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Electrical Stimulation for Post-CVA Individuals

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ELECTRICAL STIMULATION FORPOST-CVA INDIVIDUALS

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CHAPTER I

INTRODUCTION

Cerebral Vascular Accident (CVA) is a medical condition that continues to affect millions of individuals (Copstead & Banasik, 2000). Occupational therapists working with individuals post-stroke focus primarily on increasing function through the use of compensatory strategies. Much research has been conducted on electrical stimulation with post-stroke patients. The use of this physical agent modality (electrical stimulation) may help post-stroke patients regain function in their affected upper extremity, therefore reducing the need to rely solely on compensatory strategies. The intended focus of this paper is to further educate health professionals, especially occupational therapists, on how effective electrical stimulation can be with post-stroke populations.

Stroke or Cerebral Vascular Accident (CVA) is a dysfunction caused by a lesion in the brain. It represents a variety of disorders characterized by the sudden onset of neurological deficits brought about by vascular injury to the brain (Trombly, 1997). The most typical symptoms that can result from a stroke is hemiparesis (weakness) or hemiplegia (paralysis) of one side of the body, including limbs, trunk, and face/oral structures that are contralateral to the hemisphere of the brain that has the lesion (Pedretti, 1996).

Since stroke is a type of cardiovascular disease, it affects the arteries leading to and within the brain (American Stroke Association, 2000). A stroke occurs when the supplied blood to the brain is suddenly interrupted or when a blood vessel in the brain bursts, causing blood to spill into the spaces surrounding the brain cells (Goodman &

Boissonnault, 1998). The function of the brain is dependent on blood that flows through the blood vessels. If blood flow is obstructed in any area of the brain, possible injury to the brain can occur. When the brain is unable to get the blood and oxygen supply it relies on, part of the brain tissue starts to die (American Stroke Association, 2000).

Stroke is the third leading cause of death in the United States just after diseases of the heart and all forms of cancer. Stroke is currently, and is likely to remain, a leading cause of death and disability among adults in the United States (Billings-Gagliardi, Fontneau, Wolf, Barrett, Hademenos, & Mazor, 2001). Recent projections estimate that the annual incidence of stroke in the United States among all races is about 700,000 (Sacco, Boden-Albala, Abel, Lin, Elkind, Hauser, Paik, & Shea, 2001). According to the American Stroke Association (2000), 160,000 people affected by a stroke will die each year.

Statistics from the American Stroke Association (2000) state that every five seconds an individual has a stroke and every 3.3 minutes someone dies of a stroke. Stroke accounts for one out of every 15 deaths in the United States. Individuals who have suffered from a stroke account for more than half of all patients hospitalized for neurological diseases that strike quickly. There are about 4 million stroke survivors alive today that are living with varying degrees of disability (Copstead & Banasik, 2000).

Strokes are often thought of as an “old person’s disease”, when in fact 28 percent of strokes occur in people under the age of 65 (American Stroke Association, 2000, p. 1). Although most strokes occur in older patients, there has been an alarming increase

in stroke incidence in patients between 45 and 65 years of age (Stroke Therapy Academic Industry Roundtable, 1999). With the aging population of the United States, the incidence of stroke is expected to rise significantly (Trombly & Radomski, 2002).

It is estimated that the economic cost of stroke in the United States in 1997, was $40.9 billion. Twenty-six point two billion dollars was the cost of direct hospital care, professional care, and drugs, and $14.7 billion was lost during output (Barnett, Mohr, Stein, & Yatsu, 1998). "The fact that the loss of quality-adjusted life-years caused by stroke is greater than that of any other disease implies that the economic burden of stroke to humankind is also great" (Stroke Therapy Academic Industry Roundtable, 1999, p. 2752).

Strokes are classified by the mechanism and location of the vascular damage. Strokes are divided into two categories, ischemic and hemorrhage. Ischemic stroke is divided into two sub-types, embolism and thrombosis. An embolic stroke is where a clot is formed in an artery causing the width to narrow, thus blocking blood supply. Thrombotic stroke is the most common type and occurs when a blood clot is formed in a cerebral artery, eventually blocking the flow of blood to and from the brain (Trombly, 1997).

Hemorrhage stroke is divided into two sub-types, intracerebral and subarachnoid. Intracerebral hemorrhage occurs when a vessel within the brain leaks blood into the brain itself, usually due to the condition of hypertension. Areas that are usually affected are located in the basal ganglia, cerebellum, thalamus, and the pons (Barnett, Mohr, Stein, & Yatsu, 1998). The last type of stroke is subarachnoid hemorrhage and

occurs when there is bleeding within the outer membrane of the brain (National Institute of Neurological Disorders and Stroke, 2003).

The severity of the deficits presented after a stroke depends on the location of where the stroke occurred and the severity of it. If the occlusion occurred in a large artery, such as the middle cerebral artery or the basilar artery, permanent tissue damage or death can occur (Trombly, & Radomski, 2002). The resulting factor is more profound deficits of many systems of the body. Many of the common deficits include hemiparesis or hemiplegia of one side of the body, speech-language problems, visual-spatial difficulties, and possible memory loss (American Stroke Association, 2000). "Hemiparesis is a striking manifestation of stroke and is strongly correlated with level of physical disability" (Chae & Yu, 2002, p. 24).

Many patients that suffer from a stroke, experience decreased function in their upper extremity as well as lower extremity. "Cerebrovascular accidents are currently the leading cause of motor disabilities; a flexor synergy typically develops in an upper extremity during recovery. This pathological synergy may persist for years as a motor paralysis on one side of the body, which creates difficulty in isolating movements out of synergy" (Cauraugh & Kim, 2002, p. 2). Hemiparesis following stroke displays a qualitative characteristic pattern, as described by Chae and Yu (1999):

> At stroke onset, there is total loss of power with decreased tone. Within a few days, tone begins to increase and limbs become hypertonic. Initiation of movement occurs within the limits of a flexor synergy pattern in the upper extremity that consists of combined shoulder adduction, elbow flexion, wrist flexion, finger flexion, and forearm pronation. This is followed by movements

outside the synergy pattern with eventual recovery to isolated movements and reduction in spasticity (p.280).

Recovery time following stroke varies with each individual, although the most recovery occurs during the first month with improvements even up to 3 months. Motor improvement can continue beyond the first 3 months, although a plateau of recovery is complete by 6 months (Chae & Yu, 1999). "The best methods of treatment to encourage maximal recovery of the upper limb after stroke remain uncertain. If a low-cost treatment were found that reduced functional impairment and disability, this could benefit many stroke patients" (Powell, Pandyan, Granat, Cameron, & Stott, 1999, p.1384).

Motor function recovery occurs proximally to distally usually leaving the arm the last to gain any motor control, specifically the hand and digits. Only 20% of all stroke survivors have an entirely normal arm function three months after the onset of stroke, which leaves many individuals with a nonfunctional or an impaired arm (Kroon, Van Der Lee, Ijzerman, & Lankhorst, 2002). Decreased function of the upper extremity can result in an overall loss of independence with activities of daily living (ADL's) such as eating, dressing, bathing, etc. "Limitations of motor coordination after stroke may result in a failure to return to activities important to a person's quality of life" (Trombly & Wu, 1998).

This paper will present an extensive literature review on the efficacy of electrical stimulation for treating clients post-stroke with decreased function in the upper extremity, therefore contributing to a more independent lifestyle with everyday activities of selfcare. Electrical stimulation is a modality treatment used by

occupational therapists as well as many other health professionals, although not every professional uses this treatment approach (Weingarde, Zeilig, Heruti, Shemesh, Ohry, Dar, Katz, Nathan, & Smith, 1998).

The review of this literature will contribute to the body of knowledge in the profession of Occupational Therapy for treating post-stroke patients successfully. By utilization of effective modalities to help increase overall function of the upper extremity affected by stroke, positive results of this project may help promote the use of electrical stimulation with post-stroke patients. It may create more opportunities for post-stroke patients to experience an increase in function.

CHAPTER II

REVIEW OF LITERATURE

History and Background of Electrical Stimulation:

The use of electricity to treat disease dates back to 1745 with the use of electricity to treat persons with paralysis to kidney stones. It wasn't until 1791 that there was a connection between muscle contraction to electrical stimulation (Baker, Wederich, McNeal, Newsam, & Waters, 2000). Currently, the use of electrodiagnostic procedures has ranged from cardiac pacemakers to the use of electrical current to treat chronic pain and paralysis. There has been a growth with the use of electrical stimulation since 1965 due to advances in technology. Manufacturers continue to develop small, portable units with many options so patients can use it in the convenience of their home with ease (Bracciano, 2000).

Neuromuscular stimulation has been used for physical rehabilitation with these three methods: diagnostic, functional, and therapeutic. Diagnostically, electrical stimulation is applied to nerves and muscles to measure various responses and help determine their neurophysiological muscles affected by stroke (King, 1996).

Baker et al. (2000) has defined the term, neuromuscular electrical stimulation as achieving reduction in impairments and to increase voluntary functional activities. Functional electrical stimulation (FES) is the use of neuromuscular stimulation for long- term use to induce functional and purposeful movements. One of the first clinical applications of FES was designed to dorsiflex the ankle during the swing phase of gait of a hemiparetic patient (Baker, et. al., 2000). "Functional neuromuscular stimulation is defined as the use of electrical stimulation to activate paralyzed or paretic muscles in

precise sequence and intensity to assist in the performance of activities of daily living (ADL)" (Chae, Kilgore, Triolo, & Yu, 2000, p. 1).

Therapeutically, electrical stimulation is used to help decrease spastic contractions in spinal muscles, increase voluntary movements in paralyzed muscles, and increase strength in dysfunctional muscles that are affected by stroke, spinal cord injury, and head injuries (King, 1996). Repetitive stimulation is used to address impairments such as motor weakness, decreased range of motion, and cardiovascular deconditioning. "While therapeutic neuromuscular stimulation may lead to functional improvements, the electrical stimulation does not directly provide function" (Chae, et. al., 2000, p. 1).

> With regard to therapeutic electrical stimulation (TES), several methods of application can be distinguished. Neuromuscular electrical stimulation (NMES), EMG-triggered electrical stimulation, positional feedback stimulation training, and transcutaneous electrical nerve stimulation (TENS) are applied by different devices, with different possibilities for the adjustment of stimulation parameters. The specific setting of the parameters determines the type of reaction provoked by the stimulation (Kroon, Van der Lee, Ijzerman, & Lankhorst, 2002, p. 351).

Electrical stimulation has been widely used on patients with central nervous system disorders such as stroke or traumatic brain injury to correct contractures, decrease impairment and increase overall hand function (Baker et al., 2000). According to Shanker and Randall, (2002), "Neuromuscular stimulation can be effectively used as a muscle re-education tool" (p. 103). Neuromuscular electrical stimulation is a physical agent modality and according to the American Occupational

Therapy Association (AOTA), modalities may be used "as an adjunct to or in preparation for purposeful activity to enhance occupational performance" (King, 1996).

Before initiating a program of electrical stimulation the treatment goal and desired motor responses should be well defined (Baker et al., 2000). "After a thorough assessment of the case, each clinician must select which combination of physical agents best matches the set of specialized physical, medical, or surgical interventions that, together, will lead to optimal therapeutic outcomes" (Belanger, 2002, p. 18). Using knowledge of kinesiology, joint mechanics, muscle anatomy and lines of muscle action, it must be determined what muscle or muscle group is appropriate to stimulate and what general treatment protocol should be followed. Electrical stimulation of the upper extremity requires precise placing of electrodes due to the combination of small muscle mass and the large number of individual muscles that control the fine movements of the arm and hand. More emphasis is placed on extensor stimulation to help overcome a tendency for flexor patterns to develop (Baker et al., 2000).

Reorganization of the Brain:

It is important that before using any type of electrical stimulation there be some motor return to the affected limb. This occurs through reorganization of the brain. The initial deficit and the degree of motor recovery after ischemic stroke vary greatly and are related to such factors as lesion type, topography, and size. Studies using PET (Positron Emission Topography), fMRI (Functional Magnetic Resonance Imaging), transcranial stimulation, and magnetoencephalography have shown that there is a cortical "reorganization" in patients with complete or partial upper limb recovery (Feydy, Carlier, Roby-Brami, Bussel, Cazalis, Pierot, Burnod, & Maier, 2002). Studies

using PET, functional MRI, transcranial stimulation, and magnetoencephalography (MEG) support the concept of functional reorganization after stroke. PET studies on blood flow distribution during finger movements in a previously paretic hand have demonstrated complex patterns of activation. "It has been reported that changes in activation patterns can be induced by active repetitive movement training of the paretic hand even 4 to 15 years after stroke onset" (Johansson, 2000, p.226).

> The use of electrical stimulation has been shown to produce therapeutic effects: decreased spasticity, increased movement range and speed, and increased muscle strength. The mechanisms by which those changes are occurring are still controversial. It has been hypothesized that functional electrical stimulation (FET) generates activity-dependent changes within the CNS when applied during appropriate motor tasks. This follows the findings that the brain possesses the capability to reorganize itself in a way to allow neighboring cortical regions to expand into areas normally occupied by input from other organs. The FET most likely manipulates with the sensory input, thus modulating the magnitude of cortical response and motor pathway excitability, which produces a mixture of excitation and inhibition at supraspinal levels (Popovic, Popovic, Sinkjaer, Stefanovic, & Schwirtlich, 2002, p. 274).

Cortical reorganization may have a role in the improvement of the motor and sensory functions of the stimulated limb. "A glove or sock electrode stimulates cutaneous and muscle afferents of a large area and motor fibers of intrinsic muscles and may facilitate cortical synaptic reorganization and increase the contribution of the

remaining motor structures in the restoration of voluntary activity" (Peurala, Pitkanen, Sivenius, & Tarkka, 2002, p. 710).

Clinical studies have suggested that post-stroke motor recovery or motor relearning of the paretic limb may be maximized by the active repetitive use of the affected limb, such as with "forced training" (Chae & Yu, 1999). There has been a significant reduction in acute inpatient rehabilitation length of stay, which causes rehabilitation professionals to focus on compensatory strategies to maximize function in the shortest amount of time rather than the restoration of motor control (Chae, Bethoux, Bohinc, Dobos, Davis, & Friedl, 1998).

Reacquiring movement capabilities involves relearning to initiate motor actions on voluntary command as well as knowing that the impaired limb is moving. Indeed, a coherent perception-action relationship must be reestablished in stroke patients so that they will be able to expand their limited motor repertoire (Cauraugh & Kim, 2002):

> Motor recovery rehabilitation protocols traditionally focus on single-limb (unilateral) tasks for the affected upper extremity. However, dynamic systems theory (bimanual coordination) and interlimb coupling should not be neglected. The phenomenon of 2 arms working together bilaterally in coordination situations has been studied by many researchers. Evidence has indicated that both arms are centrally linked as a coordinative structure unit: hands and fingers function in a homologous coupling of muscle groups on both sides of the body. Coordinated movement patterns emerge spontaneously from the constraints on the system as a function of dynamics. This approach emphasizes the inherent characteristics of muscles as important for motor control. When 2 limbs execute the same type of

movement at the same time, the complex system is referred to as stable and in phase (p. 3).

Motor relearning has been described as the reacquisition of motor skills previously learned after an injury to the central nervous system. There is clinical data that suggests that active repetitive movement that is goal oriented contributes to post-stroke motor relearning. Researchers questioning the fact that if active repetitive movement facilitates motor relearning, then the use of neuromuscular repetitive movement may also influence this relearning process (Chae & Yu, 2002).

Golaszewski, Kremser, Wagner, Felber, Aichner, and Dimitrijevic (1998) studied the effect of cutaneous stimulation in the immediate post-stimulation period during simple motor tasks with MRI. Increased signals in the pre and post-central gyri after cutaneous stimulation as well as the inferior parietal lobule were activated in both hemispheres. It is possible that additional afferent stimulation may trigger the remaining plastic capacity for sensorimotor reorganization in the brain and promote functional recovery in chronic stroke (Peurala et. al., 2002).

Current Research of Electrical Stimulation:

Kroon, et al. (2002), discussed the implications of therapeutic electrical stimulation in post-stroke patients with a look at the effects of motor control and functional ability in the upper extremity. A systematic literature search was performed in MEDLINE, EMBASE, CINAHL, and the database of the Cochrane Field Rehabilitation and Related Therapies. The selection criteria included, TES applied to the upper extremity of post stroke patients aimed at improving motor and functional abilities; use of surface electrodes; relevant outcome measures with respect to motor

control and functional abilities; and randomized controlled trial. Of the studies found, the number of patients included in a study was from 11 to 60.

The study outcomes were measured to evaluate therapeutic electrical stimulation (TES). Six randomized controlled trials were studied. Of these 6, only two measured the effect on functional ability with one reported a positive effect. All of the studies measured motor control using active range of motion (AROM), isometric strength, grip strength, Fugl-Meyer Motor Assessment, Action Research Arm Test, 9-Hole Peg, and box & block test. In two studies, they concluded that less severely patients responded better. No other conclusions between patient characteristics and effect could be made. This study suggests that electrical stimulation had a positive effect on motor control of the affected upper limb. It was uncertain whether the improvement in motor control were clinically relevant or if functional improvements were achieved with the use of electrical stimulation.

A study by Peurala, et al. (2002), investigated if cutaneous electrical stimulation helped increase motor function in individuals with chronic stroke. Fifty-nine stroke patients participated in this study, 42 males and 18 females with a mean age of 54 years. Twenty four of the patients had left-sided hemiparesis and 35 had right-sided hemiparesis. Thirty two patients received treatment in the paretic hand and eight received a placebo treatment with no electrical current in the paretic hand. Nineteen patients received treatment on their foot. Cutaneous stimulation was given to the affected hand or foot twice daily for 20 minutes each session. In addition, the patients underwent their regular rehabilitation training during this 3 week inpatient period. Stimulation was given with a sock or glove electrode. The outcomes were measured

using the modified motor assessment scale, 10 metre walking test, paretic limb function, limb skin sensation and somatosensory evoked potentials. The patients were assessed before treatment began and at the end of the 3 week rehab period using the outcome measures mentioned previously.

The results of this study showed significant improvement in sensory and motor function in the actively treated group. In 22 out of 32 patients who assessed themselves, their paretic hand function improved. Extension of all fingers showed significant improvement in the hand stimulated patients. The study showed that cutaneous stimulation may improve motor and sensory function in stroke patients, even after years of the onset of their stroke. In the modified motor assessment scale, there was an improvement of 2.3 points in the total score, which was clinically significant.

Popovic, et al. (2002), conducted an investigation to determine if functional electrical therapy (FET) can improve function in post-stroke patients. Sixteen subjects were involved in the study. The subjects were assigned to a higher functioning group (HFG) or lower functioning group (LFG) prior to the study based on active range of motion at the wrist and fingers. The HFG group was achieved when the subject could actively extend the paretic wrist more then 20 degrees and actively extend the MP and IP joints of all digits to at least 10 degrees. The requirements of the LFG group were that the paretic wrist could actively extend at least 10 degrees and extend the metacarpophalangeal (MP) and interphalangeal (IP) joints at least 10 degrees. Eight subjects were assigned to the HFG group and eight subjects to the LFG. A 4 channel functional electrical stimulation was applied to stimulate finger flexors and extensors for 3 weeks for 30 minutes daily. The exercises consisted of actively reaching for

objects for daily activities such as writing, using a telephone receiver, and drinking from a can. Evaluations were done at the beginning and end of the FET.

The results of this study were measured using the upper extremity function test (UEFT). The UEFT determines the differences in the performance of daily activities before and after the FET without the use of the stimulation. The tasks were graded as success (yes) and failure (no), and if yes, the time for accomplishing the task. The results indicated that the LFG functioning improved although the improvement in the functioning was not good enough to engage the affected arm usefully in daily activities. This study may have shown more precise results if the study would have been conducted for a time period greater than three weeks.

A study conducted by Chae, et al. (1998), studied the effects that neuromuscular stimulation had on increasing motor function in the upper extremity of post stroke patients. The subjects of the study had unilateral strokes and were admitted to an inpatient rehabilitation unit within 4 weeks. The subjects were randomly assigned to receive neuromuscular stimulation or a placebo. The subjects were 18 years of age or older with moderate to severe upper extremity paresis. All subjects received standard physical, occupational, and speech therapy interventions as part of the inpatient stroke rehab program. The treatment group received stimulation to produce wrist and finger extension and the control group received placebo stimulation over the paretic forearm. All subjects were treated 1 hour per day for a total of 15 sessions. Outcomes of this study measured using the Fugle-Meyer Assessment and the self care component of the Functional Independence Measure (FIM) prior to treatment, after treatment, and again at 4 and 12 weeks after treatment.

The results of this study demonstrated significant gains for the treatment group on the Fugle-Meyer scores. The FIM scores were not different between the treatment and control groups during the study. This study indicated that post-stroke patients treated with therapeutic electrical stimulation gained upper extremity motor recovery, yet did not improve the performance in basic self-care activities. A limitation of this study is that of the 46 subjects enrolled in the study, only 28 completed the treatment protocol. There was a high dropout rate due to pain from the stimulation.

Powell et al. (1999) studied the effects of cyclic neuromuscular electrical stimulation on wrist function as well as upper extremity disability in patients during the rehabilitation phase of treatment. Sixty hemiparetic patients were included in the study with a mean onset since CVA of 39 months. The inclusion criterion for the study was that patients were required to have a grade of 4/5 or worse at 2-4 weeks post stroke. The treatment group received electrical stimulation daily for 8 weeks at 3, 30 minute periods. The patients also spent time with physical, occupational, and speech therapists. The outcomes of the study were measured using a device that was specifically designed to measure the strength of wrist extension and active and passive motions. The assessment of upper limb disability was measured with the Action Research Arm Test (ARAT).

The results of this study indicated that the strength of wrist extensors improved significantly compared to the control group at both 8 weeks and 32 weeks. The effects of electrical stimulation in hemiparetic stroke patients did enhance recovery of wrist strength and reduce upper limb disability. The drawback was that it was not known how long the improvements would last after electrical stimulation stopped.

Hofer, Mayr, Stohr, Unger, and Kern (2002) studied the concept of direct electrical stimulators and their usefulness for treatment of denervated muscles. The concept of this stimulation is considered controversial by many professionals due to the contradictory effects on nerve growth and re-innervation. The purpose of this article was to look at a possible electrical stimulator that is more suitable to stimulate muscles. In order to produce muscle excitability in the fibers, the pulse width of the stimulator has to be in a range of 1 to 300 ms. A stimulation system was designed to suit the needs of patients with denervated muscles. The stimulator had a control unit, power supply, and output stage. The power supply was made up of battery packs with monitors for temperature as well as signals to warn when battery power is low. The output stage consisted of the impulses to the skin that are delivered simultaneously to two different muscle groups to reduce training time and increase compliance. The control unit created pulse width, pulse shapes, frequency, amplitude, and duration of training sessions. The control unit was equipped with a memory of the training sessions so that the information could be downloaded to a personal computer. In time, treatment of denervated muscles with this stimulator restored physiological function and metabolism of muscle cells.

King (1996) investigated whether electrical stimulation can reduce tone in post stroke patients. Twenty-one subjects (14 men and 7 women) with chronic wrist flexor spasticity due to stroke participated in this study. The mean age was 67 years. The subjects were assigned to a passive stretch group or the neuromuscular electrical stimulation (NMES) group. The wrist flexor muscle group was measured using a torque meter developed by McPherson. Prior to treatment, the affected wrists were

measured by the torque meter and passively extended to 15 cm-kg. After treatment, resistance of wrist flexors to passive movement was measured with the torque meter at the same angle of wrist extension measured prior to treatment. The NMES group received electrical stimulation for 10 minutes. The results of the study indicated that the NMES group had significantly greater resistance of the wrist flexor muscle group compared to the group only receiving passive stretch. The results supported that NMES is effective in reducing tone in wrist flexors.

Cauraugh and Kim (2002) conducted a study with electromyogram (EMG) triggered neuromuscular stimulation and bilateral coordination training. EMG stimulation required the patients to voluntarily contract a group of muscles for a particular movement. The EMG activity level was supplemented by an electric stimulation on the skin above the involved muscle when the limb goes through a particular motion (Cauraugh, & Kim, 2002). Twenty-five subjects volunteered to participate in the study. Twenty-one were male and 4 were female. All subjects had mild to moderate upper extremity hemiparesis. Subjects were measured using the box and block test, simple reaction time for speed of information processing and rapid muscle onset, and sustained muscle contractions and force modulation. The subjects were assigned to 1 of 3 groups; coupled protocol of EMG triggered stimulation and bilateral movement, EMG triggered stimulation and unilateral movement, and a control group. All subjects completed 6 hours of rehabilitation during a 2 week time period.

The results of the study indicated that the treatment groups (unilateral and bilateral) both had significant measures in the amount of blocks moved, reaction times to initiate movement, and sustained muscle contraction. Chronic hemiparesis

decreased in the wrist and fingers as motor function increased. The results were very positive in that the more motor function that returned, the greater the possibility for regaining more independence. According to the authors of the study, Cauraugh and Kim (2002), the results of this study supported the proposition that specific rehabilitation protocols assist voluntary control and motor repertoire in stroke patients with chronic hemiparesis.

The theoretical basis for EMG triggered neuromuscular stimulation is that alternative motor pathways can be recruited and activated to assist the damaged efferent pathways from the stroke. This explanation is based on the theory of sensorimotor integration, which explains that sensory input from movement of the affected limb has a direct influence on motor output. Post-stroke individuals attempt to voluntarily extend their wrist and hand; the EMG assists with this movement by a means of neuromuscular stimulation (Cauraugh, Light, Kim, Thigpen, & Behrman, 2000).

The method of EMG-triggered neuromuscular stimulation was studied by Cauraugh, et al., 2000. The purpose of their study was to investigate the effects of electromyography triggered neuromuscular electrical stimulation on the wrist and finger extension muscles in individuals who had a stroke one year prior to the study. Eleven subjects participated in the study. The mean age was 61.64 years. Six women and 5 men participated in the study. The participants were assigned to a treatment group or a control group. Seven individuals were part of the treatment group and four were part of the control group.

Motor functions were measured using five scales. Box and block tests were used to measure dexterity. The Motor Assessment Scale and Fugl-Meyer were used to

evaluate the recovery of the hand. Reaction time was measured using computer programs, BioPac and AcqKnowledge, in the laboratory. EMG activity was measured using surface electrodes attached to the dominant muscle area for the extensor communis digitorum and extensor carpi ulnaris of the affected limb. Subjects were given two treatment sessions for 60 minutes at 3 days per week for 2 weeks. The treatment group completed 12 treatment sessions of electrical stimulation. Before each treatment session, passive range of motion exercises and stretching was done to the hemiparetic limb. During these exercises, the subjects attempted to lift their wrist for 2 sessions of 30 trials. After the 12 sessions, the subjects performed 360 wrist and finger extension trials supplemented with EMG triggered electrical stimulation.

The results of the study revealed significant gains for the box and block test for the treatment group. On the average, they grasped, transported, and released 9 more blocks after the treatment than before. The treatment group had gains in the Fugl-Meyer scores after treatment compared to the control group. The results of this study support the theory that electrical stimulation is beneficial to hand function after stroke.

A specific type of electrical stimulation device was created to help promote recovery following stroke. Stroke Recovery Systems, Inc., has developed a device called the AutoMove, which helps individuals extend their wrists and fingers. This device has recently been approved by the Food and Drug Administration for use with stroke rehabilitation. This is a muscle-triggered electrical stimulation device, which helps patients fully extend the limb they are trying to move (Powell, 2000). After 12 sessions of 30 attempted extensions, patients receiving the experimental treatment doubled the number of blocks they could move in 60 seconds with their affected hand.

Leslie McCellan who is 4 year post-stroke survivor, began using electrical stimulation and has experienced much improvement that he was able to return back to work part-time. According to McCellan, “Out of all the different therapies I’ve had, this one has helped me the most. I am driving easier and holding a newspaper” (p.1).

Following the information that was gathered from the research studies, recommendations and guidelines were created for the proper use of electrical stimulation.

Guidelines and Recommendations:

The use of electrical stimulation should be conducted by health professionals that have the knowledge and skills to properly care for patients undergoing this intervention. "Each patient is like an individual fingerprint in terms of his or her needs. A knowledgeable clinician or clinical team is required to determine candidacy for electrical stimulation" (International Functional Electrical Stimulation Society, 2002, p. 1). It is important that the health professional review the patient's current and past medical history before the use of any physical agent modality, especially electrical stimulation (Trombly, 1995).

An expected measurable outcome that may improve one's daily life should be set for a patient before electrical stimulation is started. Electrical stimulation, when added to a patient's rehabilitation plan, may reduce the number of clinical visits, cost, and increase the expected outcome. Although, it should not act as the sole intervention of treatment (International Functional Electrical Stimulation Society, 2002).

The contraindications for electrical stimulation include the presence of a cardiac demand pacemaker. There is a possibility that the use of stimulation may cause interference with the pacemaker and documented cases have been reported. If a patient may benefit remarkably from the use of electrical stimulation, consulting the patient's cardiologist is extremely important (Baker, et. al., 2000).

Other precautions and contraindications for the use of electrical stimulation include active cancer, stimulation of the carotid sinus, local infections, decreased cutaneous sensation, pregnancy, transcranial electrical stimulation, and electrical stimulation of the anterior chest wall (Trombly, 1995). During the course of treatment

with electrical stimulation, it is important to monitor for possible skin irritation. Some patients may have hypersensitive skin, causing an allergic reaction. If irritation occurs, moving the electrodes to a different location on the skin may help. "Electrodes should not be placed over an open wound and a stimulated contraction should not place stress on an incision site" (Baker, et. al., 2000, p. 85).

When surface electrodes are being used, it is important to maintain good contact between the skin and the electrode, otherwise possible reddening and burning of the skin can occur. Special attention should be given to patients with impaired sensation or cognition to prevent possible burning or irritation (Chae, Kilgore, Triolo, Yu, 2000). Some individuals may feel pain during the course of electrical stimulation. The clinician should closely monitor an individual's pain threshold. This was evident by some research studies having a high dropout rate of participants due to pain (Chae, Bethoux, Bohinc, Dobos, Davis, & Friedl, 1998).

Other factors to consider when using electrical stimulation include general obesity. An individual who is obese may have a significant amount of fat overlying on targeted muscle groups, which can make it difficult to generate a muscle response with surface stimulation (Baker, et. al., 2000).

An individual's perspective on their quality of life should be taken into consideration with the treatment of electrical stimulation (Chae, Kilgore, Triolo, & Yu, 2000):

> The principal goal of the rehabilitation management of persons with hemiplegia is to maximize quality of life. While quality of life is clearly influenced by a wide range of variables including social, emotional, psychological, vocational, and

> educational factors, persistent neurological impairment, after injury, to the central motor system remains a powerful reminder and determinant of one's physical disability and handicap. For many stroke and brain injury survivors, significant residual hemiplegia will persist (p. 19). Quality of life varies with each individual, however, the ability to complete activities that one was doing prior to stroke is important.

The dynamic nature of the health care system in this nation proves to be ever changing. New technology and ideas are influencing how clinicians are directing treatment with patients (Chae, Kilgore, Triolo, & Yu, 2000):

> Consumers will direct future developments. In the present health care environment, in which cost has become an overwhelming factor in the development and implementation of new technology, the consumer will become one of technology's greatest advocate. The usual drive toward greater complexity will be tempered by the practical issues of clinical implementation where patient acceptance is often a function of a tenuous balance between the "burden or cost" associated with using a system and the system's impact on the user's life (p. 20).

Patients' perception of use and cost of electrical stimulation will have an impact on future issues regarding electrical stimulation.

According to Glanz, Klawansky, Stason, Berkey, & Chalmers (1996):

> Although our results do not necessarily confirm sustained improvement in muscle strength or actual functional improvement, they nonetheless provide promising support for the use of FES. The units that deliver electrostimulation are relatively inexpensive ($1,250) extremely durable, and reliable, and can be applied by the

> patient or family member without the ongoing assistance of professional personnel. There is little if any risk associated with their usage. Given the large burden of disability from cerebrovascular disease and the paucity of efficacious therapeutic modalities, further research on the use of electrostimulation would appear to be prudent (p. 552).

The guidelines and recommendations presented in this chapter coincide along with the recommendations presented in chapter four. These recommendations are important to understand before using electrical stimulation. Chapter three describes the procedure and methodology conducted to produce the recommendations in chapter four.

CHAPTER III

ACTIVITIES/METHODOLOGY

The procedure used to develop the product was an extensive literature review of many research studies conducted on the use of electrical stimulation with post-stroke patients. The literature review focused on the upper extremity, specifically the wrist and forearm rather than the shoulder. The type of electrical stimulation that was used for each particular research study varied, which was helpful to see the differences in research results. For example: Information was received from occupational therapists on various types of electrical stimulation and from a medical doctor who has conducted many research studies on this treatment intervention with post-CVA clients.

One specific clinician, John Chae, MD, has conducted many research studies on electrical stimulation with post-stroke patients. Dr. Chae conducted all of his research on the wrist and forearm, which was the focus of this research paper. Dr. Chae kindly took time out from his busy schedule to send more information on electrical stimulation as well as answer questions. His research has produced positive results in post-stroke individuals; although, the translation to an actual increase in function is still unclear. Dr. Chae's research studies were very detailed in explaining electrical stimulation as well as covering other factors such as costs to the client, future directions of electrical stimulation, and determining if electrical stimulation can increase function. Dr. Chae continues to conduct research on electrical stimulation to gain further information on the effectiveness of this treatment modality.

Upon completion of the procedural steps, recommendations were developed for occupational therapists on the correct use of electrical stimulation, cost effectiveness,

and the need for further research on this modality. The recommendations are outlined in detail in chapter four.

CHAPTER IV

RECOMMENDATIONS

Recommendations on the proper use and advantages of electrical stimulation were developed from the methodology for clinical occupational therapists. The recommendations were formulated from evidence from the research studies, as well as guidance from clinical manuals, experienced clinician advice, and personal experience with using electrical stimulation.

Benefits of Electrical Stimulation:

Electrical stimulation is psychologically enhancing. This modality helps contract muscles to produce movement when an individual does not have the ability to voluntarily move his/her wrist. It is helpful to have the patient visualize that they are moving their wrist on their own. The next benefit of electrical stimulation is the enhancement of motor recovery.

According to a study conducted by Powel, et. al. (1999), electrical stimulation is an economical intervention that has proven to enhance motor recovery and reduce disability in the upper extremity. Although electrical stimulation has proven to enhance motor return, it is recommended for some return of motor return.

Recommendations For Use of Electrical Stimulation Post-Stroke:

1.) The first recommendation for the use of electrical stimulation is that clients should have a muscle grade of at least 1/5 or better in the wrist/forearm. A grade of 1/5 is when there is a palpable or observable flicker of a muscle contraction with none of the available range of motion (ROM). This scale is based on a scale of 0 to 5; 0/5 means there is no palpable muscle contraction and no available ROM. A scale of 5/5 is

when there is full available ROM against gravity and against maximal resistance (Clarkson, 2000). Along with motor return, it is important to follow time guidelines after the onset of stroke.

2.) The second recommendation is regarding the timeframe post-stroke to begin electrical stimulation. In the evidence reviewed, the onset of stroke ranged from as early as 2 weeks post-stroke up to an average of 3.5 years (Cauraugh, et. al., 2000). The result of the study that started at the two-week mark of post-stroke did not necessarily have greater gains compared to the research study that started treatment at the mark of three and a half years. There is not substantial evidence in the research to determine if starting an electrical stimulation program earlier post-stroke has more benefit. Although, starting electrical stimulation at least 2 weeks post-stroke would be highly beneficial and recommended so that individuals post-stroke have the opportunity to gain as much motor return as possible.

3.) The third recommendation for the use of electrical stimulation is that patients have a high motivational level. The use of electrical stimulation may not provide visible results for quite a while, so it is important for a patient to not become discouraged. Also, a patient must be able to tolerate the involuntary muscle contractions produced by electrical stimulation.

4.) The fourth recommendation is amount of time that an individual spends in therapy with electrical stimulation. From the evidence of research, it is recommended that a patient spend 30 minutes daily on electrical stimulation with 3-4 sessions per week. The use of electrical stimulation should be supervised by an occupational therapist while the patient is undergoing therapy.

5.) The fifth recommendation is that the use of electrical stimulation be used in conjunction with rehabilitation treatments such as occupational therapy and physical therapy. A patient undergoing the regular regimen of occupational therapy and physical therapy may produce more brain reorganization, therefore increasing motor return. It is beneficial if electrical stimulation is used as an adjunct to these therapies and is proven from the evidence of research (Chae, et. al., 1998).

6.) Currently, there is no substantial evidence that implies that one method of therapeutic electrical stimulation is better than the other. Kroon, et. al. (2002) studied six randomized controlled trials on the use of electrical stimulation on motor control and functional abilities. From the results of the six studies, consisting of NMES (2 groups), TENS, EMG-stim (2 groups), and positional feedback stimulation training (PFST), the use of therapeutic electrical stimulation proved to have a positive effect on motor control of the upper extremity in post-stroke patients. Since evidence has suggested that one method of electrical stimulation does not provide more results than one another, the use of a more economical type of electrical stimulation is recommended.

7.) Transcutaneous electrical nerve stimulation (TENS) was originally used to treat pain. TENS can be used to contract muscles in addition to pain control. The use of a TENS unit for treating individuals post-stroke is as effective as other higher technological methods such as EMG-triggered electrical stimulation, Positional feedback stimulation training, and surgically implanted devices (Kroon, et. al., 2002). The TENS unit is portable and less complex because of it's small size. When electrical stimulation is used as a home treatment, it is easier for individuals to learn the use of

the TENS device. As health costs are dramatically rising, keeping the costs of technology reasonable becomes a treatment consideration. TENS is economical when compared to other devices, so the ability for hospitals and clinics to obtain these devices is improved. The price of the TENS unit associated with the positive outcome of treating an individual need to be considered. A TENS unit is easy to use, so clinicians can learn the proper use of it, as well as patients who will use this device at home. Although, there are disadvantages to using TENS, the positive results, price, ease of use, and simplistic method still make this method very reliable and effective.

8.) There are some advantages and disadvantages in relation to using surface electrodes to deliver current to muscles transcutaneously. Some disadvantages to using surface electrodes is that many times a good contraction from muscles can be difficult due to the inability to isolate certain muscles. Sometimes pain is associated with the use of these electrodes. Inability to reproduce contractions due to variable placing of electrodes is another consideration. Attaining good contact with electrodes and skin can be difficult. Making mistakes in application of electrodes and placing them in the same location every time can cause possible skin irritation or even slight burning to the skin. Some advantages to using surface electrodes is that the procedure is noninvasive since it is right on the skin. Placing electrodes and removing them is very simple and relatively pain-free. The cost associated with the electrodes is very reasonable; as well as the fact that there are many manufacturers that produce them. Although there are disadvantages to using TENS, the positive results (price, ease of use, and simplistic method) still make this method very reliable and effective.

9.) It is important for health professionals to continue with educational courses, to keep up with the increasing technological advances. For those clinicians who have not used electrical stimulation before, taking a physical agent modalities course would be essential to effectively and safely apply this new treatment method to various patients that would benefit from its use.

Further Considerations:

There is no evidence as of yet that therapeutic electrical stimulation has a positive effect on functional abilities such as increased independence with self-care or using their hand/arm to facilitate this. At this point it is not known whether improvement in motor control, such as wrist extension and grip strength, is clinically relevant or whether functional improvement can be produced by electrical stimulation (Kroon, et. al., 2002).

The benefits of electrical stimulation highly outweigh any disadvantages. The use of electrical stimulation, when following the recommendations, may produce outstanding results for patients post-stroke with decreased function in their upper limb.

CHAPTER V

SUMMARY

Occupational therapists frequently work with many CVA patients due to the high incidence of this disease. The use of electrical stimulation is an effective adjunct to rehabilitative treatments provided by therapists, as demonstrated by the research summarized in the literature review. As clinicians strive to find more effective treatment techniques for clients post-stroke, it is important to remember that electrical stimulation is indeed an all around economical and effective method to help individuals overcome motor limitations associated with stroke.

Electrical stimulation can be used for many other conditions such as traumatic brain injury, spinal cord injury, cerebral palsy, multiple sclerosis, amyotrophic lateral sclerosis, incontinence, pain management, and general muscle weakness or paralysis. Electrical stimulation has proven to help with the lower extremity as well as the upper extremity. More sophisticated methods of electrical stimulation are being introduced such as surgically implanted electrodes. However, implanted electrodes are currently much more expensive compared to traditional methods of electrical stimulation. More research will continue to be conducted to compare the efficacy of the implanted device compared to the surface electrode method of electrical stimulation.

There is still a great need for further intensive research on electrical stimulation to clarify if this method of treatment has an effect on functional abilities of post-stroke patients and what method is more effective. The length that improvements will last after stopping treatment with electrical stimulation is in need of more research evidence. The use of electrical stimulation in post-stroke individuals is going to need

continual research to determine if an individual's function can improve with its use and to further assess new technological advances in this area.

Despite the need for further research on the functional outcomes of electrical stimulation, present research on upper limb motor outcomes exist. Based on the evidence, the following recommendations for usage of electrical stimulation by trained clinicians were presented in chapter IV:

- Motor return of at least 1/5 muscle grade
- Beginning electrical stimulation as soon as 2 weeks post-stroke
- Patient should possess high motivation for recovery
- Thirty minutes daily, 3-4 times per week of electrical stimulation treatment supervised by an occupational therapist
- Using electrical stimulation in conjunction with occupational therapy and physical therapy
- No specific type of electrical stimulation has been proven to be the most effective
- Using TENS is economical and effective
- Using surface electrodes correctly to prevent skin burning/irritation
- Taking an educational course on physical agent modalities

As you can see, electrical stimulation is a treatment intervention that can be used with many various clients. Electrical stimulation will continue to be an effective method of treatment for post-stroke clients, especially when the guidelines and recommendations are used. As the number of stroke survivors is steadily increasing, it is important for health professionals to continue to find treatments that will benefit

them the most. Occupational therapists are truly an essential component to a patient's recovery following stroke. Using traditional occupational therapy treatment methods in conjunction with electrical stimulation may bring more functional results to individuals recovering from a stroke, therefore increasing independence in all areas of their life.

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