surgical interventions carried out on tendons, peripheral nerves, or the spinal cord to establish input-output functions in a stable state with the hope that experimental laboratory research will bring together expertise and unleash the potential of regeneration, in which new cells are able to search for and recognize appropriate target neural circuits to restore function.

Damage, either through injury or disease process, to the multi-parallel conducting systems and processing networks is practically never total. There are almost always some surviving and functioning structures that, depending on their newly establish functional relationships, generate ***clinical and sub clinical residual movements***, known in clinical practice as motor syndromes. Neurophysiological methods for the assessment of processing and conducting neural systems can elucidate and measure the characteristics of this residual function.

The spinal cord, ***being output station of the central motor system,*** has a fundamental role to play in the restoration of motor function. It consists of neural networks located within its gray matter connected to long white matter intersegmental connections (propriospinal system), ascending and descending tracts (corticospinal, reticulospinal, vestibulospinal, rubro and tectospinal). This neural circuitry integrates the nervous system and can be visualized as a common final network within which is executed the motor control required for reflex activities, volitional, postural and gait activities. There, descending influence is exerted over the control of reflexes at the interneuronal level and through the convergence of descending pathways and primary afferents on common interneuron projecting to motoneurons (6). Furthermore, this capability of the spinal cord to integrate converging brain input has been shown in humans with altered descending input to the spinal interneuronal network can also be elicit in the absence of brain input through the external application of sustained electrical stimulation of posterior roots. Different strengths, site and frequency of posterior root stimulation can elicit functional and nonfunctional motor output patterns (7). This finding opened the ***approach of external control and configuration of spinal networks*** for use in the clinical practice of restorative neurology for augmentation and modification of residual motor control (8).

In current clinical practice, the modification of spinal cord network configuration is accomplished by ***applying electrical stimulation to the afferents of peripheral nerves, posterior roots and posterior columns of the spinal cord*** in order to maintain an adequate central state of the excitability. Such excitability should be maintained at an operational level in order to elicit responses to input to the spinal cord network with intended configuration to generate functional motor output. It is also essential that central state maintain dynamic equilibrium between excitatory and inhibitory mechanisms within the processing networks (1). ***The addition of pharmacological intervention can be of certain supplementary value.***

Restorative neurology is ***academically a multidisciplinary brunch of human neurosciences*** and the contemporary clinical practice for movement recovery.

Thus, while presenting where we are today with the development of restorative neurology, just by reviewing topics in the series of publications, it is obvious that restoration of function requires a multidisciplinary approach in science and medicine (1, 2). Let us list some of pertinent topics for clinical practice and human neurosciences of motor control.

1. Neurosciences as a bases for clinical practice for recovery of neurological functions
2. History of Neurosciences.
3. Overview of assessment the human motor control [
4. Recreation of the original neurology versus t he restorative approach
5. Maximizing the new anatomy and residual functions.
6. Clinical evaluation and its characterization of the presence of subclinical control.
7. Neurophysiological characterization of the new anatomy and residual function.
8. Advancing imaging technique and characterization of residual anatomy.
9. Physical intervention to restore function.
10. Pharmacological intervention to restore function.
11. Neuromodulation to restore motor function
12. Neurosurgical approaches for the restoration of function.
13. The Neurobiology of Restorative Neurology and the future of the discipline.
14. The future of Restorative Neurology: a clinical perspective.

Intact or impaired volitional, patterned or skilful, automatic and postural movements are the result of neurocontrol accomplished through the integration of converging descending brain input, intact or impaired, with input from primary afferents by the spinal cord and delivered in processed form to motor neurons. This operational and simplified neurocontrol scheme can help in understanding the rationale of manipulating residual motor control as a treatment strategy. However, as already mentioned clinical practice is multidisciplinary and most effective when based on the assessment of residual motor functions.

In conclusion, for restoring connections between disconnected parts of the nervous system, there are two options. The first is to build connections between different neurons within the damaged adult CNS. However, we do not have solution yet for how to prevent new and inappropriate connections that might lead to pain and/or further motor dysfunction. A second option is to augment surviving capabilities by taking advantage of responses of processor(s) to establish external control as can be done to increase walking endurance through spinal cord stimulation of the lumbar network (1, 7).

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