NEUROMODULATION THERAPIES

The term "neuromodulation" encompasses a broad array of treatments, both electrical and chemical, targeting a variety of locations in the body to best achieve the desired outcome. Some of the more frequently used techniques are described in detail below.

ELECTRICAL STIMULATION THERAPIES

Brain and Spinal Cord Therapies

Many therapies target the brain and spinal cord, the root of the nervous system, to deliver relief to patients. Brain and spinal cord neuromodulation therapies that are currently in use as well as in development today, include the following.

Figure 1: Spinal Cord Stimulator (Provided by Medtronic, Minneapolis, MI)

Spinal Cord Stimulation

Electrodes in the back are connected to an implantable pulse generator to transmit electrical impulses to the spinal cord. These electrical impulses interfere with the nerve impulses responsible for pain. Spinal cord stimulation is used for severe, chronic neuropathic back and leg pain, ischemia related pain (angina and critical limb ischemia) and visceral pain.

Deep Brain Stimulation (DBS)

A small device, similar to a pacemaker, is surgically implanted to deliver electrical stimulation to targeted areas of the brain. This procedure is used to treat a variety of disabling neurological symptoms, including pain, tremors and movement disorders that can be associated with Parkinson disease, as well as pain, depression, tourettes syndrome, stroke recovery, hypertension, addiction disorders and epilepsy. DBS can also be applied to treatment for severe intractable depression and obsessive-compulsive disorder.

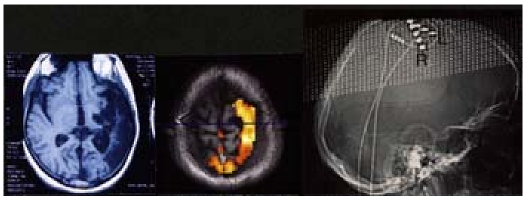

Figure 2:Cortical Stimulation for Stroke Rehabilitation (Provided by Sergio Canvero, et al.)

Cortical Stimulation

Viewed as a potential alternative to Deep Brain Stimulation, cortical stimulation is being used to treat pain, and is under investigation to treat stroke, movement disorders and depression. The pace of activities and promising clinical results bode well for the future of this therapy.

Cerebral Cortex Stimulation (Motor Cortex Stimulation)

Stimulation of the cerebral cortex has been shown to relieve neuropathic pain. The cerebral cortex is the area of the brain responsible for many complex functions such as memory, language and consciousness. Motor cortex stimulation stimulates the part of the brain that controls movement and is used to treat drug-resistant neuralgia pain such as pain after a stroke.

Figure 3: Sacral Nerve Stimulation (Provided by Advanced Neuromodulation Systems, Plano, TX)

Sacral Nerve Stimulation (*also known as* ***Urologic Nerve Stimulation)***

A small electrode tip is placed near the sacral nerve—the nerve that controls voiding function—in the lower spine. An implanted device stimulates the nerve to act as a sort of pacemaker for the bladder, improving urinary function and reducing or eliminating pain.

Neuromodulation Treatments – Current & Emerging

Peripheral Nerve Stimulation

Similar to the way that spinal cord stimulation and deep brain stimulation work on the spine and brain, peripheral nerve stimulation involves the implantation of a device along the peripheral nerves—limbs, for instance—to further target the delivery of electrical impulses. There are currently two types of peripheral nerve stimulation therapies in use today.

Figure 4 Bilateral Neurostimulator Implant, Lateral View (Provided by Louis Whitworth et al.)

Occipital Nerve Stimulation

A subcutaneous electrode is placed at the back of the skull stimulating the occipital nerves to relieve pain, migraines, cluster headaches and hemicrania (a type of headache).

Pudendal Nerve Stimulation

Pudendal nerve stimulation is an alternative method to sacral nerve stimulation to treat incontinence. Stimulating the pudendal nerve, which controls the pelvic floor muscle, can improve the function of the bladder and pelvic floor muscle groups. It can also be used as a treatment for urogenic, iliac crest and abdominal pain.

Cranial Nerve Stimulation

There are 12 pairs of cranial nerves controlling a host of motor and sensory function. The following two therapeutic applications for cranial nerve stimulation include the following.

Vagal/Vagus Nerve Stimulation

The vagus nerve is one of a dozen pairs of cranial nerves controlling motor and sensory functions of the viscera. Electrical stimulation of this nerve has been found to affect the connections within the brain that are prone to seizure activity, and has also shown a positive effect on mood in patients who have tried antidepressant medications without symptom relief.

Trigeminal Nerve Stimulation

One of 12 pairs of cranial nerves, stimulation of the trigeminal nerve has been shown to reduce seizure activity in epilepsy.

Functional Electrical Stimulation

Using implanted devices to generate electrical impulses to activate nerves and restore function in patients with paralysis from spinal cord injuries, stroke, head injury or other neurological disorders. These devices can also restore neural activity in cases of sensory damage, including cochlear implants for deafness and retinal stimulation for blindness caused by macular degeneration or retinitis pigmentosa. Some examples of these therapies include:

Retinal Stimulation

Devices are being developed to restore vision to patients blinded by retinitis pigmentosa or macular degeneration. These devices mount tiny cameras or receivers on a pair of glasses and process the images into electrical signals that are transmitted to electrode arrays implanted within the retina. The signals are travel to the brain through the optic nerve, enabling the patient to “see” patterns of light and darkness. With practice, these individuals can interpret these patterns into useful images that help them to navigate and identify their surroundings.

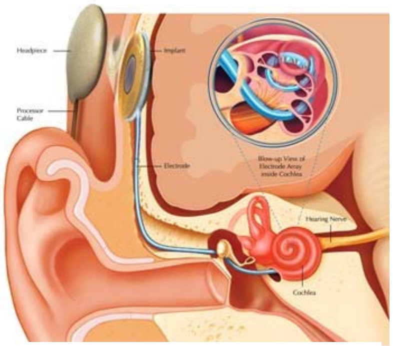

Figure 5: Cochlear Implant (Provided by Advanced Bionics, Sylmar, CA)

Cochlear Implant

A cochlear implant is a small electronic device that is implanted in the skull to restore hearing in a deaf individual by bypassing damaged portions of the ear and going directly to the auditory nerve. The device has a series of parts: an external microphone; a speech processor, which arranges the sounds that the microphone has picked up; a transmitter and receiver, which receive signals from the speech processor and convert them into electrical impulses; and an electrode array, which collects the impulses from the stimulator and transmits them to various locations along the auditory nerve. While it does not restore normal hearing, it provides a representation of sounds that enables the deaf person to hold conversations and function more normally. According to the Food and Drug Administration, more than 100,000 people worldwide have received cochlear implants.

Diaphragm (Phrenic) Pacing

The market for implanted diaphragm stimulation systems is experiencing steady developments, both in clinical and financial terms. Phrenic pacing provides ventilatory support for patients with chronic respiratory insufficiency whose diaphragm, lungs, and phrenic nerves have residual function. Typically, these patients have high spinal cord injuries, a paralyzed diaphragm, central sleep apnea or other central neurological disorders.

PHARMACOLOGICAL THERAPIES

Pharmacological therapies work by surgically implanting pumps that deliver pain medication directly to the target site, enabling lower dosages and mitigating the side effects that certain pain medications can cause. Some examples of pharmacological therapies include:

Intrathecal (Intraspinal) Drug Delivery

Pain medication is administered directly to the area around the spinal cord via a surgically placed pump and catheter. By directing medication directly to the site of pain, less medication is necessary, and with fewer side effects than are seen with orally administered drugs that require metabolization. New agents such as ziconotide have profound analgesic effects with fewer side effects, it can only be given by intrathecal drug delivery.

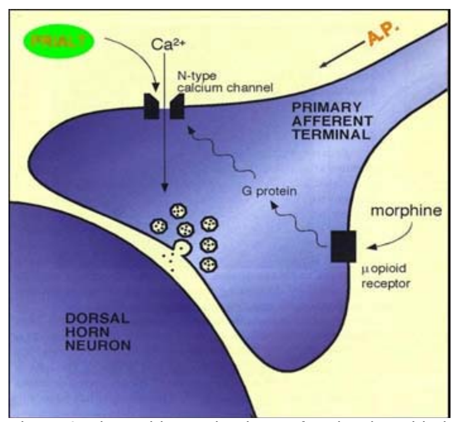

Figure 6: Ziconotide Mechanisms of Action (Provided by Elan Pharmaceuticals, Dublin, Ireland)

Intraventricular Drug Delivery

Intracisternal drug delivery is the delivery within the cerebrospinal fluid of the cistern (C1-2 vertebra) and intracranial ventricles of analgesic agents. As with intrathecal delivery, by directing medication directly to the site of pain, less medication is necessary, and with fewer side effects than are seen with orally administered drugs that require metabolization. This delivery system requires an implanted intracisternal or intraventricular catheter connected either to an implanted programmable or non-programmable pump or to an external pump. Intracisternal delivery and intraventricular delivery of analgesic agents are usually used for patients with head and neck pain, as in pain from tumors of the face and neck.