Deep Brain Stimulation - Advancements in Clinical Medicine, Innovation in Cutting-Edge Technology

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Introduction

Scientific innovation has been incredibly influential, leading to countless breakthroughs, especially in surgical technology. These discoveries have revolutionized access to quality patient care and adequate treatment. We have seen new creations and developments in Artificial Intelligence, leading to optimized support and management for triage, and efficient reviewing of electronic health records (EHR). However, a relatively new remedy called Deep Brain Stimulation has become more prominent in the treatment of several debilitating neurological symptoms. This procedure is most commonly used to treat diseases like Parkinsons, Essential Tremors, and Epilepsy (especially focal epilepsy which originates in the frontal, occipital, temporal, and parietal part of the brain). These diseases are characterized by tremors, rigidity, stiffness, and slowed movement (National Institute for Health, 2017). DBS is considered a plausible treatment option for movement disorders, and is generally performed when medications have become less effective and begin interfering with daily life activities (UI Hospitals).

Anatomy of Deep Brain Stimulation

DBS uses a surgically implanted, battery-operated medical device called the implantable pulse generator (IPG), which is placed deep into a central location in the brain. The IPG is similar to that of a heart pacemaker, and dimensions are approximately similar to that of a stopwatch. DBS is designed to deliver electrical stimulation to localized regions of the brain that control movement, which ultimately block or inhibit the nerve signals that cause the symptoms. DBS consists of three components: the lead, the extension and the IPG. The lead (commonly known as the electrode), is a thin, insulated wire that is inserted through a small opening in the skull and positioned in the brain. Next, we have the extension component, which is an insulated wire that is passed underneath the skin, and connects the lead to the IPG. Lastly, the IPG (our "battery pack") is the third and final part that is implanted under the skin near the collarbone. The length of the wire and the distance between the electrode will determine the ideal placement at which the IPG can be planted.

Mechanisms of DBS

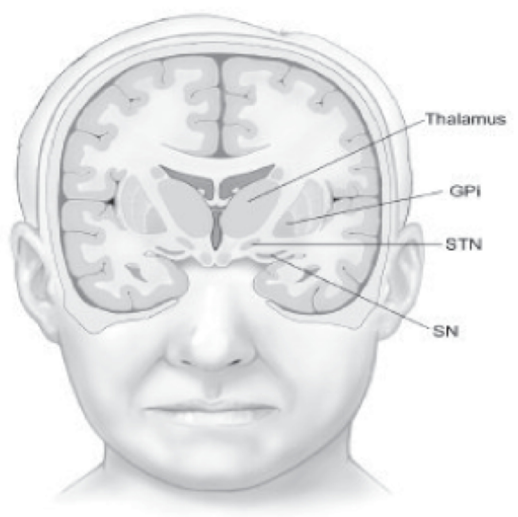
Implants have become widely accepted over the last few years and research has led to the development of several advanced designs and blueprints for them. All modern Implantable Pulse Generators (IPG) contain a radiofrequency antenna, which leads to increased usability, and enables clinicians to deploy external programming devices to monitor for impedence and for editing stored data. In 'closed-loop' or 'adaptive' DBS, the stimulator is able to measure neural activity while synchronously stimulating the target zone. These devices are increasingly taking the form of 'apps' on consumer-grade mobile devices such as smartphones and tablets. IPGs use proprietary radio communication protocols. More recently, sumer-grade mechanisms such as bluetooth are being utilized in order to facilitate over-the-air modifications and remote connections.

As for diagnoses, neurologists and other clinicians use powerful magnetic imaging to make a clear and concise decision regarding the exact target for surgical implantation within the brain. These regions include the subthalamic nucleus, the thalamus, and the globus pallidus. During the operation, surgeons are able to use microelectrode monitoring to improve the overall condition of the patient.

In most circumstances, DBS has been approved for a wide variety of conditions and has shown to be remarkably safe and effective (Cleveland Clinic, 2020). While symptoms may not be eliminated, they can be reduced to a tolerable amount. The results are widely dependent on the appropriate selection of patients, stimulation of the correct brain region, and precise positioning of the electrode during surgery, and evidence-based programming and medical management.

Functionality & Implementation

Parkinson's Disease is closely linked with a significant loss in functionality of dopaminergic cells within the substantia nigra pars compacta (SNc). These dopaminergic cells also project to the striatum - a major arc of the basal ganglia (American Association of Neurological Surgery). Dopaminergic regions primarily consist of motor, cognitive, and limbic loops. The SNc has connections to locations of the brain that control both motor and non-motor functions. Two important regions, the subthalamic nucleus (STN) and the globus pallidus internus (GPi) have proven to be powerful targets for managing abnormal electrical circuits. They alleviate the symptoms of bradykinesia, motor fluctuations, and dyskinesia (John Gardner, SagePub, 2013). Following activation, the lead and electricity it emits will work to normalize brain signals, resulting in a smoother response to medication. DBS has proven to be an exciting and effective tool for treating a large spectrum of conditions, but there is a good reason that the field is only beginning to recognize its full potential. Subsequently, use of a powerful technology for modulation purposes will inevitably lead to dire consequences and serious negative risk in the case of poor implementation.



Programming Adjustment

The programming of the stimulator system is usually performed in an outpatient setting, but in some circumstances, it may be activated before the patient's discharge from the treatment facility. Generally, there is an immediate improvement in some PD symptoms, however, some patients may take up to a week or a month to notice improvements. Patients may also be admitted to a rehabilitation center, allowing clinicians to closely evaluate and monitor their response to DBS and adjust medication as needed. The endless combinations and configurations of DBS make it difficult to find a setting which is best suited to the individual. Each DBS electrode has four leads within it, of which two are activated. The lifespan of the battery should last anywhere from two to five years. A DBS programmer should regularly check on the device to ensure that there is no loss of therapy efficacy.

Research Obligations & Ethical Validity

DBS faces several prominent concerns due to its widespread adoption and establishment. A complete investigation pointed to many complexities, which have acted as impediments to the continued progression of DBS. The successful translation and interpretation of research into clinical use is thwarted by obscurity in adopting suitable clinical trials. For most experiments, blinding is unachievable, as patients are actively awake during the stimulation. Nonetheless, performing well blinded trials is easier to achieve in comparison to traditional ablation surgeries, as neurostimulators can be activated and manipulated without the need for unnecessary surgery. Additionally, DBS is an expensive tool to use and maintain. DBS is game-changing and life-saving; however, it should only be used in extremely rare and heightened emergencies due to the non-trivial risks associated with surgery (University of Virginia Health, 2021). This expense is problematic in the real world, as very few people have the resources to afford the treatment and hardware, even if the treatment warrants consideration. Increased production of low-cost IPGs would be logical, although the lack of surgical centers and providers still create barriers.

Nowadays, DBS systems rely on stimulation parameters set forth by a neurophysiologist, clinician, or even the patient. The system will remain static until manually modified. The rollout of DBS has been limited due to a wide variety of challenges in optimizing each component of the feedback (John Gardner, SagePub, 2013). IPG designs have also improved in terms of their ability to network with other devices. This networking may occur between smartphones and tablets, leading to wider accessibility. Nonetheless, the inherent cybersecurity risk does increase with wirelessly communicating electronic devices. Attackers who could potentially gain access to the IPG could cause considerable harm to patients and their clinical state.

Potential Advancements for Treatment

Refinement of DBS gives way to changes in medical applications and furthers the spectrum of improved technology. In the future, technological advancements may allow the implantation of several electrodes in the brain. This can enable the treatment and diagnosis of multiple symptoms at once, or the synergistic treatment of one symptom via multiple apparatuses. Currently, a few IPGs are highly capable of stimulating up to two different frequencies simultaneously. However, newer devices may allow new stimulation protocols to be established for each parameter that involves electrode contact with the respective region (Cedars-Sinai Medical Center, 2016). It is important to remember that DBS does not restore one's previous quality of life; it will only allow one to achieve more independence in one's daily life.

Conclusion & Constraints

As we strengthen our perspective surrounding neurophysiological contraptions, we gain a stronger perspective on how we can successfully target multiple structures in the brain for electrical modulation via DBS. DBS has single-handedly drawn out curiosity in both scientists and the general public by offering a humanitarian and scientific perspective. The indicators for DBS will continue to expand to cover a wider range of disorders. The development of more effective paradigms such as closed-loop simulations will enhance refractory movement disorders, resulting in stronger microelectrode mapping. The increase in fundamental knowledge concerning human health and mechanisms of disease have made it easier to invest in biological advancements and innovation. The next few years of modernization will be crucial, and should spark an uptick of growth, leading to a scientific revolution of sorts.

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