Transcutaneous Electrical Stimulation after Spinal Cord Injury in Electrode Array

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Abstract

Spinal cord injuries affect hundreds of thousands of people worldwide. Other vertebrate species, such as rats, can be used in order to model the effects of various treatments on impaired or contused spinal cords.

Our client, Mr. Daniel Hellenbrand, has tasked our team with developing a spinal cord electrode array that fulfills these criteria for rats, while keeping in mind that much of the research and design will be transferred to human models in the future.

Within the scope of this project, our team tested the effectiveness and correlation between three main design elements prior to formulating an electrode array: frequency mode of stimulation, number of electrodes within the array, and the location at which the array will be placed on the spine.

Background and Motivation

Motivation: Spinal Cord Injuries plague about 54 people per one million in the United States [1], and an electrical stimulation has been shown to repair lesions on nerves from incomplete spinal cord injuries.

Figure 1: A standard "TENS unit," with hydrogel adhesive electrodes and a user interface

Common Types of SCS: Epidural implants and transcutaneous (TES) arrays are two methods currently on the market. Epidurals must be surgically implanted by medical professionals and are very targeted, while TES arrays are less targeted but are accessible out of clinic [2].

Design Criteria

- Involves **non-invasive, transcutaneous** electrode placement
- Averts costly and inconvenient surgeries
- Made to be testable on a rat model
- Enhances quality of life with significant positive results in motor function post-stimulation

Testing

Issue		Variable
Stimulation of Superficial Nerves	→	Frequency Mode (Tonic and High Burst)
Insufficient Electric Field Strength	→	Number of Electrodes (2 and 4)
Stimulating Wrong Region of Nerves	→	Location of Electrodes (Lumbar)

Testing Protocol

Constant current supply with voltage output collected on oscilloscope and LabView, stimulating using 1.25" diameter electrodes. Incisions were made directly above the spinal cord.

Phase 1: Meat - Determining initial trends, testing procedure, limiting extraneous noise

Phase 2: Post-Mortem Rat Testing - Verifying trends with superficial stimulation visualization, levels of current

Phase 3: Live Rat Testing* - Trends in physiological responses, spinal cord injury recovery

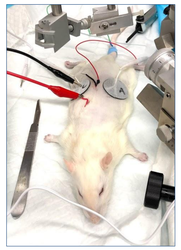


Figure 2. Post-Mortem Rat with Stimulation. A cathode and an anode were placed on either side of the spinal cord while two recording probes were used to measure the voltage generated at the lumbar portion of the spine.

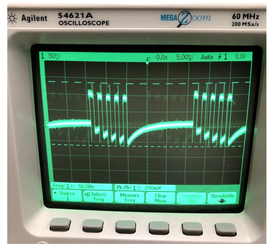
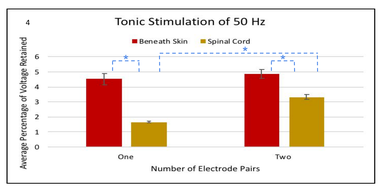
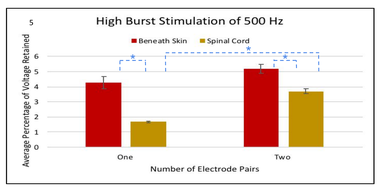


Figure 3. High Burst Stimulation, read from beneath skin in post mortem rat at 2mA

Results





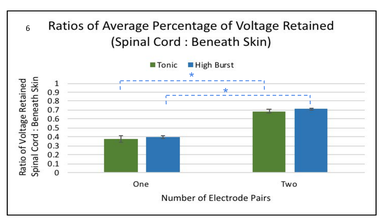


Figure 4. Comparison of Stimulation Between One and Two Electrode Pairs during Tonic Frequency Stimulation.
Figure 5. Comparison of Stimulation Between One and Two Electrode Pairs during High Burst Frequency Stimulation.
Figure 6. Comparison of Ratios of Stimulation at Spinal Cord Compared to That Beneath the Skin Across Various Modes of Frequency

Implications

Number of Electrodes:

- Increasing # of electrodes **increase the ratio of retained voltage at deep nerve, with relations to the skin**
- Increasing the # of electrodes allowed us to stimulate more efficiently **without increasing superficial stimulation**

Frequency Mode of Stimulation:

- Our results may be conclusive in that there is no difference
- We only used one frequency within each mode [3] [4]
- Different frequencies for each mode could lead to different results

Future work

Ideally, this project will continue with a greater focus on:

Focality of stimulation

- We saw significant superficial stimulation testing on the post mortem rat, i.e. muscle spasms and full limb movements
- Develop a mechanism to actively target deep nerves, reduce unwanted effects of surrounding stimulation and increase recovered voltage at the target location
- Continue testing different frequencies within our frequency modes
- Design a physical electrode array to optimize stimulation targeting

Live rat testing protocol and analysis of how the stimulation affects nerves and bodily functions as well as spinal cord injury recovery.

Motivating goal: a stimulation system used with physical therapy to help those with spinal cord injuries regain motor function and improve quality of life.

Acknowledgements

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References

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