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Electrical Stimulation In Stroke And Brain Injury

Problems To Be Addressed In The First Weeks And Months After Stroke Or Brain Injury

During this time period, electrical stimulation [ES] may be suggested by the medical care team. Each individual patient must be evaluated to determine if there are any contraindications to or precautions in the use of ES. If the patient is a candidate, ES may be incorporated into daily therapy protocols and it will be a part of the patient's 24 hour per day regimen. Each application of ES will be designed to accomplish a specific goal in terms of prevention of a complication or accomplishment of a functional goal along the road to recovery.

Prevention Of Deep Venous Thrombosis

During periods of immobilization or paralysis, it is important to continue to contract the limb muscles to move the venous blood back to the heart and to prevent pooling of the blood. Goals of treatment during this period will include the prevention of deep venous thrombosis [DVT]. Pooling of the blood in the leg, or calf, is a particular problem. ES of the calf muscles has been shown to be effective in preventing DVT in a variety of patient groups. It has been reported that the ES induced muscle contractions significantly improve venous drainage in the leg and that ES increases plasma fibrinolytic activity, or reduces the potential for clotting, in the spinal cord injury patients studied. In some studies, ES was used successfully in combination with low-dose heparin therapy [or anti-coagulant] therapy.

Although some investigators have reported limited effectiveness for the patient who is at high risk for DVT, ES can provide a simple means of contracting the leg muscles when the patient cannot do it for himself. It is important that the stimulation characteristics be adjusted to provide maximal comfort and minimal muscle fatigue during the "calf pumping" exercise. It is essential that all caregivers, medical or family, understand that the stimulation is to be used frequently throughout the day and night during the period of paralysis or immobilization. For example, the stimulator may be programmed to turn on and provide 10 to 15 minutes of exercise each hour. This intervention can be carried out in a hospital or home setting at minimal cost.

Encouragement Of The Return Of Voluntary Movement

After stroke or brain injury, every attempt is made to help the patient regain control of weak or paralyzed muscles. ES may be incorporated into a variety of therapeutic strategies to enhance motor control. After injury to the brain, learning to move again is improved by the sensation or awareness of movement. Electrical stimulation augments this sensory awareness by stimulating receptors

in the skin, muscles and joints and it is a natural addition to "exercise" protocols that may be learned during therapy visits and practiced at home. Objective documentation of brain activity after ES indicates that there is an amazing ability to adapt [called cortical re-organization] and ES along with voluntary effort appears to provide optimal rehabilitation. ES may be used as a sensory cue to increase the patient's awareness of muscles and joints and to encourage muscle recruitment. ES may be employed to contract the muscles of interest so the patient can exercise with the stimulation. These activities can be carried into functional tasks such as using the hand or standing, shifting weight from one leg to the other, and walking. Regardless of the objective for adding ES to the rehabilitation protocol, ES must be comfortable if the user is to be compliant.

Most of the functional applications of ES during this early period require the use of a small, wearable ES system that can be programmed and triggered to meet the changing needs of the recovering patient. There are a number of relatively inexpensive ES devices that could be employed. Although ES is effectively integrated with clinical therapy visits, a 24 hour per day ES protocol is essential for optimal recovery of voluntary movement. Successful ES outcomes require that ES is available around the clock at work and at home.

Reduction Of A Subluxing, And Possibly Painful, Shoulder

A subluxing, or dislocating shoulder is common after paralysis of the upper extremity. The goal of intervention is to minimize stretching of the shoulder joint capsule and structures of the shoulder, to prevent pain and to encourage the return of voluntary muscle activity about the shoulder. A shoulder sling supports the forearm and hand, but it does not replace the normal shoulder alignment. ES can reduce the shoulder and maintain that reduction for as many hours each day as needed.

A simple ES device with skin electrodes can be extremely effective. The stimulation characteristics will need to be adjusted by a therapist in order to assure the effectiveness of the early ES protocol and to accomplish the goal of almost continual ES during the day to maintain shoulder alignment. ES may be used for sleeping, if pain is a problem at night. The muscle stimulation to reduce the shoulder also results in stimulation of sensory nerves that carry pain impulses from the shoulder. Pain may be relieved by proper positioning of the shoulder and by ES to modulate pain. This application is extremely economical and can be carried out at home with stimulation characteristic modification at the appropriate therapy visits.

In the future, shoulder subluxation may be managed with implanted ES devices in patients who do not recover voluntary control of the shoulder. Clinical investigation of the efficacy of implanted ES devices for shoulder subluxation in the first few weeks after stroke or brain injury is currently in progress.

Prevention Or Correction Of Joint Contractures

After stroke or brain injury motion of the joints may be lost. This is known as a joint contracture. For example, it may become difficult for the patient to open their

hand or straighten their elbow and their shoulder may not move easily. The hip and knee may become stuck in a bent or flexed position and the foot cannot be moved into a neutral position for standing. ES can be used to prevent or to treat joint contractures. Although the chance of correcting a joint contracture is greatest when the problem is of recent onset, various investigators have reported significant improvements in long-standing joint limitations. ES will be used in conjunction with specific exercise protocols, with splinting or bracing, or before and after surgical intervention to correct deformities. The optimal use of ES would include early intervention and prevention of loss of joint motion.

It is critical to the success of range of motion [ROM] protocols to use ES several times each day. The exercise must be done regularly during the day or evening to regain motion. When the body segment to be moved is relatively small [fingers, wrist or ankle], the muscle pull created by ES alone may accomplish the goal. When the body segments are larger, at the knee or hip for example, ES may assist the patient in exercising to the end of their range. Whenever possible it is advantageous to combine ES with voluntary effort. Most home programs have been accomplished with skin electrodes and inexpensive stimulators.

The reports from investigators using implanted ES systems at the hip are promising and implanted ES devices may be used to correct hip joint contractures in the future. It should be recognized that the reduction of spasticity and the encouragement of voluntary muscle control [courtesy of ES] also contribute to prevention or correction of joint contractures.

Management Of Pressure Sores

Severely paralyzed stroke or brain injury patients who have reduced or absent sensation are at risk for development of skin breakdown, or pressure sores. In addition to the use of pressure distributing mattresses and cushions as well as properly fitted wheelchairs, frequent positional changes and inspection of the skin are essential to the prevention of pressure sores. Once a pressure area has developed, electrical stimulation may be added to wound care and positioning. The success of ES protocols in wound healing have varied according to the depth of the lesion, the extent of infection and the severity of metabolic compromise of the patient. The results of ES have been statistically and clinically significant for patients who are candidates. Successful protocols have included daily stimulation for a total time of two or more hours. Some clinicians use a very low intensity direct current while others use a pulsatile current and generate a visible muscle contraction in the area of the pressure sore. Electrodes may be placed adjacent to the wound or one of the electrodes may be placed in the wound. In the latter case, an electroconductive dressing is used as the electrode. After wound closure, the mechanical integrity of the skin will return to normal and it will be necessary to continue routine skin checks and take measures to relieve pressure throughout the day.

Management Of Spasticity [One Form Of Involuntary Muscle Activity]

The use of ES to manage spasticity [or involuntary muscle contraction because of increased stretch reflex sensitivity] dates back to the 1700's, and there is a

wealth of literature related to ES and spasticity in the last 60 years. Not everyone may benefit from ES to reduce spasticity, but the majority of stroke and brain injured patients have been relieved of pain and movement restriction when their spasticity was reduced.

A number of ES protocols with skin electrodes have been studied. All of these protocols would point to the efficacy of a home program for optimal success. The use of a sensory level stimulus intensity over the spastic muscles, or over areas of skin that receive a similar nerve supply as the spastic muscles, have significantly reduced spasticity during clinical tests and during everyday activities. The use of skin electrodes to train muscles, or to contract muscles for exercise, have resulted in less spasticity and improved function. When electrical stimulation is used regularly in other parts of the body, for example to control the hand, spasticity has been documented to be less in the lower limbs.

It is important to remember that the maximum benefit of ES in the reduction of spasticity may not be realized until ES has been used for 1-2 hours per day for 1-3 months. It is equally important to realize that the reduction of spasticity may increase joint range of motion and **unmask existing voluntary muscle control.** If ES is discontinued, spasticity can usually be expected to return. For this reason, many patients elect to continue ES throughout their life.

Procedures that paralyze muscle, such as medications, a chemical nerve block or surgically cutting the nerve, will reduce spasticity but they result in a weaker or a completely paralyzed muscle. The advantage of ES is that it acts to reduce spasticity (without causing weakness or paralysis) and previously unrecognized abilities to move may be discovered.

The specific physiological mechanisms of spasticity modulation are not completely understood, but there is a consensus among researchers and clinicians regarding the merits of an ES trial to reduce interfering spasticity. The side effects of ES for spasticity are minimal. If spasticity is made worse on the initial treatments, the effect will subside within 1-2 hours. If this should happen, a preliminary trial of low intensity, or sensory level ES is indicated. If the patient is using their spasticity to initiate movement or to stabilize a joint, then the reduction of spasticity may make them temporarily less capable. So, it is important to utilize the expertise of a therapist who can evaluate the effects of ES on spasticity and provide an ES training protocol to improve muscle performance and provide suppression of spasticity over time.

Previous research with implanted ES systems [on the spinal cord or in the brain] revealed a reduction in spasticity and an improvement in voluntary control. Clinicians and researchers who are using spinal cord stimulation to reduce pain are also reporting reduction of spasticity in their stroke, brain injury and spinal cord injured patients. Spinal cord electrical stimulation is available in specialized centers throughout the world.

Recipients of neural prosthetic ES systems for hand function or assistance in walking report that interfering spasticity throughout their body is improved. Objective research studies have demonstrated that spasticity is reduced when

ES is used on a daily basis and that it may be expected to return when ES is discontinued.

Stabilization Of The Hip, Knee And Ankle For Standing And Moving From One Seat To Another

When the ability to stand on one foot in order to take a step or to walk is impaired by inadequate muscular support, ES can be used to give a sensory cue as a reminder to contract the muscles at the hip, knee and ankle or it can be used to help contract the muscles at the right time. It may not be possible to achieve a strong contraction of the deep hip muscles with skin electrodes, but it is quite practical to augment knee and ankle performance. It is usually necessary to use ES in exercise prior to seeing the optimal response in walking. Small, relatively inexpensive stimulators can be used for exercise. When a footswitch trigger is available to turn the stimulation on at the appropriate time, these same devices can be used for learning to stand, shift the body weight from one leg to another and to walk. In the hemiplegic population, ES is used to augment volitional control that is insufficient for function, by itself.

It has been demonstrated that electrodes or stimulation devices implanted directly on the deep muscles of the hip, and lower limb, are more effective than skin electrodes in controlling the hip and thigh muscles. The protocols were most effective when a clinical therapy protocol was used in addition to a daily home ES program. At this time, however, there are no commercially available, implantable devices for this application.

It is extremely important that the ES, whether cutaneous or implanted, is comfortable and is integrated into a physical therapy program designed to enhance volitional control and assure that new skills are learned as a result of intervention.

Assistance In Bringing The Lower Limb Forward To Take A Step

When ES is applied over the leg muscles that are responsible for picking up the foot in the swing phase of gait, or when ES is applied to the peroneal nerve via an implanted ES device, the toes do not drag on the floor and there is less chance of tripping and falling. It also is possible that the ES may elicit a flexion reflex in the entire lower limb, allowing ankle, knee and hip flexion. This was first demonstrated in the early 1960's, and it is a commonly employed therapeutic approach in many physical therapy clinics, where the elicitation of this reflex is useful in reaching the goal of independent walking. It must be recognized that not all stroke or brain injury patients will have this reflex to the extent that it can be useful for walking, but in those who do have it, it is possible to change from dragging the lower limb during walking to a brisk stepping response. The reliance on ambulatory aids, such as a walker or crutches, may be reduced or eliminated. It has been shown that hemiplegic patients continue to use ES for walking long after completing their rehabilitation program, because it makes walking easier.

This therapeutic intervention may be accomplished with a variety of skin electrode devices, including those that are specifically engineered to accomplish

limb advancement by elicitation of the flexion reflex. Implanted ES systems were first used for this purpose approximately 35 years ago, and implanted technology is available today in selected centers around the world.

Considerations After Initial Recovery Has Plateaued

Continued Use Of ES To Maintain Joint Range Of Motion Or Correct Contractures

When the initial rehabilitation period has been completed and the return of volitional recovery has plateaued, continued use of ES may be indicated to maintain joint range of motion, correct contractures or maintain shoulder alignment. If the individual has volitional control of the extremity and spasticity does not interfere, ES should not be necessary. If joint stiffness or loss of range of motion reoccur, ES may be indicated once again to gain range of motion and reduce spasticity.

Continued Use Of ES To Suppress Interfering Spasticity

Although some patients do not need continued ES for spasticity modulation, others may require it the rest of their life to suppress spasticity. This can be accomplished very economically with an inexpensive stimulator and an appropriate home program. It has been demonstrated that electrical stimulation need only be done for 1-2 hours per day to suppress unwanted muscle activity throughout the 24 hour period.

Assessment Of Muscle Activity That Is Interfering With Function Because The Brain Is Sending Incorrect Signals

When it appears that muscles are coming on at the wrong time and interfering with functional activities, it is important to determine if the muscles are spastic [and might be corrected with an appropriate ES protocol or combined ES and other measures] or if the muscles are being instructed to come on at the wrong time by the motor control areas of the brain. It is critical to perform this assessment in the upright posture, or in the most challenging upright activity, because spasticity and muscle activity that is "out of phase," may be obvious only in this position.

If muscles are, indeed, coming on at an inappropriate time because of the brain's instruction, it may be necessary to surgically inactivate or move the muscles that are causing the problem. There are many considerations in planning such intervention. Intramuscular, fine wire electromyography [or assessment of muscle recruitment] during upright activity or walking is the only way to determine if specific muscles are appropriate in their timing, or not. It may be necessary to temporarily anesthetize these inappropriate muscles during the test to determine if eliminating their influence would cause any other penalties in walking. If not, permanent inactivation or moving of the muscle tendon may result in improved function. If the penalty is too great, it may not be possible to improve the patient's function beyond the reduction of spasticity.

For example, the stroke or brain injury patient who has full range of knee motion, but who walks with a straight knee may have inappropriate activity in one or more of the four muscles that straighten the knee. If the rectus femoris, or the muscle that crosses the knee and the hip, is keeping the knee straight in swing while the other three vasti are appropriately active, intervention can be directed specifically to the muscle that is out of phase [ie the rectus]. If, however, the vasti are on during early swing or if temporary inactivation of the rectus impairs hip flexion, then the stability of the knee and the critical hip flexion for limb advancement cannot be sacrificed.

The intramuscular fine wire assessment is not available in all rehabilitation centers, but there are more than 50 laboratories in the United States, affiliated with major medical centers, and there are similar laboratories in a number of other countries. In order to determine which muscles might be helped by surgery, it is essential to use intramuscular. Assessment of muscle activity with skin electrodes can lead to errors in making surgical decisions and penalize the rehabilitation outcome.

Continued ES To Encourage Muscles To Work Effectively For Daily Activities

When recovery of voluntary movement is incomplete, ES can continue to be used every day. It is not uncommon to need some assistance with specific muscles or muscle groups such as the ankle or knee flexors, the hip stabilizers or abductors, and the extensors of the elbow, wrist and fingers.

Neural Prosthetic Applications

When ES is used to support every day activities such as standing, walking or hand use, it may be called a "neural prosthetic" application. Neuroprostheses are devices which aim to substitute for the control of bodily functions which have been impaired by neurological damage. Some patients prefer to continue to use external ES systems or neuroprostheses. A small, wearable stimulator with skin electrodes may be the device of choice for applications requiring only a few channels of stimulation. The Handmaster external neuroprosthesis, developed in Israel, is a combined cutaneous electrical stimulation and bracing system for control of the hand. Expected outcomes from the daily use of such a system include reduced spasticity, improved range of motion, potential improvement in volitional control and improved hand function with hand positioning and ES.

Implanted ES systems have been successfully used in research studies and clinical trials over the past 40 years. Either implanted electrodes or entire ES systems can control specific muscles for joint stability and useful limb movement in stroke and brain injury. Commercially available implanted systems for the hand and upper limb have been developed for spinal cord injury patients [NEC system in Sendai, Japan and the Freehand System from NeuroControl, Inc., in Cleveland, Ohio]. Because stroke and brain injury patients usually retain some capacity for movement, it is appropriate to reduce spasticity and evaluate each individual’s motor capabilities. The severely paralyzed patient may be a candidate for a fully implanted ES system to provide hand function.

Implanted ES technology is not routinely available for management of the hemiplegic lower extremity. Stroke or brain injury patients in Ljubljana, Slovenia, however, may receive an implantable peroneal nerve stimulator [IPPO-2] to pick up the foot and encourage ankle, knee and hip flexion for advancement of the limb in walking.

Recent technological advances promise to bring new capabilities to the clinical world of ES in the years to come. The injectable, microstimulator will offer the advantages of implanted ES control of one or many muscles, as required, without the need for invasive surgery. This technology is not commercially available at this time.

Contributors:
J.M. Campbell, Ph.D., P.T. 2002

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R. Acimovic-Janezic, Prim. Dr.
T. Bajd, Dipl. Ing. Dr.
R. Nathan, B.M.E.
U. Stanic, Dr.

See:
General Considerations in the Clinical Application of Electrical Stimulation

References:
ES in Stroke and Traumatic Brain Injury
Comfort in Electrical Stimulation
ES for Improving Joint Range of Motion
ES in Modulation of Spasticity
ES in Pain Modulation
ES and Muscle Performance
ES in Walking
ES in Wound Healing