Mohana Greeshma Gudhimalla
BMEN 3330
Final Project

PAIN RELIEF FOR BURN INJURIES USING A RADIO FREQUENCY DEVICE

INTRODUCTION

Experiencing intense pain following burn wounds is a common distressing problem that can significantly affect a person's quality of life. They have the highest incidence of prolonged discomfort and require a lengthier recovery period. Third-degree burns are very sensitive and painful and require a lot of medical attention than first- and second-degree burns. Therapies can cause pain that is equivalent to or worse than the pain of an initial burn injury.[1] As the level of pain increases, the healing process takes longer due to the patient's experience of constant discomfort and trauma. Medication is the main treatment of pain during skin healing and the tissue that has been burnt. The number of doses of the given medication vary depending on the wounds. Commonly used medications in controlling pain in a severely burned patient include Midazolam for anxiety, Propofol for sedation, Morphine for pain, Dilaudid for pain, Ketamine, Nitrous oxide.[2] In cases where severe burns have caused damage to multiple parts of the body, medication may not be effective. Burned patients may demonstrate variable or unpredictable responses to drugs, thereby requiring adjustments to dosing or complete exclusion of certain drugs (e.g., succinylcholine)[3]. Opioids are another method for treating pain which is inexpensive, widely available, and familiar to the majority of clinicians, but they may far exceed standard dosing recommendations; therefore, tolerance is a challenge throughout burn care.[4]

The damage to the skin is sensed by pain receptors. Each pain receptor trigger responses in neurons which are connected to other neurons in the spinal cord. When the pain receptor is activated, it sends an electrical signal up the nerve fiber. The nerve fiber is bundled with many others to form a peripheral nerve which carries electric signal to the spinal cord in the neck which is then passed to the brain.[5] Nociception is the process by which intense thermal, mechanical, or chemical stimuli are detected by a subpopulation of peripheral nerve fibers, called nociceptors.[6] The signals are then passed to the thalamus. This is a sorting station that relays the signals on to different parts of the brain. Signals are sent to the somatosensory cortex (responsible for physical sensation), the frontal cortex (in charge of thinking), and the limbic system (linked to emotions). The severe burn pain during the healing time lasts up to a period of 5-9 months, which can be considered as chronic. During this time period, the brain and the spinal cord may fail to dampen down the pain signals as the body gets used to the medication overtime

[1] Griggs, C., Goverman, J., Bittner, E. A., & Levi, B. (2017, April 18). *Sedation and pain management in burn patients*. Clinics in plastic surgery. Retrieved March 20, 2023, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5642992/.
[2] M., A. & D. (n.d.). *Pain management in burn patients*. Sacramento Personal Injury Lawyer - AutoAccident.com. Retrieved March 20, 2023, from https://www.autoaccident.com/pain-management-in-burn-patients.html.
[3] Griggs, C., Goverman, J., Bittner, E. A., & Levi, B. (2017, April 18). *Sedation and pain management in burn patients*. Clinics in plastic surgery. Retrieved March 20, 2023, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5642992/ .
[4] Griggs, C., Goverman, J., Bittner, E. A., & Levi, B. (2017, April 18). *Sedation and pain management in burn patients*. Clinics in plastic surgery. Retrieved March 20, 2023, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5642992/.
[5] myDr. (2018, June 24). *Pain and how you sense it*. MyDr.com.au. Retrieved March 20, 2023, from https://mydr.com.au/pain/pain-and-how-you-sense-it/.
[6] Basbaum, A. I., Bautista, D. M., Scherrer, G., & Julius, D. (2009, October 16). *Cellular and molecular mechanisms of pain*. Cell. Retrieved March 20, 2023, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2852643/.

for 9 months.[7] Examples of chronic pain in bodies include, arthritis, cancer pain, peripheral nerve pain tumors etc.

One of the aspects of treating the chronic pains mentioned above is radio frequency ablation (RFA) which is still being researched. Radiofrequency ablation is also called radiofrequency neurotomy, uses radio waves to create a current that heats a small area of nerve tissue. The heat destroys that area of the nerve, stopping it from sending pain signals to your brain.[8] The heat does not actively burn the area nor leave a scar and induce more pain. It only burns the pain receptors in the skin. Radiofrequency ablation employs electric current in the radiofrequency range (450 – 500 kHz) for chronic pain.[9] RFA is also used in dramatosurgical procedure that aims at the surgical management of benign and malignant skin conditions by using various forms of alternating current at ultra-high frequency (500-4000 kHz). This kind of frequency cuts through the skin to remove superficial lesions and vascular lesions.[10] Many have found radiofrequency nerve ablation to be 70-80% effective for those who have had successful nerve blocks. Patients will experience pain relief as soon as ten days after treatment, and it can last anywhere from 9 months to 2 years.[11] This is the same amount of time range that a severely burned patient might experience pain. The study of Radio frequencies in health care is still ongoing and its potential applications can be expanded and diversified across different domains.

PROBLEM STATEMENT

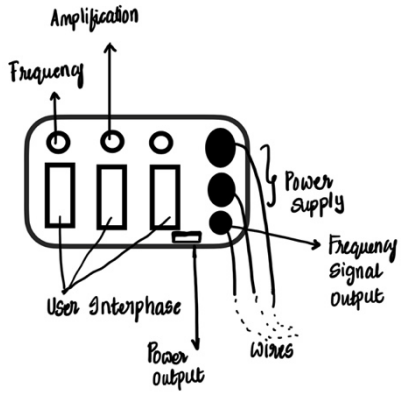
The purpose of this project is to alleviate discomfort caused by burn injuries in turn facilitating the healing process of the burnt skin. The approach will involve the application of radiofrequency technology that can be utilized to treat injuries throughout the body. Additionally, the device may incorporate blue and red-light therapy to promote skin regeneration and calming effect. This device will be referred to as Radio Frequency for Burn Injuries or RFBI.

DESIGN

The RFBI generator requires power supply and an oscillator which will allow us to set desired radio frequencies. The predicted frequency for this device to operate is between 300-500kHz. The control circuit supervises the functioning of the generator such as frequency, temperature, and power. The frequency with which the radio signals are transmitted determines

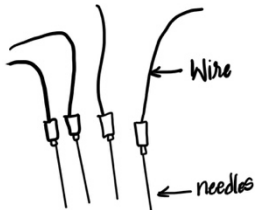
[7] myDr. (2018, June 24). *Pain and how you sense it*. MyDr.com.au. Retrieved March 20, 2023, from https://mydr.com.au/pain/pain-and-how-you-sense-it/.
[8] *Radiofrequency ablation (RFA): What it is & procedure*. Cleveland Clinic. (n.d.). Retrieved March 20, 2023, from https://my.clevelandclinic.org/health/treatments/17411-radiofrequency-ablation.
[9] Haemmerich, D., & Schutt, D. J. (2010, October 17). *RF ablation at low frequencies for targeted tumor heating: In vitro and computational modeling results*. IEEE transactions on bio-medical engineering. Retrieved March 20, 2023, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3108076/.
[10] Sachdeva, S., & Dogra, A. (2007). *Radiofrequency ablation in dermatology* . Indian Journal of Dermatology. Retrieved March 20, 2023, from https://www.e-ijd.org/article.asp?issn=0019-5154;year=2007;volume=52;issue=3;spage=134;epage=137;aulast=Sachdeva.
[11] *Is radiofrequency nerve ablation effective for lower back pain?* Boise Pain Center - Sandra Thompson, MD, MBA. (n.d.). Retrieved March 20, 2023, from https://thepaincenterinc.com/Blog/ArticleID/1039/Is-Radiofrequency-Nerve-Ablation-Effective-for-Lower-Back-Pain.

the signal strength.[12] The diagram below will help us understand how the interface for this device looks like:



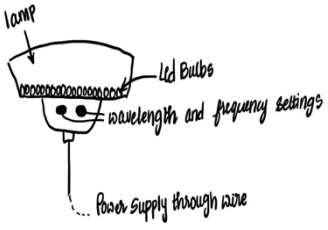
RFBI frequency generator 1

The wires of the RFBI device are connected to the generator on one end and the other end consists of thin and long needles that are penetrated into the peripheral nerve of the pain receptors. The amplified signal is applied when the needle is inside the body, and it is predicted to be targeting the pain receptors for the localized burn pains.



Needle and Wire for the RFBI device 1

The RFBI tool also consists of blue and red-led therapy that is used for calming the invasive needle method on a burn patient. Blue light therapy uses light to treat certain conditions on or just under the skin. It's considered a pain-free procedure and is most commonly used to treat sun damage and premalignant or malignant skin cancer growths. Blue led light therapy is also known to have anti-inflammatory properties which can help skin inflammation and have a calming effect on irritated skin.[13] The RFBI device below consists of a lamp like structure which has strong led bulbs in it and the wavelength and frequency can be changed depending on blue or red light. Blue light has a wavelength of (450-495nm) and Red light will have between (620-750nm)



Blue and Red-light therapy 1

[12] *Radio Frequency Remote Controls for mobile machines*. CrossCo. (2021, January 26). Retrieved March 20, 2023, from https://www.crossco.com/resources/articles/radio-frequency-remote-controls-for-mobile-machines/.
[13] Griggs, C., Goverman, J., Bittner, E. A., & Levi, B. (2017, April 18). *Sedation and pain management in burn patients*. Clinics in plastic surgery. Retrieved March 20, 2023, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5642992/.

At a molecular level, blue light is absorbed by flavins, porphyrins, nitrosated proteins, and opsins; inducing the generation of ROS, nitric oxide release, and the activation of G protein coupled signaling.[14] The red-light therapy also uses the same mechanism but is used for promoting healing of the skin and stimulating cellular activity and blood circulation. Red light is thought to work by producing a biochemical effect in cells that strengthens the mitochondria.[15] Once the radio frequencies are transmitted through the needle and the pain receptors are turned off, the blue-red light therapy can be administered as the following step.

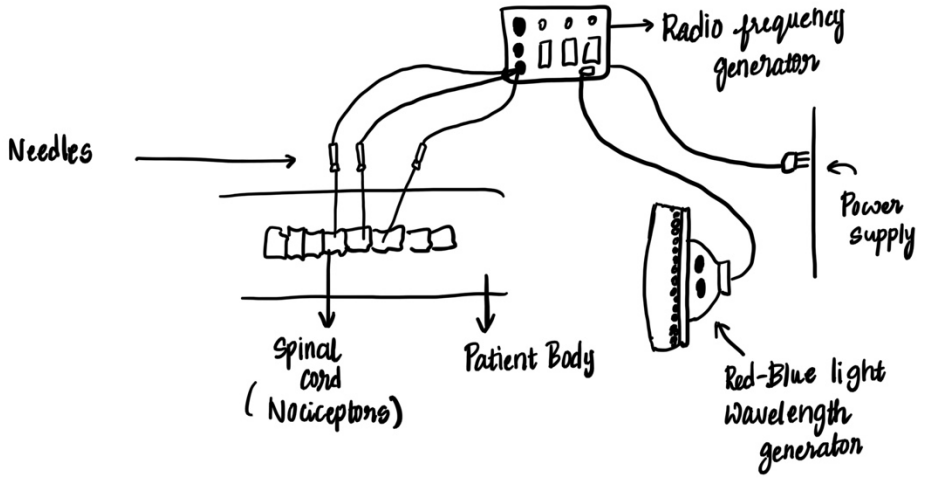


Figure: Radio Frequency for Burn Injury device.

The target area or the tissue that requires the treatment is identified and the insertion of the electrode is done using the imaging guidance in the RFBI device. And after placing the needles, the radio frequencies are generated. The frequencies will generate heat and destroy the targeted cells. This will disrupt the receptor cell's ability to function. The post procedural care is done using the blue and red-light therapy and supporting treatment for discomfort.

Advantages and Disadvantages

The implementation of this tool is less painful, and it is mildly invasive as the needle is penetrated inside the body. The system is very effective as it more targeted because it can reach deeper into the skin structures relatively quickly. The results for medication for pain relief usually wears off after a certain period of time according to the given medication life. On the

[14] Z.C, G., Hilbers, B., Riel NAW, van, & M, L. (2018). *Visible blue light therapy: Molecular mechanisms and therapeutic opportunities*. Current medicinal chemistry. Retrieved March 20, 2023, from https://pubmed.ncbi.nlm.nih.gov/28748760/.
[15] Cafasso, J. (2023, February 23). *Red light therapy: Uses, benefits, and risks*. Healthline. Retrieved March 20, 2023, from https://www.healthline.com/health/red-light-therapy.

other hand, RFBI is precited to provide results up to an average of 6 – 12 months[16] according to the usual results from radio frequency ablation technique.

While opioids delivered via oral and intravenous routes are the main treatment for burn pain, it is important to note that bodily changes have been documented for morphine, fentanyl and propofol throughout the hyperdynamic and hypermetabolic stages of burn recovery. Animal studies of burn injury have shown changes in spinal cord receptors including down regulation of opioid receptors, and upregulation of PKC-γ and N-methyl-D-aspartate (NMDA) receptors.[17] This suggests that the opioid medication provided during the healing process for pain might lead to addiction. That is why RFBI is a good alternative as it does not have any addictive properties.

Unfortunately, this tool has disadvantages as well. This tool was not used on humans for relieving pain that are related to burn injuries. In third and fourth degree burns that are all over the body, radio frequency might not work as it is localized. Immediately after the burns, the skin is still bleeding, RFBI cannot work on severely bleeding and sensitive skin. It can only be predicted to work when profuse bleeding stops. Radio frequency would have hard time working on certain location as the burn becomes more severe. Injecting sites can lead to infections, but the probability is very low.

Furthermore, in future, we can achieve mildly invasive, complete treatment for people who have severe third and fourth degree or non-localized degree burns. There will be an insulation technique which helps resistance from the minimal heat and soothes sensitivity of the skin.

ETHICS

Radio frequencies are always associated with fear most of the times because people fear it can disrupt hormones or induce any alterations in the cells other than the targeted ones, which is not true. Radio frequency procedures that exist have a minimum cost of 3000-5000$ with insurance which is usually covered. The cost of this procedure would be around similar comparing with medication pain relief as this procedure gives long term affects while medication should be given daily and the charge for medication is also high over a long period of time.

Environmentally, the procedure does not pose a threat. The RFBI procedure includes radio frequencies which are stigmatized to cause cancer. The radiation frequencies to treat this procedure is very low. The chances of carcinogens are still present, but it is very low, which is why many people would not want to adopt this procedure. Politically there is not much impact that can cause social change.

One of the most important things in this procedure that needs to get paid the most attention is the amount of frequency. It is very important to enter the right numbers and the right units (Hz, or kHz, Watt etc.) for frequency and power and have to make sure that the right amount of energy is delivered at that frequency. Severe health risks include damage such as

[16] Smith, K. (2020, December 1). *How long does RFA last?: Integrated Pain Consultants, Scottsdale*. Integrated Pain Consultants. Retrieved March 20, 2023, from https://azipc.com/how-long-does-rfa-last/.
[17] Griggs, C., Goverman, J., Bittner, E. A., & Levi, B. (2017, April 18). *Sedation and pain management in burn patients*. Clinics in plastic surgery. Retrieved March 20, 2023, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5642992/#R17.

bleeding, long term change of neural activity, cell damage/death, intensive internal bleeding, or cancer.

Since the device is constructed with typical Radio frequency generator, led lights for curing, and needles for the dedicated procedure, it is manufacturable. This procedure is sustainable as well, because the procedure doesn't require after care and the recovery period are quick, and the results last up to months without any intervention compared to medication and plastic waste.

REFERENCES

1. Griggs, C., Goverman, J., Bittner, E. A., & Levi, B. (2017, April 18). *Sedation and pain management in burn patients*. Clinics in plastic surgery. Retrieved March 20, 2023, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5642992/.
2. M., A. & D. (n.d.). *Pain management in burn patients*. Sacramento Personal Injury Lawyer - AutoAccident.com. Retrieved March 20, 2023, from https://www.autoaccident.com/pain-management-in-burn-patients.html.
3. Griggs, C., Goverman, J., Bittner, E. A., & Levi, B. (2017, April 18). *Sedation and pain management in burn patients*. Clinics in plastic surgery. Retrieved March 20, 2023, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5642992/ .
4. Griggs, C., Goverman, J., Bittner, E. A., & Levi, B. (2017, April 18). *Sedation and pain management in burn patients*. Clinics in plastic surgery. Retrieved March 20, 2023, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5642992/.
5. myDr. (2018, June 24). *Pain and how you sense it*. MyDr.com.au. Retrieved March 20, 2023, from https://mydr.com.au/pain/pain-and-how-you-sense-it/.
6. Basbaum, A. I., Bautista, D. M., Scherrer, G., & Julius, D. (2009, October 16). *Cellular and molecular mechanisms of pain*. Cell. Retrieved March 20, 2023, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2852643/.
7. myDr. (2018, June 24). *Pain and how you sense it*. MyDr.com.au. Retrieved March 20, 2023, from https://mydr.com.au/pain/pain-and-how-you-sense-it/.
8. *Radiofrequency ablation (RFA): What it is & procedure*. Cleveland Clinic. (n.d.). Retrieved March 20, 2023, from https://my.clevelandclinic.org/health/treatments/17411-radiofrequency-ablation.
9. Haemmerich, D., & Schutt, D. J. (2010, October 17). *RF ablation at low frequencies for targeted tumor heating: In vitro and computational modeling results*. IEEE transactions on bio-medical engineering. Retrieved March 20, 2023, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3108076/.
10. Sachdeva, S., & Dogra, A. (2007). *Radiofrequency ablation in dermatology* . Indian Journal of Dermatology. Retrieved March 20, 2023, from https://www.e-ijd.org/article.asp?issn=0019-5154;year=2007;volume=52;issue=3;spage=134;epage=137;aulast=Sachdeva.
11. *Is radiofrequency nerve ablation effective for lower back pain?* Boise Pain Center - Sandra Thompson, MD, MBA. (n.d.). Retrieved March 20, 2023, from https://thepaincenterinc.com/Blog/ArticleID/1039/Is-Radiofrequency-Nerve-Ablation-Effective-for-Lower-Back-Pain.
12. Pareek, A. (2022, October 18). *Types of signal generators & applications, Block Diagram*. Tesca Global Blog. Retrieved March 20, 2023, from https://www.tescaglobal.com/blog/signal-generators-types-application-block-circuit-diagram/.
13. *Understanding matching networks: Selected topics: Electronics textbook*. All About Circuits. (n.d.). Retrieved March 20, 2023, from https://www.allaboutcircuits.com/textbook/radio-frequency-analysis-design/selected-topics/understanding-matching-networks/.
14. *Radio Frequency Remote Controls for mobile machines*. CrossCo. (2021, January 26). Retrieved March 20, 2023, from https://www.crossco.com/resources/articles/radio-frequency-remote-controls-for-mobile-machines/.
15. (2022, September 12). *Generator cooling system comparison*. Kinsley Group. Retrieved March 20, 2023, from https://www.kinsley-group.com/generator-cooling-system-comparison-difference-between-air-cooling-and-water-cooling-systems/.
16. Griggs, C., Goverman, J., Bittner, E. A., & Levi, B. (2017, April 18). *Sedation and pain management in burn patients*. Clinics in plastic surgery. Retrieved March 20, 2023, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5642992/.
17. Z.C, G., Hilbers, B., Riel NAW, van, & M, L. (2018). *Visible blue light therapy: Molecular mechanisms and therapeutic opportunities*. Current medicinal chemistry. Retrieved March 20, 2023, from https://pubmed.ncbi.nlm.nih.gov/28748760/.

18. Cafasso, J. (2023, February 23). *Red light therapy: Uses, benefits, and risks*. Healthline. Retrieved March 20, 2023, from https://www.healthline.com/health/red-light-therapy.
19. Griggs, C., Goverman, J., Bittner, E. A., & Levi, B. (2017, April 18). *Sedation and pain management in burn patients*. Clinics in plastic surgery. Retrieved March 20, 2023, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5642992/#R17.
20. Wiltschko, R., Thalau, P., Gehring, D., Nießner, C., Ritz, T., & Wiltschko, W. (2015, February 6). *Magnetoreception in birds: The effect of radio-frequency fields*. The royal society publishing . Retrieved March 20, 2023, from https://royalsocietypublishing.org/doi/10.1098/rsif.2014.1103.