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NEURAL BYPASS TECHNOLOGY ALLOWS FOR VICTIMS OF PARALYSIS TO REGAIN INDEPENDENCE

Nadine Humphrey (nrh23@pitt.edu)

INTRODUCTION

Paralysis is a result of various diseases and trauma, one of which is stroke, which, per the CDC, occurs in over eight hundred thousand people annually in the United States alone. This long-term disability robs patients of their autonomy to different degrees, but it also inconveniences families and companies, whose employees can no longer work.

However, through a relatively new technology called the neural bypass system, patients would be able to have the signals from the brain navigated to circumvent the damaged neurons and regain control over their limbs. Just recently, a man was provided the chance to regain control of his hand after he received a spinal cord injury that left him paralyzed from the neck down.

Scientists have been working on this problem for decades, trying to regenerate the neurons themselves, but have faced serious challenges in further degradation in nervous tissue. This technology would allow scientists to not have to deal with this severely inhibiting challenge.

I believe this new technology to be a great potential contribution to augmenting the way we think about mediating disabilities. As tentative as this new step is, it has a significant impact in changing the economic implications of obtaining these injuries and lower the impact that it has on the patient’s life. While there are few opinions on this topic, because of how recent the development is, both engineers and scientists alike are excited for the future implications of this technology.

PREVALENCE OF SPINAL CORD INJURIES ON CITIZENS IN THE UNITED STATES

A 2016 report from the National Spinal Cord Injury Statistical Center states that, in the United States alone, there are approximately 17,000 new spinal cord injury (SCI) cases each year, not including those who die at the scene of the accident. Of these cases, only about 0.4 percent emerge completely healed after hospitalization. Most cases result in incomplete tetraplegia, followed by incomplete paraplegia, and complete tetraplegia and paraplegia [1]. These statistics do not include the paralysis induced in patients caused by stroke. Statistics show that 90% of stroke victims suffer some degree of paralysis.

Zawn Villines, a journalist and advocate for spinal injury victims, explained the difference between the two in an article that provides a succinct description of these SCI complications. She describes tetraplegia as a type of SCI that occurs above the first thoracic vertebrae and results in the patient no longer has control over any of the limbs below the neck. Some cases are so severe that it inhibits the patient’s ability to breathe on his or her own. Paraplegia, she defines, is a SCI that occurs below the first thoracic spinal levels. This results in the patient having complete control over the arms, but varying degrees of immobility in the legs [2].

An incomplete form of either of these types of paralysis is is when the sensory neurons from the neck down function properly, but the brain is no longer able to send signals through its motor neurons to control the affected limbs. In a complete paralysis, neither the body’s sensory nor motor neurons can communicate with the brain, leaving the patient unfeeling and unmoving of their own free will.

While rehabilitation can substantially help people regain some degree of motion, it cannot reverse damage to the brain or spinal cord, some of which are permanent. Scientists have been trying to use organic methods to reverse the effects of nervous damage, there is slow headway because of the cascade of negative effects that would subsist even if new neurons were grown. By using implantable devices, engineers would be able to bypass these complications to engage with the peripheral muscles themselves, as opposed to trying to repair the damaged nerves.

IMPLANTABLE DEVICES: COULD THEY BE USED TO RETURN PATIENTS TO NORMAL FUNCTIONING?
Nadine Humphrey

The development of implantable devices was a crucial step in the creation of brain-machine interfaces. But even then, many advancements had to be made before scientists and engineers could even consider the possibility of applying this technology to addressing paralysis and other neurological disorders and trauma. An article from the International Neurology Journal compiles this history and an interesting perspective on how they are constructed.

A medical device is implantable if it is either partially or completely introduced into the human body with the intention to remain after a surgical or medical procedure. Over the past sixty years, implantable devices have advanced through discoveries and innovations in science and engineering, especially in microelectronic, biotechnology, and materials [3].

Implantable medical devices are nothing new. The first pacemaker implant was done in 1958. From there, things have only improved. However, there are still complications to address. As quoted from this paper, “The human body is a complex system operated by mechanical, chemical, and electrical mechanisms of numerous organs, tissues, and cells. Furthermore, the system has different shapes, sizes, placement, functionality, and reactions according to age, sex, and race” [3]. Because of the variety and complexity of the human body and how it reacts to outward invasions, engineers must find materials and procedures that are compatible with this new environment and the reactions that take place there.

Therefore, when an engineer designs an implantable medical device, they must overcome challenges such as biocompatibility, structural design, delivery system, power management, wireless communication, and other considerations, all of which require extensive research and pre-implant testing. Any ill-thought-out executions in any one of these categories can result in serious complications in patient health.

For the most part, this technology has been used in cardiac disorders, such as synthetic pacemakers. However, more recently, engineers and medical staff have worked together to develop this technology to work for different systems, specifically in the nervous system.

**Value to Society, Engineering, and Me**

The National Academy of Engineering (NAE) has decided that one of the great engineering challenges that engineers should be tackling is reverse-engineering the brain. Quoted from the summary provided by the NAE, the possibility that “Neurological disorders may someday be circumvented by technological innovations that allow wiring of new materials into our bodies to do the jobs of lost or damaged nerve cells” [4].

This technology has the potential to open the possibilities of more development in understanding the mechanisms of the brain, as well as how it codes information. Because of the prevalence of neurological damage caused by disease and trauma in not only the United States, but also around the world, understanding how to integrate one of the world’s most complex and mysterious operating systems into machinery that we already understand would allow us to implement treatments in a much more effective fashion.

It would also allow engineers to develop artificial intelligence with increased complexity, such as parallel processing and increased connectivity. This technology, when applied to neurological systems, would lead engineers to deeper insights about how and why the brain works and what happens when it fails [4]. As an engineer with a heavy interest in neuroscience and how we can interact with it, the possibility of using implantable devices to communicate between neurons is exciting.

**NEURAL BYPASS SYSTEM USED TO RESTORE LINK FROM BRAIN TO HAND**

Only relatively recently (in the past three decades) have the considerations of implantable devices been applied to the neurological disorders and trauma in humans. The brain-machine interface (also known as neuroprosthetics) is the latest attempt in remedying the lack of implantable devices to benefit patients with neurological injuries. There have been experiments have been performed on non-human primates with great success. By getting the primates to visualize the movements of the paralyzed limb, researchers could record the signals that the brain sends out to activate those muscles.

A study conducted in the past two years dealt with a 24-year-old male with quadriplegia from a cervical SCI sustained in a diving accident 4 years previously. He underwent implantation of a Utah microelectrode array (Blackrock Microsystems) in his left primary motor cortex [5].

An article from IEEE Spectrum gives a succinct description of how the neural bypass system works: the implanted medical device has an array of ninety-six electrodes that record the electrical activity when brain cells activate in a part of the patient’s motor cortex. This occurs when the patient visualizes hand movements. However, the overwhelming influx of activity, most of it noise that obscure the signals that carry out the hand motion.

It took some time for the machine-learning algorithms implemented into the implanted the device to decode neuronal activity and control activation through an electrical stimulation system. The patient had to attend almost fifty sessions to train the system to understand his
brain signals, filtering out the noise from the relevant data.

Once the system recognizes the signals and can connect these signals to a physical action, engineers could code the electrical impulses that need to be sent by the implanted device to the sleeve of electrodes on the patient’s forearm. This sleeve that the patient wears, composed of about 130 electrodes, transmits electrical signals recorded from the brain and stimulates the patient’s forearm muscles in precise patterns to get it to move as originally desired [6].

**Current Challenges with the Technology**

Currently this technology is limited to being used in the lab. To use the system, the patient need a physical connection to the computer to utilize the implantable device. However, one of the long-term goals of this technology is to build a system that is simple enough for people to operate at home, and maybe even on the go. Researchers want to develop a wireless connection from the device to the computer. As mentioned above, the sheer amount of data that neurons send and that the device picks up poses a problem. As Nick Annetta, one of the coauthors, observes, “About 1 gigabyte of data comes off Ian’s brain every three minutes” [6].

There are also some difficulties in keeping the implant functional over many years. As with most foreign implants in the body, whether it is an organ or a pacemaker or a device implanted in the brain, the body treats it as a foreign object. Which is to say, it tried to get rid of it as quickly as possible. In this case, the brain tries to “encapsulate” the electrodes, preventing it from recording signals from the neurons. As the article reports, “In the two years since Burkhard received his implant, some of the 96 electrodes have stopped transmitting data... But enough are still operating to keep the system functioning” [6].

If the electrodes keep “dying,” then the patients may need multiple surgeries, which costs lots of money and increases the chances of complications during surgery and with the brain’s interactions with the implant. However, the positive implications of this technology certainly has a serious impact on society, which will be discussed below.

**Value to Society, Engineering, and Me**

This example is a historical moment in science and technology. For the first time, a human with tetraplegia has regained voluntary, functional movement using intracortically recorded signals linked to neuromuscular stimulation in real-time. As the study claims, “This improvement in function is meaningful for reducing the burden of care in patients with SCI as most C5 and C6 [high tetraplegia] patients require assistance for activities of daily living, while C7–T1 level [low tetraplegia] patients can live more independently” [5].

This concrete proof that regaining mobility after paralysis is possible demonstrates what is possible in the future and can offer hope for movement restoration to people living with paralysis worldwide. There have also been findings that support the use of neuroprosthetics in stroke patients, though to what extent remains to be seen [7].

To engineers, this also doubles as a chance to monitor how neurons interact with each other and to replicate these systems in artificial intelligence systems. However, perhaps the most important implication of this technology would be how it would impact patient health and economic stability.

**TACKLING SPINAL CORD INJURIES IMPACTS HEALTHCARE COSTS AND THE ECONOMY**

Along with the leaps in research, there is also a health component in how this technology impacts society. When a person becomes paralyzed, their life expectancy drops significantly compared to a person without an SCI. Americans can expect to live for about an average of 90 years. However, with an SCI, that number can drop to about 60 or even 40, before they die. They are also more susceptible to disease, which is usually the cause of death. Nervous system diseases and musculoskeletal, and mental disorders are on the rise for causes of death in patients with SCI, and as engineers, we about the preservation of human life.

There are also the costs of lifetime care that incur from SCI. Even for the least amount of permanent damage caused by SCI, the lifetime cost can be over $1 million. Tetraplegia, the most common injury sustained, would cost a person just shy of $5 million over the course of their lifetime to care for them. Not to mention the time that must be put in by other family members.

The initial surgery that could grant a patient control over their body would cost around $100 thousand. Combined with (possibly) home rehabilitation, this implant would dramatically reduce the lifetime cost of living with paralysis. The economic benefits of this technology are also a promising aspect.

On average, 17 thousand people in United States are no longer able to work because of the tetraplegia resulting from their spinal injury per year [1]. That is 17 thousand jobs that are left vacant and 17 thousand more people who can no longer provide for themselves. With this technology, patients with SCI would be able to regain their independence, and eventually return to their lives, to college or the workforce. While they would (presumably) still receive disability checks and such, the cost of their
care would be lowered significantly, plus they would be able to go back to contributing to society.

**NEURAL BYPASS TECHNOLOGY IS KEY IN MEDICAL AND ENGINEERING TO UNDERSTANDING HOW TO REPLICATE NEURAL SIGNALS**

There are about 300 thousand people alive in the United States with spinal cord injuries. About half of these injuries result in tetraplegia. Without the use of their limbs, they have had to put their lives on hold. They are also at a greater risk for neurological and musculoskeletal disease.

The neural bypass system is a recent technology developed to grant those with paralysis a chance at independence. By recording neural activity and replicating them in electrode impulses directly to the paralyzed muscle, patients would be able to regain control of their limbs, allowing them to resume their lives.

This technology is important to medical staff and neural engineers, who can help patients regain independence while simultaneously gaining a better understanding for how the neurons in the brain communicate. This would be useful to apply to artificial intelligence, allowing for more complex connections and enabling them to carry out complex judgement decisions. Though how long it will take to reach these points in technological advancement will depend on the new generation of engineers.

**SOURCES**


**ADDITIONAL SOURCES**


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