Neuroplasticity in Post-Stroke Patients:

A Literature Review

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Abstract

Objective: The purpose of this article is to collect and analyze information found published in the literature concerning the progression of events that lead up to a stroke, the motor impairment that occurs after the stroke and the neuroplastic events that occur during the rehabilitation stage.

Data Collection: A systematic search utilizing the PubMed search engine to generate articles. Referenced sources from the PubMed articles were also used for further information.

Discussion: Approximately one-third of post-stroke sufferers demonstrate a disability; the majority of these disabilities present as a motor impairment in some form.[2] Neuroplastic changes that occur during the rehabilitation stage are increasingly becoming more thoroughly researched and better understood. This deeper understanding leads to a direct correlation of more effectively guided rehabilitation, retraining and remapping neurologically to the post-stroke individual; the understanding of these mechanisms is crucial in obtaining optimal prognosis.

Conclusions: Exercise and training have been the protocol for rehabilitation for post-stroke individuals for many years now. Due to our increased knowledge on functional anatomy of the body and the brain, we are able to help restore more function by developing the most effective combination of therapies for each individual. Due to the fast-growing nanotechnology field, we are finding out more details all of the time concerning the neuroplastic changes that occur after a significant trauma has taken place; proposals continue to arise with new theories on how to manipulate neuroplasticity for beneficial purposes.

Key Index Terms: *neuroplasticity, stroke, nanotechnology, rehabilitation, motor impairment*

Neuroplasticity in Post-Stroke Patients: A Literature Review

Introduction: Over half a million people suffer from a stroke within the United States every year. Approximately one-third of these sufferers will be left with serious neurological damage that will result with new challenges that will lead to extensive rehabilitative therapy.[2] Unilateral paresis is a common and unfortunate outcome for many of these individuals. The old school of thought on neurological injuries, such as those procured from a stroke, would result in permanent disabilities for that patient. Now with the knowledge and acceptance that neurological insult is not the ultimate annihilation that it was once thought to be, the therapeutic world has been revolutionized. Therapies within the stroke population now focus on navigation of the healing brain to help rewire itself while also creating opportunity for new pathways to derive.

The purpose of this literature review is to discuss the various presentations of a stroke, some high risk factors with the development of a stroke, and common disabilities that transpire as a result of a stroke. Other topics discussed will be what the definition of neuroplasticity is, why neuroplasticity plays such an important role in the recovery of neurologically damaged individuals, and a few of the individuals that have played an important role within the study of neuroplasticity. To finish, there will be a brief history concerning the discovery of neuroplastic events along with the therapies that are being used on patients who have suffered a stroke.

Discussion: According to the CDC's Prevalence of Stroke Report, stroke is the third leading cause of death within the United States.[1] There are approximately 700,000 reported strokes that occur in the United States each year. Approximately 225,000 stroke survivors suffer from residual hemi paresis and approximately 165,000 suffer with cortical damage that requires assistance with walking.[13, 14] Stroke affects all genders and all races; however African Americans, American Indians, Hispanic, Asian and Pacific Islanders all tend to die from strokes at younger ages than Caucasians do. A stroke is often referred to as a "brain attack." A brain attack occurs when the blood supply to the brain is compromised. Interference of this blood supply can occur via a blood clot within the vessels or by having one of the vessels burst.[3] A stroke can result in death or significant disabilities.

The American Heart Association explains that there are three different types of stroke that a person could suffer from. The three stroke types are ischemic, hemorrhagic, and transient ischemic.[4, 5] The most common form of stroke is the ischemic stroke; the ischemic stroke accounts for about 87% of all stroke cases. This type of stroke is caused by a lack of blood delivery to the brain and is caused by fatty deposits lining the vessel walls.[4, 5] The second most common type is the hemorrhagic stroke. This stroke is caused by weight compression of blood on top of the brain as a result of a ruptured vessel. Hemorrhagic strokes account for around 13% of all stroke profiles.[4] The third type of stroke is the transient ischemic attack (TIA) and is often referred to as a "mini-stroke." TIA's occur when a clot blocks a blood vessel temporarily.

All symptom occurrence and disappearance happen in a short amount of time; the entire event often lasts less than five minutes with no permanent injury attained.[4]

Some conditions or lifestyle choices that will put an individual into a high risk group for experiencing a stroke include having high blood pressure, atrial fibrillation, atherosclerosis, diabetes, a smoking habit, or a family history involving strokes. [3, 6] Making certain lifestyle changes can help reduce risks of developing a stroke. A few examples of these lifestyle changes are to exercise on a regular basis, maintain a healthy weight, limit alcohol consumption, decrease stress levels, quit smoking, and control cholesterol and blood pressure levels.[6] Keeping the heart tissue healthy is important prevention for stroke assimilation.

In the 1970s, neuroscientists began to recognize the brains ability to develop new neurons and neural networks where injury has transpired.[17] Before this time it was thought that any damage to the matured brain would result in permanent loss with no chance of recovery to that area. It is now scientifically accepted that the brain does in fact have means of rewiring itself after it has endured a traumatic event; this is where the field of Neuroplasticity gains merit.

Examining the severity and the location of the brain lesion will likely help determine the degree of the deficit that will be procured. This accounts for the various presentations that stroke sufferers present with. In general, a stroke will result with one of five quandaries; these five types of deficits are paralysis, sensory disturbances, problems with language understanding or production, deficits with thinking or memory, and emotional disturbances. [5, 8] After

experiencing a stroke many individuals are left with unilateral motor deficits of an extremity, as a result this severely limits their functional movement control.[7] It is not uncommon for post-stroke patients to suffer with gait disturbances due to a one-sided paralytic limb; this hindrance severely limits mobility to the individual while also creating a higher energy demand for daily activities and also increasing the risk of falls to that patient.[15]

According to physician, neurologist, and best-selling author Dr. Oliver Sacks, *neuroplasticity* is the brain's ability to create new pathways. These new pathways are what allow the brain its ability to transform and renew itself.[11] Dr. Sacks is a highly revered professor at the Columbia University Medical Center; he is best known for his collection of published neurological case histories. These case histories sample individuals who have had to learn to compensate for their lost senses, their paralysis, or their cognitive deficiencies after suffering from a debilitating illness or injury.[11, 12] Dr. Sacks recognizes that the brains ability to transform and renew itself is a crucial part of recovery for any individual suffering with a motor or a cognitive disability. Dr. Norman Doide, author of the 2008 bestseller *"The Brain Changes Itself",* defines *neuroplasticity* as *Neuro* meaning the neurons, nerve cells, the nervous system and *Plastic* meaning the brain's ability to be modified, changeable, and malleable .[10] Dr. Doide explains in his book how neuroplastic events give hope to the future for those who suffer from a brain injury; those who used to be thought of as incurable.

The term *neuroplasticity* is documented as first being used in 1948 by a Polish neuroscientist named Jerzy Konorski; however the theory of neuroplasticity is believed to have first been

presented by an American psychologist and philosopher named William James around 1890 in his book titled “Principle of Psychology”.[9] In this book James suggests that the human brain has the capability of reorganizing itself. Konorski expressed his theories about neurons stating that he believed that neurons that maintained similar position and function could learn to share pathways if needed; provoking the commonly used phrase of today saying “neurons that fire together wire together”.[9]

American neuroscientist Paul Bach-y-Rita was among the first to create treatment protocols for guiding neuroplastic events during the rehabilitation stage for those with an acquired neurological deficit. Bach-y-Rita’s philosophy concerning neurological damage affirms that even when the pathway from one sensory organ is demolished that a substituted pathway can be utilized to make up for this deficit. He believed that our brains could learn to read sensory information no matter from what sensory organ it was sent from.[24] Bach-y-Rita believed that the brain could learn how to restructure itself if it was provided with a learned substituted passageway.

Bach-y-Rita’s passion was working with post stroke patients that had obtained neurological damage; Bach-y-Rita was so fervent in this area due to witnessing his father who suffered a major stroke that resulted in severe damage to most of his brainstem. With the help of his psychiatrist brother, Bach-y-Rita was able to successfully treat his father by developing specific exercises for him that resulted in an almost complete recovery.[10]

Bach-y-Rita is notorious for his work with individuals that had developed vestibular damage as a result of their stroke. The vestibular system is located within the inner ear and is the system

that allows an individual to obtain balance while standing. He created a sensory substitution device called a *brainport* that would stimulate areas of the brain while simultaneously training the nervous system to accept a new pathway.[24] The treatments to help these individuals consisted of placing a thin plastic strip wired with electrodes underneath the patients tongue. This electrical stimulation would send signals through it depending on where the patients head was placed. This sensation allowed the patient a way of recognizing where their head was at in space allowing them to retain their balance.[24, 25] The effects of this therapy are noticeable almost immediately. He later developed a device called a *tactile-vision machine* that provided some vision to blind patients by using a specialized camera and a metal chair that translated spectrums of light into vibratory signals.[25] Bach-y-Rita's work is acknowledged within the neurological field for broadening the scientific understanding of how plastic the healing brain is.

Functional magnetic resonance imaging (fMRI) has proven to be an important tool in the field of neuroplasticity. fMRIs allow for monitoring of neural activity within the brain or spinal cord by detecting cerebral blood flow. This imaging modality allows the specialist to map an individual's brain during inspection of its metabolic changes and neural activity while having the patient perform particular tasks;[20] this modality has been used extensively to investigate changes in the brain following a stroke. [21]

Recent studies concerning neuroplasticity after an injury to the cortex are suggesting that specific training interventions that target the use of hemiparetic limbs can actually improve motor control in the individual while creating new neural pathways within the brain and spinal cord.[15] As a result of this new information several focused therapy protocols are being

integrated and assessed for productivity. One efficacious therapeutic approach, termed treadmill training, targets individuals who are suffering with a hemiparetic lower limb. This therapy focuses on basic motor learning strategies as a way to improve both balance and gait.[16, 17] This training protocol's focus is to stimulate the neural mechanisms within the central nervous system. This repetitive stepping pattern from the treadmill training helps the neurologically damaged areas regain sensory input by creating new connections from the surrounding unaffected neurons. Research has shown that treadmill therapy has been more effective on a chronic stroke patient for recovering both functional mobility and cardiovascular fitness than other commonly used rehabilitation procedures.[19]

Another rehabilitation technique that has proven to be a viable learning stimulus for triggering central neuroplastic responses is called Constraint-Induced Movement Therapy.[22] This therapy is targeted at individuals who suffer from unilateral paresis of an upper extremity. This treatment requires that the less-affected arm is restrained in a sling for 90% of waking hours for two weeks while practicing repetitive actions on the more-affected side. This continuous sensory stimulation into the damaged area of the cortex is what mechanistically drives the neuroplastic changes that result and allows for restoration of motor function.[23] Success of any therapeutic technique however is always contingent on patient participation and repetitive applications.

Additional non-invasive techniques continue to be assessed for their competence on neuronal stimulation. Continued cortical activation via repetitive sensory input and repetitive motor tasks is what drives every rehabilitative protocol for the post-stroke population. Continued

therapeutic breakthroughs give validity to the notion that the brain is in fact a living, plastic, formative organ that can change its own structure and function. As a result of this knowledge on neuroplasticity, we are able to expand our understanding to the resilience of the human brain.

Conclusion: Neuroplasticity occurs when neurons, or neural networks, within the brain alter their response to different physiological changes that occur within the central nervous system due to damage or dysfunction. In the past it was believed that there was no repair or change that would occur to neurons once the brain aged to a point during early childhood. It is now understood that the brain is susceptible to change throughout adulthood and neurological remapping is possible after a significant injury. The literature conveys that patient improvement heavily depends on enhanced task-specific cortical input along with rhythmic motor contribution. The brain has an amazing ability to recover from damage, and this is witnessed all the time.

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