Neurotechnology for Spinal Cord Injury
Part 1 – An Overview and Explanation

You or someone you care about has sustained a spinal cord injury (SCI). You have heard that there are many advances and research occurring in the treatment and management of spinal cord injury. This Fact Sheet will help inform you about neurotechnology, a new field that offers technical devices and therapies for persons living with SCI. It is divided into two parts. Part 1 provides an overview of neurotechnology and its applications to spinal cord injury. Part 2 provides a listing of the devices and therapies available and additional resources. We recommend reading Part 1 first and then using Part 2 as a more specific resource.

Neurotechnology, the use of medical electronics to interact with the human nervous system, has made rapid advancements in recent history: components have shrunk, electronics improved, and we, as a society, have become more accepting of interacting with technology. Devices are available commercially for SCI treatment in such areas as pain management, spasticity control, breathing assistance and new rehabilitation techniques. There are also many new technologies being investigated in research centers. These devices and technologies are not attempting to “cure” spinal cord injury; they cannot reverse the damage to the spinal cord. Instead, they are tools that can be used, for instance, to combat secondary conditions, provide further independence and/or aid in the rehabilitation process. This Fact Sheet describes neurotechnology and its relationship to spinal cord injury; it will describe evolving resources to help you learn more about possible treatment options.

What is Neurotechnology?
Neurotechnology is a broad term used to refer to medical electronics that interact with the human nervous system. The basis of neurotechnology is the electrical signals the body uses to send messages. Electrical stimulation is the primary feature of this technology. Even though a muscle is paralyzed, it does not mean that the muscle can not contract when it is stimulated. For those with mobility impairments that do not have peripheral nerve damage, electrical stimulation may be utilized; it is being demonstrated through exciting new technologies and explained in this Fact Sheet.

In the 1950’s, the first attempt was made to apply electrical stimulation to the phrenic nerve to allow a person to breathe without a ventilator. This gradually developed into a field of science called FES (Functional Electrical Stimulation). FES encompasses a variety of therapeutic techniques and treatments used to activate muscles that may not be functioning properly due to injury, disease or a physical abnormality. Over the decades, this field of science that combines medicine, biomedical engineering and technology evolved into what is now called neurotechnology.

Areas of Neurotechnology
Neurotechnology can be divided into four areas: Neuromodulation, Neural Prostheses, NeuroRehabilitation and NeuroSensing and Diagnostics. Each area has a distinct definition however some devices may be applicable to more than one area.

- **Neuromodulation** works by using electrical stimulation to improve control of an existing part of the nervous system. Some examples include the spinal cord stimulation system used for chronic pain management that blocks pain signals to the brain and gastric stimulation systems which are used to block the signals of hunger.

- **Neural Prostheses** are used to replace or improve function of an impaired nervous system. For instance, FES systems can restore some hand function for quadriplegics while drop foot stimulators can aid walking.
NeuroRehabilitation is an emerging field of therapy applied to the body to provide healing or encourage natural restoration of a missing or impaired body function. Robotics may be used for repetitive therapy or suspension treadmill training systems can improve function of voluntary movement.

NeuroSensing and Diagnostics are tools to improve monitoring of activity in the nervous system or improve diagnosis of a condition. A peripheral nerve sensing test system that detects sensory impairments due to carpal tunnel system is an example of a neurosensing system in practice. Another example is pressure monitoring devices utilized to assess the potential for development of and thus the prevention of pressure sores.

These four segments make up the innovative field of neurotechnology. This is an emerging field; it is essential that the consumer carefully consider each device, therapy or treatment protocol before choosing to participate.

Important Considerations of Use
Below are some important considerations to review prior to participating in a therapy, treatment or device use.

- It must be recognized that all neurotechnology programs may not be appropriate for all people with SCI. Researchers and clinicians currently working in this area, understand the existing criteria and are developing new guidelines to determine for whom neurotechnology devices and therapies will be most beneficial and successful. Some levels of injury are more adaptable to some treatments than others.

- Systems are implanted, external or are a combination (hybrid) of both.
  - Implanted systems tend to be more “invasive” and therefore require a surgical or other procedure to install the system into the body of a potential user.
  - External systems are applied outside the body or on the surface of the skin.
  - Hybrid systems have components that are both implanted and external.

- The cost of the use of various systems is a very important consideration. In many cases, insurance does not reimburse for devices and therapies, especially if they are considered research or experimental. Review your insurance policy very carefully. Do Not Agree to participate in a protocol, therapy or research project until you have thoroughly explored the reimbursement options, out of pocket expenses and know the cost to you!

- Be aware that such treatments, therapies or devices are potentially dangerous if not used correctly.

- Not all people with SCI are appropriate for particular neurotechnologies. Your specific case should be reviewed by a medical professional, with SCI expertise, during consideration and prior to starting to use any technology.

Individuals interested in neurotechnology treatments, therapies or devices should consider the time commitment and financial requirements and be evaluated and supervised by a clinician specializing in spinal cord injury.
Applications

Here is a brief introduction to a few advances that are currently available, as well as some resources that will help you stay updated on what is coming in the near future. This section describes neurotechnology applications for different functional needs for a person living with spinal cord injury. Part 2 offers a listing of specific devices, therapies and treatments for each of these related sections. We recommend that you read this section first and then refer to Part 2. **Again, not all devices and therapies are appropriate for all injury levels. Consult a physician prior to consideration for use.**

Breathing and Cough Assistance

Current neurotechnology alternatives to mechanical ventilation are hybrid systems that include either a phrenic nerve stimulator or diaphragmatic stimulator. Unlike ventilator systems, which use mechanical pressure to force air into the lungs, the stimulation system pulls air into the lungs by stimulating the diaphragm muscle or the phrenic nerve. As the diaphragm contracts, the chest cavity expands and air is pulled into the lungs. As the diaphragm relaxes, the chest cavity retracts and air pushes out of the lungs. The use of a breathing stimulation system is only possible if the diaphragm, lungs, and phrenic nerves are intact and responsive to stimulation, thus allowing the system to work using these body parts.

Persons with quadriplegia and thoracic level SCI often have paralysis of the muscles responsible for coughing. Cough assistance systems (CAS) are vital to reduce the frequent respiratory complications that can occur. CAS that are currently available use different pressures to clear the lungs through an external breathing mask attached to a separate control unit. It applies pressure to the airway and then rapidly changes the pressure to create a high outflow from the lungs. Under investigation is a new hybrid system that uses an external controller and implanted electrodes to achieve a cough. The goal of this electrical stimulation system is to create a ‘cough on demand’, reduce the need for frequent patient suctioning and allow the person with SCI to clear secretions more easily. Ideally, there would be a reduction in the frequency of respiratory complications.

Hand Grasp and Rehabilitation for the Upper Extremities

The loss of hand and arm function due to a cervical level SCI can severely restrict an individual’s ability to independently perform activities such as eating and personal hygiene. Regaining hand function is a high priority for persons with cervical level injuries. Although neurotechnology devices cannot reverse the damage to the spinal cord, they have the potential to provide increased function. Hand control systems can enhance rehabilitation or provide function to the upper extremities which include the hand, wrist or arm. These systems rely on the peripheral nervous system to contact muscles. There are two major components of such a system: stimulation or the stimulator and the control. The stimulation of the paralyzed muscles is what produces the desired movement, such as hand opening or closing for grasp, or elbow extension for reaching. The control describes the way that the user directs the movement; for instance, through a switch or a shoulder motion. In most cases, it is possible to customize both the stimulation and control to meet the needs of the user.

Upper extremity systems can generally be classified as either external or hybrid systems. External systems use electrodes that are attached to the skin over the muscles to be stimulated. These systems are often used for exercise, muscle conditioning and limited function. Some external systems use repetitive motion therapy or combine external electrodes and EMG signals to enhance the rehabilitation process. Other options include hybrid systems that have an implanted stimulator and an external control method. Hybrid systems are for long-term functional use. The first commercial implanted system, the Freehand System, was available through NeuroControl Corporation in the late 1990’s. Unfortunately, although the system was successful in producing hand function, the company could not maintain profitability and, in 2001, left the SCI market. Today, researchers are developing second generations of the implanted hand control systems. These upper extremity systems are being designed with a goal to provide hand and arm function with control that is as natural as possible, cosmetically acceptable, practical to use, and adaptable to new activities and environments.
Pain and Spasticity Management

Neuropathic (nervous system generated) pain is a significant problem in some people with SCI. Discussion with your physician can help you better understand where the pain is coming from, and with that understanding, what can be done about it. Pain from SCI can come from an area of the spinal cord, a nerve close to the spinal cord or a fluid filled cavity within the injured spinal cord, referred to as a syrinx. Additionally, pain can be related to the disability of spinal paralysis; it includes over-use of joints or body parts, muscle spasm pain, or instability of the spine or other body organs. Conservative medical management (CMM) for people with SCI should not only include therapies directed toward relief of pain, but also include conventional physical therapies and rehabilitation, psychological and behavioral interventions. An appropriate referral to a medical specialist trained in the field of interventional pain medicine may offer you help.

There are many new areas of neurotechnology in the treatment of pain, such as deep brain stimulation, and transcranial magnetic stimulation. For this introduction, we will discuss three areas of treatment that are currently available; transcutaneous electrical nerve stimulation (TENS), implanted drug delivery systems (IDDS) and spinal cord stimulators (SCS).

- **TENS units (transcutaneous electrical nerve stimulation) and Percutaneous Neuromodulation units** work by delivering low level electrical stimulation through electrodes placed directly on the skin of the affected area. The electrical stimulation delivered through the skin may help alleviate pain by blocking pain messages being sent to the brain. Both systems require a physician prescription but this therapy can provide a convenient means of treating some forms of pain. Both are non-invasive and can be an economical solution.

- **Implanted Drug Delivery Systems (IDDS), also known as Intrathecal Analgesia Therapy**, refers to the administration of medicine, either pain-relieving or spasticity-relieving, such as baclofen, by a medication delivery pump. The IDDS include a chamber or reservoir for the drug that delivers the medication through a catheter directly into the spinal canal (intrathecal). The pump needs to be refilled, usually once every few months, by placing a needle through the skin. This procedure is typically performed on an outpatient basis or during a regular doctor’s visit. Generally, a person first undergoes a trial of the medication by an intrathecal injection. If successful, a pump system can be implanted permanently through a surgical procedure. IDDS reduce the need for oral medications, can be more effective and is now a mainstay of therapy for intractable pain including neuropathic pain and spasticity as a result of SCI.

- **Spinal Cord Stimulation (SCS) system** is a hybrid system comprised of implanted electrodes in the spine and an external control unit. It uses electrical stimulation to block the pain pathways to the brain that travel through the spinal cord. The abnormal sensations experienced by people with SCI are particularly suitable to spinal cord stimulation. SCS has also been known to decrease spasticity. An initial trial is needed to see if effective results can be achieved. If the trial is successful, a permanent system may be implanted. The user has the ability to keep the system on permanently or as needed.

These above options should be discussed with a medical professional trained in interventional pain medicine. The use of very high frequency alternating currents as a method for blocking nerve conduction in peripheral nerves is currently under investigation. This method might be able to provide an improved alternative for blocking pain and controlling muscle spasms. A listing of the available devices for pain management can be found in Part 2 of this Fact Sheet.

Urinary Function

Most people living with SCI have reduced bladder control that requires the use of either an external or internal catheter. Neurotechnology devices offer an alternative method of bladder management that use electrical stimulation to control urination or “voiding”. Several different approaches have been developed to treat the hyper-reflexive or flaccid bladder. Hybrid devices may stimulate the sacral, tibial,
or pudendal nerves or the bladder muscle itself in order to provide bladder function. The external pelvic stimulator uses electrical stimulation delivered by a vaginal or anal probe. The appropriateness of each specific device or treatment depends on the level of injury and bladder condition. There are five basic types of devices using electrical stimulation in different ways. These include:

- The **sacral nerve stimulator** is an implanted device that manages the bladder by sending electrical impulses to the nerve that controls the bladder, its sphincter, the muscles around it, and the sacral nerve roots.
- The **tibial nerve stimulator** controls the bladder through percutaneous stimulation (an electrode inserted through the skin) of the tibial nerve in the lower leg.
- The **pelvic stimulator** is completely external and uses electrical stimulation applied to the pelvic floor muscle. Generally delivered by a vaginal or anal probe connected to an external pulse generator, stimulation of the pelvic muscles may improve the opening and closing of the urethra.
- The **bladder muscle stimulator** is a device that directly stimulates the bladder muscle with an implanted electrode.
- An implanted device, currently under investigation, uses electrodes to stimulate the pudendal nerve to provide bladder function.

Each of these therapies can help improve control of the bladder, provide peace of mind and offer more independence. However, these approaches should be discussed with your urologist and evaluated for your individual situation to determine which may or may not be appropriate for you. Please Note: In some instances, bowel function may coincidently exhibit benefits from the use of stimulators for urinary function.

**Sexual Function**

The majority of people living with spinal cord injuries experience alterations in sexual function. Men will experience dysfunction that involves erection and/or ejaculation, semen quality and sexual satisfaction. Women may experience alterations in the degree of sexual sensation and the type of injury may influence a woman’s sexual satisfaction. Electrical stimulation may be a treatment option for males but research, although promising, is inconclusive as to the role of electrical stimulation for women's sexual function.

For a man living with SCI, the use of electrical stimulation to induce ejaculation may be possible. Fertility clinics have limited success with the use of electro-ejaculation. It is known that some couples have been able to conceive using this method. Further, it is reported that selected research using a bladder stimulation system (for bladder function) has resulted in some limited return of sexual function.

More details about sexuality are available on the following websites:

- Center for Research on Women with Disabilities – Reproductive Health: [http://www.bcm.edu/crowd/?pmid=1404](http://www.bcm.edu/crowd/?pmid=1404)

**Pressure Sore Prevention and Wound Therapy**

Most people with spinal cord injury (SCI) are at high risk for developing pressure ulcers due to muscle atrophy, decreased mobility and altered sensation. The prevention of pressure ulcers is a lifetime health issue. Daily use of electrical stimulation can help maintain the bulk or mass of paralyzed muscles. External electrical stimulation has some practical problems because electrode placement in the upper buttock region can be difficult for users to achieve. Implanted stimulation systems for long-term
therapeutic use have dual advantages: 1) the electrode can be located very close to the targeted nerve for muscle contraction and 2) repetitive placement is no longer an issue. Research teams are investigating implanted stimulation systems. Dr. Kath Bogie’s team at the Louis Stokes Cleveland Department of Veterans Affairs Medical Center is investigating the use of a gluteal electrical stimulation system (GSTIM) specifically to decrease risk factors associated with pressure ulcer development for individuals with SCI.

The use of electrical stimulation for the treatment of wounds has long been used in clinical practice. Electrical stimulation (ES) for pressure ulcer treatment is one of only two therapeutic options to be recommended by the Agency for Health Care Policy and Research for severe chronic wounds. A wide variety of external stimulation devices, approved by the Food and Drug Administration (FDA) for other purposes, may be adapted for use in wound therapy. Currently approved clinical use is limited to application of electrotherapy only after there are no measurable signs of healing for at least 30 days of treatment using conventional wound treatments. New devices specifically for wound therapy are being developed and one was recently approved by the FDA.

**Assisted Standing and Ambulation Systems**

The neurotechnology systems available for assisted standing and ambulation are wide and varied. Standing allows persons with SCI additional function and improved quality of life such as the ability to reach objects from high shelves, gain entry to places inaccessible from the wheelchair, and participate in social or work situations on eye level with their peers. Ambulation systems can provide basic standing and stepping in the vicinity of the wheelchair; these provide additional or further assistance for those with voluntary movement, such as persons with incomplete spinal cord injuries. Similar to the hand systems, electrical stimulation relies on the peripheral nervous system to activate a muscle. Advantages over other assistive devices such as standing frames or ankle-foot orthotics include easy application, increased versatility and prevention of muscle atrophy by using the body’s own muscle power.

The use of mechanical standing frames and custom bracing has long been used in clinical practice. The earliest introduction of neurotechnology for standing was a combination of external electrical stimulation and bracing. As research progresses and technology improves, a hybrid electrical stimulation system was developed and is currently being investigated in clinical studies at Case Western Reserve University and the Louis Stokes Cleveland Department of Veterans Affairs Medical Center. It uses implanted electrodes and an external control device that enables persons with C6 to T12 spinal cord injuries to stand with a walker. Further investigation is being conducted to provide automatic control of balance.

New neurotechnology devices that facilitate ambulation are available for those with paraplegia or incomplete injuries in which voluntary movement is present in the lower extremities. As with standing, devices are available that use external stimulation and custom bracing with the support of a walker. On the other hand, new external systems are being developed that include exoskeletal suits fitted to the lower extremities and designed to boost mobility and standing. More advanced implanted and hybrid systems are being developed by researchers at the Cleveland FES Center. For those with complete paralysis, implanted systems to enable steps in the vicinity of the wheelchair are undergoing clinical trials. For those persons with partial paralysis due to incomplete injuries, implanted and hybrid systems are being tested in the clinic to improve baseline walking ability and achieve faster, more symmetric walking for longer distances.

There are many commercially available options for assisted stepping for persons with walking ability but who need assistance with ankle and foot control. Using external electrical stimulation, these small systems stimulate the calf muscles in coordination with the gait of the user, thus, eliminating the need for ankle-foot orthotic bracing. Such devices have been covered under Medicare for incomplete spinal cord injury. Implanted assisted stepping systems are also being studied. These systems do not cure the paralysis but make possible functional use of the paralyzed muscle.

**Exercise and Rehabilitation Systems**
For people living with spinal cord injury, exercise and rehabilitation is vital but must be accomplished differently than prior to injury. This section describes exercise of paralyzed limbs and rehabilitation of muscles that have voluntary movement. Exercise is essential to prevent the development of secondary conditions in the cardiovascular and circulatory systems of the body. These systems move nutrients, gases, and wastes to and from cells helping to fight diseases, stabilize the body and prevent obesity. An additional important consideration for persons with SCI is restoring the condition of the affected muscles. After the onset of SCI, the muscles below the level of injury generally atrophy, potential problems with osteoporosis or brittle bones may develop and circulation become impaired due to inactivity.

Exercise can be achieved using Electrical Muscle Stimulation (EMS) which relies on the peripheral nervous system. A “normal” muscle is stimulated and contracts by signals from the brain that come through the spinal cord, whereas the weak or paralyzed muscle achieves a similar result with the assistance of electrical stimulation. The EMS devices send pulses of electricity into the user’s skin that result in a contraction of the muscles. For those with incomplete SCI and voluntary movement, exercising a muscle using EMS can slowly build muscle mass to potentially gain functional movement. For those with paralysis but who have intact peripheral nerves, electrical stimulation may be used to help maintain the condition of muscles. Using EMS will help minimize the loss of muscle bulk, improve muscle size and performance, and boost physical fitness. Aside from these benefits, EMS devices have long been used by physical therapists not only for rehabilitation of atrophied muscles, but to achieve relaxation of muscle spasms or increase range of motion. Such devices as external stimulation or FES cycling may reduce the number of medical complications resulting from immobility and lead to an improved and healthier lifestyle. It is vital to understand that results produced while using EMS devices may not show immediately; it typically requires the use of stimulation for 1-2 hours per day for 1-3 months for its effect to become noticeable. The FDA does warn that EMS devices can be hazardous when used improperly, especially when used on heart patients, persons with epilepsy or pregnant women. There are a variety of EMS devices available with or without a prescription. Before starting an EMS exercise regime, you should consult a physician or professional therapist.

For those with incomplete SCI and some voluntary movement below the level of injury, muscles may be reconditioned through rehabilitation. Movement enhancement systems are devices that are used to assist with the exercise or work of muscles in a limb. They reinforce the belief behind rehabilitation therapy which is to improve the function of a weakened muscle or to “boost” the voluntary function that already exists. It has been proven that treadmill systems and robotics technology may improve locomotor (movement) skills and upper extremity function with repetitive motion therapy. These tools go beyond traditional therapy to push the body toward more potential movement and improved exercise.

**Potential Treatments for Depression**

For many people who are adjusting to life with a spinal cord injury, depression can be a struggle. Conventional treatments may be a solution to overcome episodes of depression; this includes talk therapy, psychotherapy, and pharmaceuticals (use of medications), to name a few. If depression continues, it may be diagnosed as a major depressive disorder, one of the most prevalent and serious illnesses in the U.S. If conventional treatments are not successful, the disorder may then be classified as ‘treatment resistant depression’. Recently, a method called transcranial magnetic stimulation (TMS) has become an important tool for clinical treatment. The outpatient procedure is non-invasive and painless as a therapy using short pulses to activate of brain cells (neurons) in the area of the brain associated with depression. There is typically a series of treatments for which some people will feel a mild scalp discomfort. The treatments have minimal side effects. It is not known to affect memory or concentration, plus the treatment may be used in conjunction with antidepressants.

An additional neurotechnology therapy has been approved by the FDA for treatment resistant depression. Called Vagus Nerve Stimulation (VNS) Therapy, this is an implanted device. Unlike the TMS procedures, VNS is a long term treatment for a chronic illness; it is not a temporary solution. The device consists of a pacemaker like pulse generator and a nerve stimulation electrode. This involves a
surgical procedure to implant the device. Once it is operational, it delivers intermittent stimulation to the left vagus nerve, that is in the neck area. VNS is an involved therapy but has been proven to improve quality of life for those using it.

Additional variations of non-invasive treatments include tDCS (Transcranial Direct Current Stimulation) and rTMS (repetitive Transcranial Magnetic Stimulation). More invasive and targeted treatments, including deep brain stimulation (treatment for tremors related to Parkinson’s Disease) are currently being investigation as a therapy for treatment resistant depression. Before pursuing any non-conventional treatment method, a trained neuropsychologist or psychiatrist should be consulted.

**Research Applications for the Future**

*Stimulating the Muscles & Going Wireless*

Functional Electrical Stimulation (FES) systems, explained above, typically involve wires and electrodes. Some are applied to the surface of the skin and connected to a control device while others are implanted systems. The control device activates the electrodes which stimulates or contracts a muscle. The advancement of implanted systems is related to the new electrode technology. One development is fully implantable electrodes that are surgically placed around the peripheral nerve of a targeted muscle group. These electrodes stimulated the muscle without damaging the nerve. New electrodes are being tested by the Cleveland FES Center in human clinical trials for various applications such as urinary function, hand and grasp function and standing. More information is available at [http://www.aptcenter.research.va.gov](http://www.aptcenter.research.va.gov) and [http://www.FEScenter.org](http://www.FEScenter.org). Another development in electrode technology is being developed by researchers at the Alfred E. Mann Foundation called the BION®. This tiny capsule is an implantable, programmable, battery-powered, stimulator that may be injected near a nerve to cause a muscle to contract. It also contains sensors and a transceiver that coordinate with a pocket-sized computerized controller. A few limited versions of this device are currently in clinical trials; it is not yet available to the public.
**The Human Touch**
Investigations into the loss or decrease of sensation due to SCI has received less emphasis as the field of functional movement has gained prominence. However, scientists at Purdue University and Neurometrix have given priority to sensory function. About the size of a cardiac pacemaker, the Andara™ Oscillating Field Stimulator (OFS™) System has been developed to be implanted within 18 days following a spinal cord injury. This tiny device delivers an oscillating, low-voltage, direct current of electricity to the areas above and below a spinal cord injury to stimulate nerve fibers to grow across the site of the injury. Initial clinical studies have been completed and further research for development toward FDA review is underway.

**Stimulation of the Spine**
Translating current technology to spinal cord injury has been a theme of some researchers to restore lower extremity movement. Spinal cord stimulation has been applied and is commercially available to treat chronic pain and spasticity. Most recently, the technique has been under research consideration as one component of a ‘rehabilitation cocktail’ consisting of activity-base therapy, epidural stimulation and drug treatment to restore lower extremity movement. This is still in very early human trials and still developing in the laboratory.

**Tapping into the Brain**
Brain Computer Interfaces (BCI) are a type of neurotechnology in development in several laboratories around the nation in the hopes of restoring communication and mobility to those with neurologic disease, high level injuries, or limb loss. Electrodes that are implanted in or placed over the motor cortex of the brain act as sensors that record neural activity of the user. The idea is that if a user simply thinks about movement, the brain signals generated can be sensed and translated by a BCI, and in turn used to control an external device, such as a computer cursor, robotic arm, or wheelchair. The potential of such research may be the ability to provide stable, flexible and natural control over assistive devices using brain activity.

**Merging Brain Power and Electrical Stimulation**
A different approach is to use both the power of brain signals and electrical stimulation of the muscles to improve gait in people with spinal cord injury. This is an application of spinal reflex training currently under investigation at Helen Hayes Hospital. In this study, surface electrodes are placed on the skin over leg muscles for monitoring muscle activity and over a nerve to produce reflex responses. After spinal cord injury, reflex functions often change. Because reflexes play an important part in movement, when reflexes are not working well, movements may be disturbed. Researchers have found that people can learn to increase or decrease a reflex response by means of training. Learning to change a reflex response may become an effective approach as a rehabilitation treatment. The goal of the current study is to investigate whether spinal reflex training can reduce spastic gait problems.

This is a brief overview of some of the developing neurotechnologies used in the treatment of spinal cord injury. There are several research centers around the country and throughout the world working in this field. To find out about specific devices, therapies and treatments being tested in clinical trials, see Part 2 of this Fact Sheet.

**Summary and Disclaimer**
This Fact Sheet is an overview and explanation of the applications of neurotechnology for several different conditions related to spinal cord injury. Devices are commercially available that are used for pain management, spasticity control, breathing assistance and bladder function. There are also many new technologies being investigated in research centers. These are tools that can be used to combat secondary conditions, foster or encourage further independence and/or potentially improve quality of life. These technologies are not a one-size-fits-all and not everyone is appropriate for a particular technology.
Prior to considering any new therapy, treatment or device, a proper evaluation must be conducted with a knowledgeable medical professional. There are health, medical and financial risks. Out of pocket costs and available insurance coverage for any treatment must be considered prior to starting a protocol. Finally, this is an evolving field of science and technology development. The frequent changes that are occurring in this new field will be referenced and kept current in the resources listed in Part 2.

Neurotech Network, The National Spinal Cord Injury Association and its representatives do not rate, endorse, recommend or prescribe any products, procedures or services. This fact sheet is for informational purposes only.

**Suggested Reading**

- Clinical trials.gov, search terms with spinal cord injury and any of the following: electrical stimulation, neuromuscular stimulation, spinal cord stimulation, exercise, urinary, sexual function, walking, hand function, cough, respiratory.
- IFESS Consumer Information: [http://www.ifess.org/Services/ConsumerEd.htm](http://www.ifess.org/Services/ConsumerEd.htm)
- Spinal Cord Injury Information Network for FES

**Glossary of Terms**

**Biomedical engineering.** The application of engineering principles to biology and medicine.

**Contraction.** The shortening of muscle fibers due to activation of a muscle by voluntary or external means.

**Diaphragm.** A dome-shaped muscle that separates the chest and abdominal cavities. It aids breathing by its upward and downward movements.

**Electrotherapy.** The clinical practice of applying electricity to the body to achieve a therapeutic result. This would include FES applications such as muscle strengthening, wound healing, contracture prevention and improving circulation.

**Exoskeleton suits.** A garment-type device used as an external supportive-covering over the body.

**Extension.** A movement that increases the angle between two adjoining bones of the skeletal system.

**External system.** A medical device system that is applied to the outside of the body such as the surface of the skin.

**Hybrid system.** A system that has both implanted and external components. See also, External system and Implanted system.

**Implanted system.** A medical device system which is surgically placed in the body.

**Intrathecal.** An injection into the spinal canal (intrathecal space surrounding the spinal cord) of a drug or other therapy, such as applications include anaesthesia, chemotherapy and pain management.
Movement enhancement devices. Devices used to aid in the reconditioning of weak muscles with applied movements.

Neuromodulation. A technology that acts directly upon nerves to alter or modulate nerve activity by delivering electrical or drug related agents to a targeted area of the body.

Neural Prosthesis. A device which acts to replace or improve function of a missing or impaired part of the body.

NeuroRehabilitation. The use of a nerve-related system applied to the body to provide healing or natural restoration of a missing or impaired body function.

NeuroSensing and Diagnostics. The use of a neural system to monitor or view the activity in the nervous system.

Neurotechnology. The application of medical electronics and engineering to the human nervous system.

Orthotic. A device used to support or brace a weak or disabled joint or muscle.

Oscillating. To move or travel back and forth between two points.

Protocol. A detailed plan of a scientific or medical experiment, treatment, or procedure.

Repetitive Motion Therapy. Treatment that includes assisted and voluntary motion of a limb

Robotics. Devices that automatically perform repetitive tasks used in neurorehabilitation.

Stimulation. A physical application that arouses or activates the function of sensory and/or motor nerves.

Transcutaneous stimulation. Stimulation to the surface of the skin over a muscle, peripheral nerve or skin nerve senses that is achieved by use of electrodes that are held to the skin by adhesive, tape, bandaging or tight-fitting garments.

Ventilator. A device for maintaining artificial respiration.

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informational purposes only. Further, it is not intended to cover all programs, treatments, or research in the field nor is it an endorsement of any aspect of its content. Any information that you may have to further update this Factsheet would be greatly appreciated. The National Spinal Cord Injury Association Resource Center (NSCIRC) provides information and referral on any subject related to spinal cord injury. Contact the NSCIRC at help@spinalcordcentral.org or toll free at 1-800-962-9629 (ET). July 2008
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