DISEASES AND CONDITIONS

Neuromodulation can be applied to an astonishingly broad array of disorders, ranging from migraine headaches to incontinence and from Parkinson disease to severe psychiatric disorders. However, the largest therapeutic groups treated with neuromodulation devices and systems include the following.

Pain
More than just a passing headache or the discomfort from your weekend household project, chronic pain is debilitating, not only reducing or eliminating a patient's ability to work, but affecting every aspect of life and relationships. Millions of patients suffer, but too few receive effective treatment.

According to the American Chronic Pain Association, pain is the most common reason for patients to access the health care system. The costs of treatment for chronic pain run into the billions of dollars for health care alone, not including the costs of disability or lost workplace productivity.

Neuromodulation techniques—including spinal cord stimulation, deep brain stimulation, peripheral nerve stimulation and intrathecal drug delivery—have been used in this patient population with great success. In many cases, neuromodulation can provide pain relief even after other treatment methods, including back surgery, have failed.

Psychological Disorders: Depression
In any given one-year period, the National Institute of Mental Health (NIMH) estimates that 18.8 million U.S. adults suffer from depression. While most cases of depression can be resolved with oral antidepressant medication and/or therapy, certain severe cases require more significant interventions. Deep brain stimulation and vagal nerve stimulation have been found to improve severe depression.

Neurologic Disorders: Epilepsy
When a person has two or more seizures—brief disturbances of electrical activity in the brain—they are diagnosed with epilepsy. More than three million Americans are treated for this disorder, and an Epilepsy Foundation report estimates that epilepsy contributes to more than $16 billion in annual health care costs.

Deep brain stimulation and vagal nerve stimulation have been found to provide relief of symptoms and enable the patient to live a more normal life.

Urologic Disorders: Overactive Bladder, Incontinence
One in every six Americans suffers from overactive bladder. The sudden urge to void or the inability to make it to the restroom in time occurs when there is a breakdown of the complex interplay between nerve and muscle function in the bladder.

Sacral nerve stimulation helps to restore nerve function, reducing or eliminating the discomfort and embarrassment caused by frequent urges and incontinence.

Hearing Disorders: Profound Deafness
Nearly 100,000 people worldwide have received cochlear implants. Designed to bypass damaged portions of the ear and directly stimulate the auditory nerve, an implant enables the brain to interpret these signals as sound. Different from normal hearing, cochlear implants nonetheless allow many people to recognize enough sounds to hold a conversation or recognize warning signals.

Diseases and Conditions Addressed by Neuromodulation

Cardiac Disorders: Arrhythmia
Nearly two million people have cardiac rhythm disorders that require a neuromodulation implant such as an artificial pacemaker. A pacemaker is a small, battery-powered device that is permanently implanted into the body, near the collarbone. The device delivers electrical impulses to the heart via leads attached directly to the heart's chambers, delivering electrical stimuli to make the heart beat in a more normal rhythm.

In addition, tens of thousands of people require an implantable defibrillator device for life threatening tachycardia.

Movement Disorders: Parkinson Disease, Dystonia
Movement disorders affect nearly a million people, encompassing everything from Parkinson disease to spasticity caused by a variety of disorders, including multiple sclerosis (MS). Therapies like deep brain stimulation, intrathecal balcofen and spinal cord stimulation can target specific nerve centers to reduce tremor, spasticity and improve function.

Angina Pain
According to the American Heart Association, 1.3 million Americans suffer from chronic persistent angina, with another 75,000 new cases of treatment-resistant angina occurring each year. Spinal cord stimulation is widely used within Europe for the treatment of ischemia-related angina pain. Further evidence is required by the Food and Drug Administration (FDA) for spinal cord stimulation to be approved in the U.S.

THERAPIES IN DEVELOPMENT

Gastrointestinal Applications
One of the newest applications of neuromodulation is treatment of obesity. There are currently several approaches under development, including vagus nerve stimulation, vagus nerve block, gastric stimulation and sympathetic nerve stimulation. Neurotech Reports projects that sales of obesity stimulation devices will grow from $81 million in 2008 to $210 million in 2010.

Blindness
Neuromodulation devices are also under development that may restore vision to individuals who were blinded by diseases such as macular degeneration or retinitis pigmentosa. Multiple companies are developing prosthetic devices that stimulate the retina. Second Sight Medical Products (Sylmar, CA) is developing Argus II, a device that consists of a tiny camera and transmitter mounted in eyeglasses, an implanted receiver, and an electrode-studded array that is secured to the retina with a microtack the width of a human hair. A belt-mounted wireless microprocessor and battery pack power the entire device. The camera on the glasses captures an image and sends the information to the video processor, which converts the image to an electronic signal and sends it to the transmitter on the glasses. The implanted receiver wirelessly receives this data and sends the signals through a tiny cable to the electrode array, stimulating electrical pulses that induce responses in the retina that travel through the optic nerve to the brain. The brain then perceives patterns of light and dark spots corresponding to the electrodes stimulated. Patients learn to interpret the visual patterns produced into meaningful images.

Intelligent Medical Implants (IMI) in Zug, Switzerland, through its acquired subsidiary IIP Technologies GmbH in Bonn, Germany, is on a fast track to develop a retinal implant that partially restores vision in people made blind by retinitis pigmentosa. IMI's Learning Retinal Implant System has three main components: a flexible foil implant with an infrared wireless receiver and stimulating electrodes that sits on top of the retina; eyeglasses with a digital camera and an infrared wireless transmitter; and a digital signal processor (DSP) that converts image data from the camera into a stream of data for transmission to the implant. The DSP and glasses are connected by a cable, which serves as the conduit for both the raw and processed image data. The infrared transmitter in the glasses sends the processed digital data through the eye to the implant, and also delivers the energy needed to activate the electrodes.

Tinnitus

The market for treating tinnitus, a complex auditory condition often associated with ringing in the ears, may represent one of the newest applications of neuromodulation. About 50 million Americans are believed to suffer from some form of the condition, and about 12 million of these are characterized as severe enough to require medical treatment. Currently, there is no single treatment regimen that has proven successful, perhaps owing to the multiplicity of possible causes—noise-induced hearing loss, ototoxic medications, sinus infection, etc.—and the differing degrees of disability.

Traumatic Brain Injury

There is a great potential for using deep brain stimulation as a treatment for traumatic brain injury. Traumatic brain injury can be categorized by the degree of motor and cognitive functional loss. This functional loss can range from a simple concussion with a full functional recovery to a persistent vegetative state, where functional recovery is very rare. Experts estimate that from 100,000 to 300,000 patients with traumatic brain injury are now diagnosed as in a minimally conscious state. Under the current standard of care, most do not receive active rehabilitation and are cared for in long-term nursing facilities.

In 2007, there was a well publicized procedure involving a patient in a minimally conscious state and investigators at three U.S. institutions. The original concept for the DBS procedure was developed at Weill Cornell by Nicholas Schiff. The operation was performed at the Cleveland Clinic by neurosurgeon Ali Rezai. The patient was a 38-year-old severely brain-injured man who had been unable to communicate or eat by mouth for six years. After a six-month, double-blinded on/off “crossover” trial, with periods of thalamic DBS alternating with periods where he did not receive the therapy, the patient now has oral feeding and verbal communication abilities. This first DBS procedure is part of an FDA-approved pilot study that will include 12 patients in post-traumatic minimally conscious state.

Direct Current Stimulation

Recent studies have re-awakened interest in transcranial direct current stimulation (tDCS) as a potential treatment of neurological disorders. Low-level DC current applied to the human skull has been shown previously to improve brain function in humans.

Anodal polarization of the motor cortex increases the amplitude of motor evoked potentials generated with transcranial magnetic stimulation. Similarly tDCS over the visual cortex increases the amplitude of visual evoked potentials and reduces the threshold for TMS-evoked visual sensation, and tDCS over the parietal cortex increases tactile sensitivity. Two recent studies suggest that in addition to effects on motor function and sensory perception, direct current stimulation may also facilitate cognitive function and ameliorate the symptoms of depression.

Motor Impairment

Currently the subject of a pilot clinical trial, the BrainGate Neural Interface System is designed to restore functionality for severely motor-impaired individuals. A sensor is implanted on the motor cortex of the brain, and the interpreted signals are transmitted directly to a computer, enabling the user to control various objects in their environment, such as lights and television, or possibly a BrainGate-compatible motorized wheelchair. It Is hoped that one day the BrainGate program will expand to allow individuals to once again use their limbs.