Review Article

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Brain Pacemaker

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Abstract

Brain implants, often referred to as neural implants, are technological devices that connect directly to a biological subject's brain - usually placed on the surface of the brain, or attached to the brain's cortex. "Brain pacemakers" are used to treat people who suffer from epilepsy, Parkinson's disease, major depression and other diseases. Pacemakers may also be implanted outside the brain, on or near the spinal cord (spinal cord stimulation), and around cranial nerves such as the vagus nerve (vagus nerve stimulation), and on or near peripheral nerves. The deep brain stimulation system consists of three components: the implanted pulse generator (IPG), the lead, and the extension. DBS leads are placed in the brain according to the type of symptoms to be addressed. Brain implants electrically stimulate, block or record signals from single neurons or groups of neurons networks in the brain. DBS reduces tremor, rigidity, bradykinesia, gait problems, dyskinesia, motor fluctuations, dystonia. The innovative technology may also come to the next generations that may replace the 1st generation Brain Pacemakers. There are very few cons for brain pacemakers that outweigh the potential benefits. In the short amount of time brain pacemakers have progressed so far. Given more time, brain pacemakers will be a really useful and a powerful technology.

Keywords: Brain pacemaker; Brain implants; Deep brain stimulation; Parkinson's disease; Alzheimer's disease.

Introduction

Neural-implants such as deep brain stimulation and Vagus nerve stimulation are increasingly becoming routine for patients with Parkinson's disease and clinical depression respectively, proving themselves as a boon for people with diseases which were previously regarded as incurable.

Brain implants, often referred to as neural implants, are technological devices that connect directly to a biological subject's brain - usually placed on the surface of the brain, or attached to the brain's cortex.[1] "Brain pacemakers" are used to treat people who suffer from epilepsy, Parkinson's disease, major depression and other diseases. The pacemaker is a medical device that is implanted into the brain to send electrical signals into the tissue. Depending on the area of the brain that is targeted, the treatment is called deep brain stimulation, or cortical stimulation. Brain stimulation may be used both in treatment and prevention. Pacemakers may also be implanted outside the brain, on or near the spinal cord (spinal cord stimulation), and around cranial nerves such as the vagus nerve (vagus nerve stimulation), and on or near peripheral nerves.[2]

Deep brain stimulation (DBS) was first used in the 1970s for the treatment of chronic pain.[3] A common purpose of modern brain implants is establishing a biomedical prosthesis circumventing areas in the brain that have become dysfunctional after a stroke or other head injuries, the sensory substitution, e.g., in vision, and even to record brain activity for scientific reasons. Some brain implants involve

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creating interfaces between neural systems and computer chips. This work is part of a wider research field called brain-computer interfaces.[1]

Components and Placement

The deep brain stimulation system consists of three components: the implanted pulse generator (IPG), the lead, and the extension. The IPG is a battery-powered neurostimulator encased in a titanium housing, which sends electrical pulses to the brain to interfere with neural activity at the target site. The lead (also called an electrode) is a thin (approximately 1.3 mm in diameter) coiled wire insulated in polyurethane with four platinum iridium electrodes which is inserted through a small opening in the skull and is placed in one of three areas of the brain.[3,4,5] The tip of the electrode is positioned within the targeted brain area. The lead is connected to the IPG by the extension, an insulated wire that runs from the head, down the side of the neck, behind the ear to the IPG, which is placed subcutaneously below the clavicle or in some cases, the abdomen.[4,5] The IPG can be calibrated by a neurologist, nurse or trained technician to optimize symptom suppression and control side effects.[3]

DBS leads are placed in the brain according to the type of symptoms to be addressed. All three components are surgically implanted inside the body. Lead and extension implantation may take place under local anesthesia or with the patient under general anesthesia ("asleep DBS"). A hole about 14 mm in diameter is drilled in the skull and the electrode is inserted. The installation of the IPG and lead occurs under general anesthesia. The right side of the brain is stimulated to address symptoms on the left side of the body and vice versa.[4]

Implantation of the DBS system is performed in 2 stages. During the first stage, the DBS lead is implanted stereotactically into the target nucleus. A combination of microelectrode recording (MER) and macroelectrode stimulation is used to refine the desired target physiologically. Magnetic resonance imaging (MRI) of the brain is performed immediately after the procedure to confirm proper electrode placement and to make sure that no hemorrhage has occurred. During the second stage, the DBS lead is connected subcutaneously to an implantable pulse generator (IPG), which is inserted into a pocket beneath the skin of the chest wall, like a pacemaker.[3]

Deep Brain Stimulation provides monopolar or bipolar electrical stimulation to the targeted brain area. Stimulation amplitude, frequency, and pulse width can be adjusted to control symptoms and eliminate adverse events. The patient can turn the stimulator on or off using an Access Review Therapy Controller or a handheld magnet. The usual stimulation parameters are an amplitude of 1-3 V, a frequency of 135-185 Hz, and a pulse width of 60-120 msec.[3]

Biochemistry

Brain implants electrically stimulate, block or record (or both record and stimulate simultaneously) signals from single neurons or groups of neurons (biological neural networks) in the brain. The blocking technique is called intra-abdominal vagal blocking. This can only be done where the functional associations of these neurons are approximately known. Because of the complexity of neural processing and the lack of access to action potential

Table 1: The following table summarizes the three different sites for DBS therapy

DBS Site	Effect of Therapy
Thalamus (Vim)	Reduces tremor but not the other symptoms of PD
Globus pallidus (Gpi)	Reduces tremor, rigidity, bradykinesia, gait problems, dyskinesia, motor fluctuations, dystonia
Subthalamic nucleus (STN)	Reduces tremor, rigidity, bradykinesia, gait problems, dyskinesia, motor fluctuations, dystonia.[6]

related signals using neuroimaging techniques, the application of brain implants has been seriously limited until recent advances in neurophysiology and computer processing power.[1]

It has been shown in thalamic slices from mice that DBS causes nearby astrocytes to release adenosine triphosphate (ATP), a precursor to adenosine (through a catabolic process). In turn, adenosine A1 receptor activation depresses excitatory transmission in the thalamus, thus causing an inhibitory effect that mimics ablation or "lesioning".[4]

Programming of the stimulator system is usually done on an outpatient basis, although in some DBS centers the system may be activated before discharge from the hospital. It may also be done in a rehabilitation center, where other therapies are being provided. Programming usually starts within a few weeks of the DBS surgery.[6]

Complications

Serious or permanent complications:

- Death is probably less than one percent.
- A 7.5% risk of stroke from bleeding in the brain during surgery.
- Hydrocephalus is a rare, but possible.

Temporary or reversible complications:

- Changes in mood, memory and thinking
- Seizures
- Infection
- Stroke
- Problems with movement and speech
- Stroke-like symptoms, such as weakness, numbness and slurred speech
- Worsening dyskinesia
- Headache, dizziness, tingling of the face or limbs, and an electrical jolting sensation

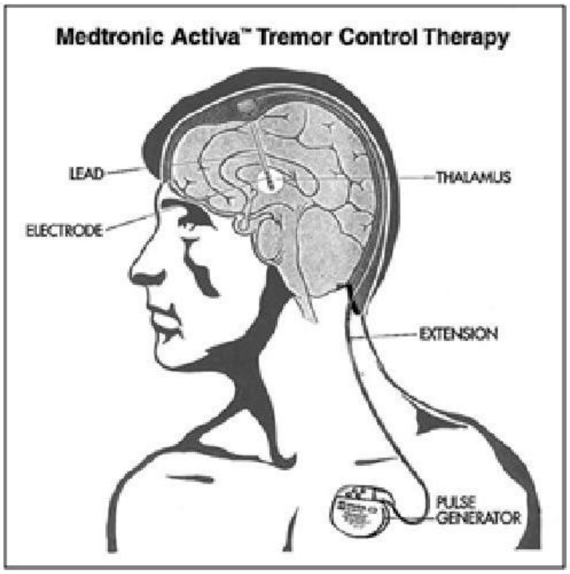
Malfunctioning DBS devices:

- Lead migration, in which the electrode has moved from the target site
- Fracture, disconnection or damage of the connecting wire
- Malfunction or injury to the neurostimulator, from direct physical contact
- Misplacement of the brain electrode.[6]

Education alerts and Warnings for the clients with brain pacemakers

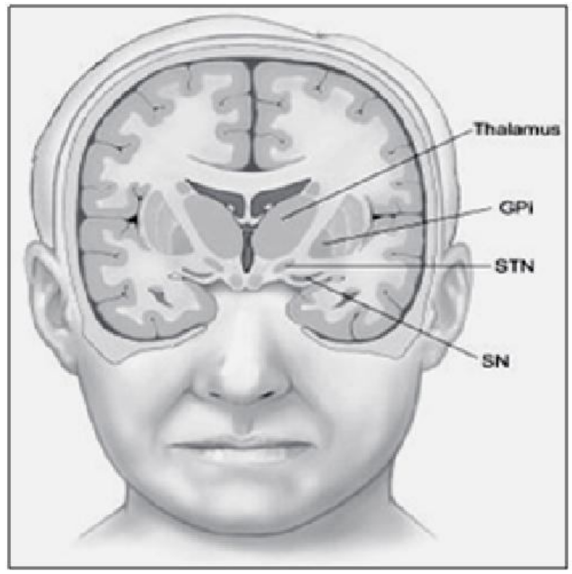
1. When entering stores with theft detection devices, walk in the middle of the door opening to minimize the likelihood of the DBS system being turned off.
2. Remove any unnecessary magnets in your home.
3. Stand away from the microwave when in use.
4. Avoid walking through metal detection devices if possible; ask security personnel to perform a manual body check at airports.
5. Carry a wallet-size medical card that describes the DBS system and warnings to show to security and store personnel.
6. Get a medical-alert bracelet that states that you have a DBS system and that you have a wallet card for special warnings and emergency contact phone numbers.
7. Do not allow any electrical or magnetic device to be placed near your neurostimulator, connecting wire or implant site on your scalp.
8. Carry your magnet or patient controller with you whenever possible.
9. Avoid hobbies or occupations that involve routine exposure to high voltage electrical and/or magnetic fields; in particular, avoid arc welding.[6]

Figure 1



Reference: Hauser RA. Deep Brain Stimulation for Parkinson Disease. Medscape reference: Drugs, diseases and procedures. 2012 Feb 1 [cited on 2013 Jul 24]. Available from URL: http://emedicine.medscape.com/article/1965354-overview#a1.

Figure 1



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Future inovative research on brain pacemakers

A thorough understanding of how the brain pacemaker works on brain cells and normalizes brain function is critical to the future success of this technology. Abnormal rhythmic brain cell firing are at the root of many movement disorders and other neurologic conditions. Therefore, a research is essential to know how therapeutic stimulation effects individual brain cells, and what improvements can be seen in patients with Brain Pacemakers.

The innovative technology may also come to the next generations that may replace the 1st generation Brain Pacemakers with leads, the generator and the electrodes which may have a small chip that can be directly implanted just beneath the brain cells where there is an essential stimulation or the

Figure 2

Unilateral DBS system with one IPG/neurostimulator	Bilateral DBS system with one IPG/neurostimulator	Bilateral DBS system with two IPG/neurostimulators

Reference: Lyons JM, Okun MS. Parkinson's disease: Guide to Deep Brain Stimulation Therapy. 2nd ed. USA, The National Parkinson Foundation Inc.– Medtronic; 2007. p 14,16.

depression of cells is required.

A second generation of Brain Pacemaker: a wireless and rechargeable system is the next technology a "smart" device, one that can sense abnormal brain firing and suppress abnormal activity only when required, in other words, work on demand that may benefit further for treating complex brain disorders.

The Brain Pacemaker has tremendous potential to treat many conditions result from disorganized brain firing, including dystonia, epilepsy, obsessive-compulsive disorder, refractory depression, chronic pain and perhaps even addiction, obesity and other eating disorders.

Further the innovation technology, which may protect the individuals with Brain pacemaker, through satellite tracked signals of impulses generated through the Medical Centers or Hospitals to control the exact frequency of Pulse generators required when the tremor attacks or malfunctions occur in the brain cells, may be developed.

Conclusion

The brain is a very complex organ, and it controls everything that the human body does. Therefore technology that can improve the health of the brain and allow those who have difficulty using their brain effectively due to medical conditions is extremely useful. Parkinson's, Alzheimer's and Depression are conditions that can cripple a person and burdena family emotionally and financially. There is tremendous promise for brain pacemakers because even though they're still in their earlier stages, they're already making a difference in people's lives. In the year 2050, the number of people with Alzheimer's is projected to triple and society needs an effective treatment for the condition. About a million people with Parkinson's disease have had brain pacemakers implanted and many of them are seeing the positive effects from the pacemaker such as fewer tremors, less spasms and overall more control of their body. Depression is such a subjective and relative condition that it is difficult to treat. Brain pacemakers can give a standardized treatment for the condition and increase self-esteem, and neural activity. Brain pacemakers scientifically have so much support at the current moment due to the recent success and the sound scientific thought process. There are very few cons for brain pacemakers that outweigh the potential benefits. In the short amount of time brain pacemakers have progressed so far. Drug therapies have been used for decades and have had limited and sporadic results that vary from person to person. Given more time, brain pacemakers will be a really useful and a powerful technology.

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