A Historical Account of the Development of Deep Brain Stimulation:A Survey

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Abstract - *Deep brain stimulation has revolutionized the therapeutic management of treatment-resistant movement disorders and is now being used to treat a growing number of neurological and psychiatric conditions. This paper briefly describes how electrical stimulation, which has been used to modulate the nervous system since antiquity, became a fundamental tool of neurophysiologic investigation in the second half of the eighteenth century and was later used for therapeutic purposes in the early twentieth century. We take a quick look back at the history of deep brain stimulation, focusing on the last 200 years, which have witnessed remarkable advancements in the safety and efficacy of the procedure. Lastly, we discuss the impact of the future technological, methodological, and research improvements in deep brain stimulation.*

Key Words: Deep brain stimulation, Movement disorders, Psychiatric conditions, Neurophysiologic investigation, Electrical stimulation, Research improvements

1. INTRODUCTION

Deep brain stimulation (DBS) is a surgical procedure that involves inserting electrodes into particular regions of the brain. Electrical impulses are generated by these electrodes and are used to modulate abnormal brain activity. Additionally, electrical impulses can correct chemical imbalances in the brain, which can lead to a variety of ailments. A programmable generator is inserted under the skin in the upper chest and controls the stimulation of brain locations.

Deep brain stimulation (DBS) has emerged as a promising treatment option for a variety of illnesses over the last 20 years. For the most part, ablative methods have been supplanted by advances in technology and surgical techniques. The ventralis intermedius nucleus of the thalamus has been demonstrated to significantly enhance tremor control in patients with essential tremor and Parkinson's disease-related tremor. Patients with Parkinson's disease can dramatically alleviate their symptoms of bradykinesia, tremor, gait instability, and stiffness. As a result of these advancements, a reduction in medication may be helpful in lessening the debilitating effects of dyskinesias in these patients.

DBS of the globus pallidus internus has been demonstrated to be effective in treating primary dystonia.[1] Because of the efficacy of these operations, they are now being used to treat a variety of other severe illnesses, including neuropsychiatric disorders, intractable pain, epilepsy, camptocormia, headache, restless legs syndrome, and Alzheimer's disease. This review will look at how deep brain stimulation has progressed to its current state, where the research is headed, and the potential dangers that may arise along the road.

2. Early History

Electrical stimulation has been used to control the neural system and treat various neurological illnesses since ancient times[2] . In his treatise "Compositiones medicamentorum" (46 AD), Scribonius Largo, the Roman emperor Claudius' physician, advised applying electric rays (Torpedo torpedo and Torpedo nobiliana) to the cranial surface as a headache treatment. Until the eighteenth century, Electric fish were later used for the treatment of seizures, depression, and pain.[3][4]

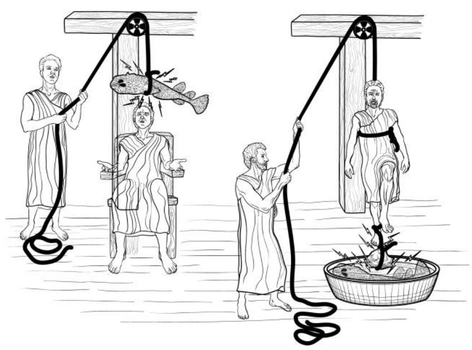

Fig -1: Artist's impression of the treatment of gout (left)and headache (right) using torpedo fish. (Adapted from Perdikis P. Transcutaneous nerve stimulation in the treatment of protracted ileus. South African J Surg 1977;17(2):81–6)

3. The 1800s

In 1804, Giovanni Aldini (1762–1834), a professor of Physics at the University of Bologna and nephew of animal electricity discoverer Luigi Galvani (1727–1798), performed electrical stimulations on the exposed human brain cortex of newly decapitated convicts. Cortical stimulation elicited awful facial grimaces, according to Aldini. This discovery led him to believe that the cortical surface could be electrically activated, implying that electricity may be used to treat a variety of neuropsychiatric illnesses.[5][6] Aldini's experiments and hypotheses led to the development of two strands of research in the nineteenth and twentieth centuries: on the one hand, the use of brain stimulation for neurophysiologic investigation (first on animals, then on humans) to understand the functioning of the brain, and on the other hand, the use of brain stimulation techniques for therapeutic purposes. Luigi Rolando (1773 – 1831) was the first to use galvanic current to spark the cortical cortex of creatures in 1809[7] , highlighting the brain area's functions.

Robert Bartholow (1831–1904), an American physician, was the first to disclose findings from experiments of electrical stimulation of the cerebral cortex in an awake human in 1874. Ezio Sciamanna (1850–1905), an Italian neuropsychiatrist, conducted a series of systematic electrical stimulation studies on a trepanned patient with a severe brain injury in 1882.

In 1883, the Italo-Argentine surgeon Alberto Alberti (1856–1913) undertook an 8-month trial of brain stimulation in a woman who, like Bartholow, had an eroding tumour of the skull that provided simple access to the dura mater surface. Unfortunately, these studies' contribution to defining the motor topography of the human brain has been underappreciated, with the exception of confirming the cortex's electrical excitability and demonstrating the contralateral cortical hemispheric representation of motor activities. Furthermore, British surgeon Victor Horsley (1857–1916) published more accurate and systematic findings on the geography of the brain in 1887.[8]

4. The 1900s

The discovery of electroencephalography (EEG) by German psychiatrist Hans Berger in 1929 was a watershed moment in medical history, introducing a new neurologic and psychiatric diagnostic tool. Volta discovered the battery after Galvani discovered "biological electricity" by accident (voltaic pile). Rolando was the first to use it to activate the brain surface. As a result, Fritsch, Hitzig, and Ferrier were able to create the concept of brain localization (Jackson, Gowers, Gotch, and Horsley). Although it was obvious that brain electrical stimulation causes a contralateral motor response, it was unclear if a spontaneous (intrinsic) brain electrical current could be measured. Caton was the first to describe the "current in the brain grey substances onto open brain" phenomenon. Berger produced the first EEG (electrocorticogram) recording on July 6, 1924, during a neurosurgical procedure on a 17-year-old boy done by neurosurgeon Nikolai Guleke, based on Caton's discoveries and those of Beck, Danilevsky, Prawdicz-Neminsky, and others. In 1929, he published a paper on the subject, using the terminology alpha and beta waves. The "spike and waves" (Spitzenwellen) were first described by an American group of EEG pioneers (H. and P. Davies, F. and E. Gibbs, Lenox and Jasper) shortly after, although Berger had seen them but dismissed them as artifacts. The development of electroencephalography, especially for patients with seizures, was a watershed moment in neuroscience and neurologic and neurosurgical practice.

The earliest modern example of therapeutic application of brain stimulation for the treatment of severe psychosis was electroshock, which was invented in 1938 by Ugo Cerletti (1877–1963).[9][10] An epileptic seizure was induced by applying an electric current to the skull, which "approximately" rebuilt the brain connections, resulting in clinical improvement for the patients.

In 1947, Ernst Spiegel and Henry Wycis created the first human stereotactic frame, modifying the original apparatus of Clarke and Horsley (1906) to determine Cartesian coordinates of structures around ventricles (basal ganglia) for identifying the precise localization of targets that had to be destroyed by radiofrequency[11][12] . Intra-operative electrical stimulation of these tissues was employed to explore and localize the deep brain nuclei, as well as to confirm target location[13][14] . These findings lead to the hypothesis that deep cerebral nuclei stimulation could be employed not just for diagnostic purposes, but also as a treatment. As a result, the progression from lesional to stimulating functional neurosurgery was established.[15]

Before brain stimulation of the human cortex could produce a truly realistic picture of human brain functions, including motor and somatosensory areas, the neurosurgeon Wilder Penfield (1891– 1976) published his fundamental studies in 1950.[16][17] After an initial experimental phase, the "gate control theory" published by Melzach and Wall in 1962 explained brain stimulation for pain management, which had been employed with good results as early as 1950 with temporary electrodes implanted into the brain areas.[18] Previous research laid the groundwork for the development of new neurostimulation techniques such as transcranial magnetic stimulation, cortical brain stimulation, and deep brain stimulation (DBS). The discovery of the effects of electrical stimulation of deep brain areas during stereotactic lesional functional neurosurgery to identify the correct position of coagulant electrodes for the treatment of dyskinetic disorders and tremors in Parkinson's disease led to the development of this technique.[4] Various studies have shown that while "low-frequency stimulation" (5–10 Hz) can improve tremor and other linked symptoms, "high-frequency stimulation" (50–100 Hz) can reduce symptoms.[19][20][21][22] Sem Jacobsen (1965), and

Cooper (1965) were DBS pioneers (1978). Deep electrical stimulation of brain areas was first developed as a treatment for behavioral disorders and chronic pain.

Based on his experience with deep neurophysiologic electrical stimulation in animals, the Spanish neuroscientist José M. Delgado first described the technique of implantation of intracranial electrodes in humans in 1952, indicating the importance of this method for diagnosis and its potential therapeutic role in patients with mental disorders.[21] Natalia Petrovna Bekthereva, a neuroscientist at the Institute of Experimental Medicine and the Academy of Medical Sciences in Leningrad, was the first to employ persistent depth stimulation as a treatment for motor problems. She published a paper in 1963 on the treatment of hyperkinetic diseases with numerous electrodes implanted in sub-cortical areas[22] . Her papers, however, were not generally known around the world because they were written in Russian. She used "electric stimulation with high-rate pulses of suprathreshold current" in her "therapeutic electro-stimulation," as she called it, and had outstanding results[22].

Dr. Jose Manuel Rodriquez Delgado of Spain demonstrated the capacity to control bulls' violent behavior with a brain implant in 1965. Carl Wilhelm Sem-Jacobsen, a Norwegian neurophysiologist and psychiatrist, was the first to employ depth electrodes implanted in patients with epilepsy and psychiatric illnesses for recording and stimulation. In order to find the optimal lesional site in Parkinson's disease, he successfully implanted numerous electrodes in the thalamus to stimulate the targets. These electrodes were frequently left in the patient's brain for months at a time, with no adverse effects. "These electrodes might then be utilized to generate gradual staged lesions in the target area, following stimulation responses," he said. [23][24][25]

Dr. Delgado used electrodes to implant in 25 people, the majority of whom were schizophrenics or epileptics. In the book 'Physical Control of the Mind: Toward a Psychocivilized Society', published in 1969, he outlined his brain stimulation research and explored crucial elements and ethical implications, demonstrating both the immense prospects and the great risks posed by neurotechnology. [21]

The American neurosurgeon Irving S. Cooper has more extensive and continuous experience inserting electrodes over the cerebellum and into the deep thalamic nuclei for central palsy, spasticity, and epilepsy. He published his good results from persistent cerebellar stimulation in more than 200 patients in 1977.[26]

In 1982, Howard J. Leonhardt's commercialization company, H.J. Leonhardt & Co., established Leonhardt Ventures. Dr. Robert O. Becker published the seminal book 'The Body Electric' three years later.

Dr. Race Kao and Dr. George Magovern, members of the Leonhardt research team, completed the first cases of large animal organ restoration with stem cells, which were published in The Physiologist in 1989. In Sunrise, Florida, Leonhardt founds World Medical Manufacturing Corporation to develop and market cardiovascular organ monitoring, regeneration, and recovery devices. Working with Dr. Ivan Casagrande at Labcor in Brazil, the Leonhardt team creates the first percutaneous heart valve. In 1997, the invention was patented. Both the Benabid and Blond and Sigfried groups published their findings on thalamic DBSs for tremors in 1991.[27][28]

Levin, Michael, Ph.D. published Current and potential applications of bioelectromagnetics in medicine in 1993, laying the groundwork for modern bioelectric regeneration research. He goes on to publish over 50 papers on the subject.

Leonhardt leads a team in Australia in 1995 that completes the first non-surgical repair of an aortic aneurysm in a clinical setting with Dr. Ken Thomson and Dr. Peter Field. Dr. Doris Taylor, a member of the Leonhardt research team, published a report in Nature Medicine on myoblast cell healing in an animal heart. Dr. Shinichi Kanno, a member of the Leonhardt research team, publishes the first publication on bioelectric limb regeneration via regulated production of proteins like VEGF in CIRCULATION, the Journal of the American Heart Association.

5. The 2000s

In the year 2000, Howard Leonhardt began filing a series of patents for organ regeneration based on bioelectric stem cell homing, proliferation and differentiation control, controlled protein expressions, and in some cases, repeat deliveries of stem cells, growth factors, nutrient hydrogel, and other organ regeneration-promoting patents. In the following year, with Dr. Patrick Serruys, Leonhardt leads a team that completes the primary non-surgical somatic cell restoration of a person's heart within the Netherlands. Working with 33 sites in the United States and 6 centers in the United Kingdom, the team completed, published, and presented Pilot, Phase I, Phase II, and Phase II/III study data.

84 percent of patients who were treated improved or did not deteriorate. Only 16% of those who were given treatment declined. In the same research, 69 percent of control or placebo individuals had impaired cardiac function.

In 2007, Howard Leonhardt and renowned bioelectric regeneration researcher Dr. Jorge Genovese, previously of the University of Utah, teamed together as co-inventors and filed a slew of patent claims for bioelectric-based organ regeneration and recovery. Since 2011, the Leonhardt team has led somatic cell and bioelectric limb salvage trials with partners within the Czech Republic, Switzerland, Germany, and Mexico, involving 70 patients with positive outcomes. Sixty-six of the 70 individuals treated had their legs rescued from amputations.

6. CONCLUSIONS

Since DBS was first introduced about 20 years ago, there has been a huge spike in interest in the neurosurgical procedure for the treatment of a variety of neurological and psychiatric diseases. The reversible aspect of the stimulation technique is appealing, and clinical disorders that were previously thought to be surgically tractable are now considered candidates for DBS therapy.

DBS has shown to be effective in the treatment of refractory Parkinson's disease, but promising findings are still awaited for other motor diseases (primary tremor, dyskinesias, medically resistant Tourette's syndrome). Major psychiatric diseases (refractory depression, obsessive-compulsive disorder), cluster headache, epilepsy, eating disorders (obesity), and drug-resistant hypertension are among the emerging areas where DBS appears to have promising therapeutic potential.

In the case of the "psychiatric" indications (refractory depression and obsessive-compulsive disorder), the evidence of organic alterations underlying these events provides a sufficient explanation for the fact that rebalancing specific neurophysiologic substrates via DBS can improve these behavioral disorders, harmonizing the physical and psychological expressions of these subjects.

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