Introduction to Neurological Surgery

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Abstract
For neurosurgery, which is a close-knitted community of professionals that share limited resources to students, surgeries such as deep brain stimulation, laminectomies, craniotomies, and lumbar disk replacements are difficult to learn and understand. In this paper, I have compiled my research that I obtained through interviews with professionals practicing neurosurgery and medical articles regarding the difficult concepts about these medical procedures.

Introduction
Many high school students and young adults exhibit an interest in medicine, surgery more specifically, but are unable to understand the medical articles that use complex medical terms and definitions. My goal with this paper is to make complex neurological surgeries understandable to those with no background knowledge on medicine and to aid my final product that I will produce in my second semester in the Independent Study and Mentorship (ISM) Program. Along with this, I also aim to explore a variety of surgeries that are both uncommon and common and how these surgeries are applied to a variety of conditions and diseases.

Methodology
While my research mainly relied on secondary sources such as PubMed articles that are accessible online, I also interviewed various medical professionals that practice neurosurgery and did fellowship to specialize in the surgeries that I researched. These individuals were neurosurgeons and physician assistants that offered their time to me, and many of these professionals specialized in the spinal aspect of neurosurgery.

Deep Brain Stimulation on Parkinson's Disease

Parkinson's Disease
Although deep brain stimulation (DBS) is currently being researched on how to control symptoms of depression and anxiety in patients, its most associated disease is Parkinson's Disease (PD). PD is defined as a neurodegenerative disorder that is characterized by symptoms that affect both the motor and non-motor abilities of the patient, which includes stiffness, slowness, tremors, dyskinesias, depression, anxiety, sleep disorders, incontinence, low blood pressure, and memory problems (Rao). And, while PD is thoroughly researched, there are no known cures and there are only temporary treatments to alleviate any debilitating symptoms.

Overview
Deep brain stimulation is an invasive surgery in which small electrodes are implanted 10 centimeters into the brain through small holes made in the skull, and the deep brain stimulator consists of: an intracranial lead, lead extensions in the neck, and a pulse generator that allows the stimulator to be programmed according to the patient's severity of symptoms (Rao). The small electrodes are then programmed by a neurologist to send electrical impulses that will control irregular impulses that cause diseases such as PD and essential tremors. The reason PD occurs also is related to

insufficient dopamine, "a neurotransmitter produced in the brain", levels (Pietrangelo). The electrical impulses the stimulators send also control those chemical levels that cause neurodegenerative diseases. Although DBS has shown promising results in the time it has been used in the medical world, dating back to 1987, there are many drawbacks when considering DBS as a viable option.

Problems Associated with DBS

Just like many other stimulating treatments, there are many risks of DBS that prevent an effective treatment:

- Immunity
- Short Battery Life
- Lack of Long-term Research
- Postoperative Health Complications

Solutions

There are many solutions to the problems posed previously. In recent research, closed-loop DBS, which is constant stimulation at one set of parameters that is responsive to patient physiology and alters cortical electrophysiology, addresses these complications (Ko). Information is constantly being taken from the stimulators, and although it requires the assistance of healthcare professionals, it prevents the development of immunity to the stimulation due to it being changed according to the response of the patient to the stimulation. Due to being constantly monitored, the short battery life is addressed and closed-loop stimulation is a stimulation that does not need to reduce the battery life of the electrodes. In addition to the short battery life, the development of health complications such as gait instability, dysarthria, and paresthesias also pose a threat to the patient (Ko). With a closed-loop stimulator, the risks of these developments becoming permanent is decreased as the patient is closely monitored to ensure that the stimulation is reducing their symptoms of PD. This research is relatively new, the research referenced being a study done in 2018, so with future more extensive research, DBS can become a more permanent solution to the alleviating of PD symptoms and further improve the patients' qualities of life.

Standard DBS

While the common image of surgery is the operation on a patient under general anesthesia, DBS is known to be safer while the patient is more awake. While the patient is awake, they can perform voluntary actions while the electrodes are being implanted and programmed to help their motor abilities. Being able to see the improvement in symptoms as the surgery progresses avoids the risks of failed surgery, and the neurologists and neurosurgeons can work together with the patient to produce the best results. Non-motor symptoms are more difficult to improve immediately upon surgery, so those symptoms need to be observed over a longer period of time.

Asleep DBS

DBS performed while the patient suffering from PD is conscious is called asleep DBS. With this method of surgery, general anesthesia is used to ensure that the patient will not awaken during surgery, but contrary to the common assumption that asleep DBS is safer than standard DBS, there are no large discremities being researched between standard DBS and asleep DBS. Asleep DBS has two common methods, which includes "intraoperative CT (iCT) confirmation or intraoperative MRI guidance (iMRI)" which are high-image resolution scanning that is done of the brain that can monitor the progression of the surgery (Kochanski and Sepehr). Although asleep DBS is not as extensively researched or commonly practiced as standard DBS, there are possibilities that it can reduce the risk of postoperative neuropsychological of the procedure and lessen complications from surgery.

Future Research

DBS is relevant in the medical community's discussions of future methods to treating PD symptoms, so while it has shown to yield improvements in the onset of PD symptoms, research still needs to be conducted to further address the issues of the short battery life of the electrodes implanted unilaterally or bilaterally into the brain and the development of immunity to the stimulation, rendering DBS useless against PD symptoms. With further research of asleep DBS, surgeons may be able to address the negative developments in the health of the patient. In an interview with Dr. Nader Pouratian at UT Southwestern Medical Center in Dallas, he stated that the future of DBS research involves how the stimulation can affect anxiety and depression in an individual as they explore to what extent DBS can alter the chemical balances in the brain (Pouratian).

Laminectomy

Overview

A laminectomy is a surgical procedure in which a neurosurgeon removes a whole part of a vertebral bone, called the lamina, in order to prevent the development of certain health complications from tumors, pressure caused by a herniated disk, and more. In contrast to DBS, laminectomies are considered one of the more common surgeries in neurosurgery as the first surgery dates back to sometime in the nineteenth century and rising in popularity during the twentieth century ("The History of Spine Surgery"). The surgery is done on the spine or neck region and is commonly used to treat conditions that are accompanied by a numb sensation whilst the patient is under anesthesia. Due to the surgery dating back to many years and extensive research being done on this surgery because of its high occurrence, there are little drawbacks related to laminectomies aside from it being a major surgery and the possibility of postoperative complications such as the development of scar tissue or neural damage.

Conditions

As previously stated, laminectomies are normally the treatment sought out by people with developments of health complications in the spine such as the following:

- Tumors
    - Metastatic tumors can develop in the spine when the patient has a malignant type of cancer in other parts of the body, such as the brain and lungs (Caldwell).
- Synovial Cysts
    - This is a type of benign fluid-filled sac that unnaturally develops in the spine. Synovial cysts may develop alongside other spine complications such as past traumatic accidents that cause disk problems. The reason why these cysts form are still not heavily researched (Caldwell).
- Herniated Disk
    - Condition in which the soft portion of a spinal disk becomes unaligned and protrudes out of the harder exterior, from a previous injury.
- Sciatica
    - When a herniated disk occurs, this can cause a sensation of numbness in the neck, or more commonly the lower back, which can cause pain and pressure on the nerves.
- Spinal Stenosis
    - An age-related condition in which "degenerative changes lead to the enlargement of the facet joints," causing pressure on the nerves and spinal cord (Health). It is also characterized by the narrowing of the opening where the spinal cord and spinal nerves pass through the spine caused by degeneration. This may develop in all parts of the spine.

Cervical Laminectomy

This specific type of laminectomy targets the back of the neck to relieve discomfort of the nerves through the removal of part of the bone. The surgery is most common in treating lumbar spinal stenosis. A few inches deep vertical incision is made in the neck to expose the site of surgery, which then allows the surgeon to remove the paraspinal muscles to remove the vertebra (Health). For laminectomies that involve the removal of a large portion of the spine, it is common practice to perform spinal fusion in order to join together two vertebrae.

Lumbar Laminectomy

A lumbar laminectomy surgery is one that targets the lumbar region of the spine, the lower back. Sciatica is most commonly found in the lower back, making it common for this surgery to be performed on patients suffering from a herniated disk or other disk complications. The surgery begins with an incision being made in the lower back a few inches deep and in length, followed by the erector spinae, the right and back muscles, being dissected off the lamina, with the surgery being concluded by the removal of the lamina (Health).

Craniotomy

Overview

A craniotomy is a surgical procedure in which part of the cranium, the skull, is removed temporarily in order to do a procedure on the brain. Previously mentioned, DBS is a procedure that requires a craniotomy to occur before the electrodes would be implanted into the brain. Although craniotomies are used for a wide variety of procedures, the use of craniotomies for removing brain tumors is one of them.

Malignant Brain Tumors

Tumors that require removal through surgery are malignant, in other words, are harmful for the health of the person. Tumors have many origins, some being hereditary while others being due to external factors such as high exposure to infectious diseases or ionizing radiation. These tumors can develop in individuals of all ages, and while some may be treated through radiation therapy, others require surgeries involving craniotomies. Brain tumors affect the patient's cognitive function and quality of life by impairing them from performing simple activities by causing balance problems, dizziness, and other symptoms. A primary brain tumor can also cause the development of metastases, which are secondary tumors that form at a distance from the primary tumor. Brain tumors may cause more visible signs and symptoms such as seizures, headaches, and confusion.

Procedure

In the surgery, a part of the skull is temporarily removed in order to access the part of the brain in which the tumor is located. Surgery varies depending on the size and shape (sometimes symmetric and asymmetric) of the tumor. In many cases, the tumor may not be removed as a whole and will be dissected or emulsified in order to avoid damage to the surrounding area of the tumor. And, in other cases, the tumor may not be entirely removed in order to protect arteries or vital parts of the brain. There is no standard way to perform a brain tumor removal, as there are many different situations that call for the use of a different method. After the tumor is removed either completely or partially, the area is soaked in papaverine using gelfoam, which is a sterilized type of sponge used in surgery, in order "protect the vessels and relieve their vasospasm," which is the contraction of the blood vessels that can cause the arteries to narrow (Cohen-Gadol).

Future Research

Cancer currently has no cure, but with the combination of different therapies and treatments, the survival rate of the patient can be significantly increased as well as the probability of recurrence of the development of brain tumors. Brain tumors have a low probability of survival, affecting "24,530 adults (13,840 men and 10,690 women) in the United States" each year, with an estimated 36% of those adults living for at least 5 years after their diagnosis ("Brain Tumor: Statistics").

Lumbar Disk Replacement

Overview
Lumbar disk replacement is a type of artificial disk replacement surgery where a neurosurgeon removes a disk of the lumbar region of the spine and replaces it with an artificial disk. There are numerous reasons as to why this would be necessary for the improved health of the patient, but the most common would be age-related: the degeneration of the disk causing lower back pain. Another common cause is the development of pain post a traumatic accident to the spine.

Degeneration
Degeneration of the lumbar spine region most commonly affects adults ranging from the ages 30 years old to 60 years old, but there are rare cases of this affecting younger groups of individuals. As well as age-related, an individual who lives a sedentary lifestyle is also at risk of developing lower back pain and seeking surgery.

Procedure
After the removal of the disc, the two surrounding vertebrae of the disk are further separated so that the surgeon is able to take measurements of what the artificial disk's size and height should be to release as much pressure on the spine as possible. The artificial disk is then inserted in the place of where the disk was removed and is fixed into place through plates, screws, or rods, depending on what approach the surgeon takes.

Lumbar Spinal Fusion
Lumbar spinal fusion surgery is an alternative to lumbar disk replacement, as they both treat lower back pain in the lumbar region of the spine. A lumbar spinal fusion surgery is one in which two vertebrae are fused together to create one unit. This fortifies the support in the spine to stop the pain but can lead to limited mobility, affecting the quality of life of the patient. In the surgery, the lamina is removed and the facet joints are trimmed to allow the surgery to be done, followed by the insertion of a "type of implant, called a cage" with a bone graft inserted into the cage to cause the growth of bone in that area (Health). The insertion of the implant along with the fixture of rods and screws to provide additional support alleviate any pressure that was previously put onto the spine due to degeneration or a previous traumatic accident to the spine.

Postoperation
As with other major surgeries, lumbar disk replacement may pose a health risk to the patient's current condition. The artificial disk implanted into the spine could possibly shift slightly, break off into pieces (this occurrence has very few cases reported), and an unsuccessful surgery can worsen the onset of symptoms such as discomfort and pain (Zigler). Along with the risks of the developments after surgery, the recovery period for lumbar disk replacement is taking pain medications and physical therapy, as well as a limited range of motion during the recovery period of a few months.

Conclusion

Neurosurgery is a small community of people compared to the other fields of medicine. Due to the limited number of people having expertise in neurosurgery, future research is open to endless possibilities as more advanced technologies develop in order to increase the likelihood of success of these complex and major surgeries. For DBS, for instance, more research is needed to limit the drawbacks such as a short battery life or the development of immunity to the stimulation, as well as what conditions this kind of stimulation therapy can improve upon.

References

"Brain Tumor: Statistics." *Cancer.Net*, Sept. 2021, https://www.cancer.net/cancer-types/brain-tumor/statistics

Christie Caldwell in discussion with the author, November 2021

Cohen-Gadol, Aaron. "Posterior Dominant Insular Tumor: Transsylvian Approach." *The Neurosurgical Atlas*, 28 October 2019.

Estefan, Martin. "Laminectomy." *StatPearls [Internet].*, U.S. National Library of Medicine, 31 July 2021, https://www.ncbi.nlm.nih.gov/books/NBK542274/.

Health, Veritas. "Cervical Laminectomy Surgery Video." *Spine*, Spine-Health, https://www.spine-health.com/video/cervical-laminectomy-surgery-video.

Health, Veritas. "Lumbar Laminectomy Surgery Video." *Spine*, Spine-Health, https://www.spine-health.com/video/lumbar-laminectomy-surgery-video.

Health, Veritas. "Posterior Lumbar Interbody Fusion (PLIF) Video." *Spine*, Spine-Health, https://www.spine-health.com/video/posterior-lumbar-interbody-fusion-plif-video.

"The History of Spine Surgery." *Spine INA*, 21 July 2021, https://spineina.com/blog/the-history-of-spine-surgery/.

Ko, Andrew. "Closed-Loop Deep Brain Stimulation for Essential Tremors - Andrew L. Ko, MD." *YouTube*, uploaded by Seattle Science Foundation, 25 April 2018, https://www.youtube.com/watch?v=6HTmQ7xVY8I.

Kochanski, Ryan B, and Sepehr Sani. "Awake versus Asleep Deep Brain Stimulation

Surgery: Technical Considerations and Critical Review of the Literature." *Brain sciences* vol. 8,1 17. 19 Jan. 2018, doi:10.3390/brainsci8010017

Nader Pouratian in discussion with the author, October 2021

"Overview Of Lumbar Disc Replacement Surgery With The M6-L." *YouTube*, uploaded by ENANDE GmbH, 25 April 2018, https://www.youtube.com/watch?v=p_P2KDG_TTU

Pietrangelo, Ann. "Dopamine Effects on the Body, plus Drug and Hormone Interactions." *Healthline*, Healthline Media, 5 Nov. 2019, https://www.healthline.com/health/dopamine-effects#drugs-dopamine.

Rao, Abigail. "Deep Brain Stimulation For Parkinson's Disease." *YouTube*, uploaded by Norton Healthcare, 25 May 2021, https://www.youtube.com/watch?v=hSaQ566_o-Y.

Zigler, Jack. "Lumbar Artificial Disc Surgery Recovery." *Spine*, Spine-Health, 26 Jan. 2018, https://www.spine-health.com/treatment/artificial-disc-replacement/lumbar-artificial-disc-surgery-recovery.