Radiofrequency Ablation and its Effect on Heat Generation on Ground Pads

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Introduction: Radiofrequency ablation is a minimally invasive solution to treating chronic pain. It can be done in a monopolar or bipolar configuration. In a monopolar configuration, the active electrode(s) is/are inserted into the region where the patient is experiencing pain and a return electrode (ground pad) is placed on the patient's skin, typically on the back of the thigh. A depiction of this set-up can be seen in **Figure 1**. During a monopolar radiofrequency ablation, current density builds on the return electrode and causes the temperature on the return electrode to rise. If the temperature on the return electrode rises too high, too quickly, it can lead to skin burns. The purpose of this study is to evaluate the effect of applying a constant current for various amounts of time in order to see the return electrode temperature rise in real time.

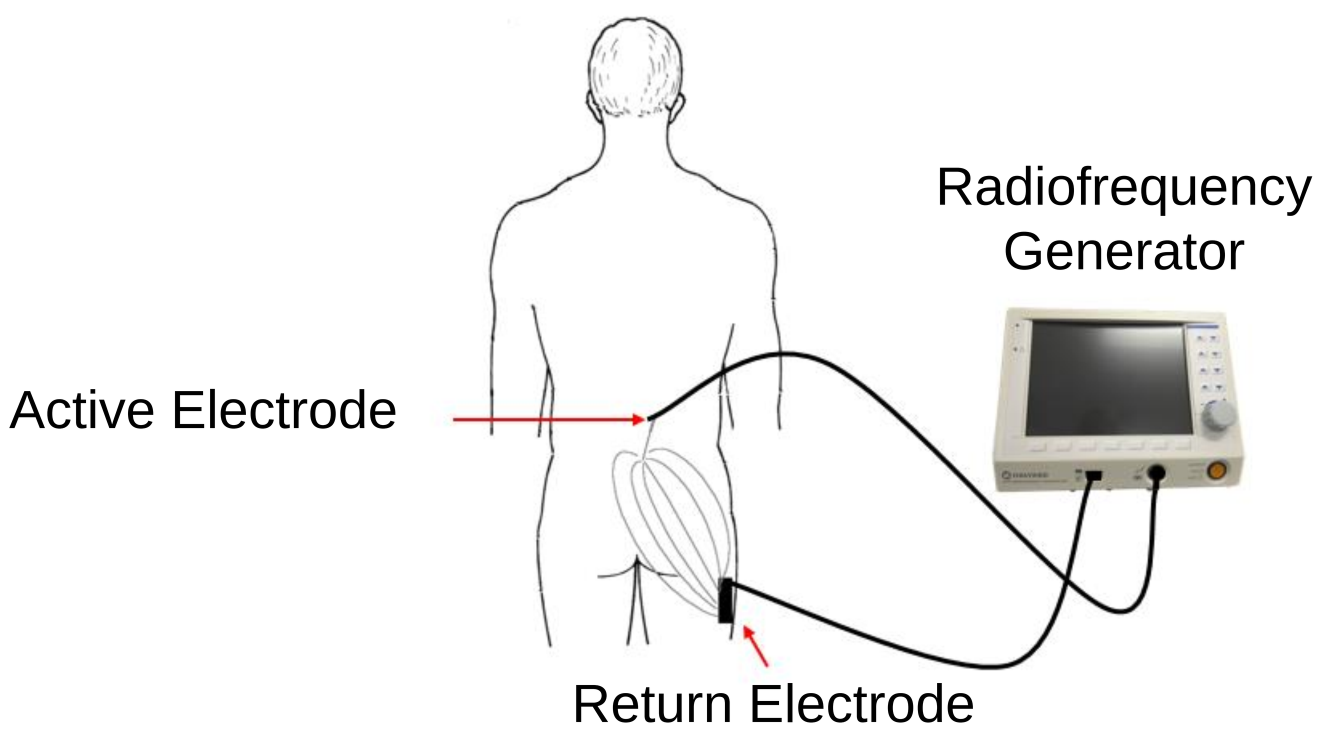

Figure 1. Radiofrequency Ablation System

Computational Methods: The model geometry consists of 1 m^3 of muscle tissue with a 2 mm border of skin. The active electrode was modeled as 8 cm^3 of stainless steel, embedded within the muscle tissue. All material properties were found in the reference literature [1,2] and the built in materials library in COMSOL. A commercially available return electrode was modeled independently. Examples of the geometry can be seen in **Figure 2**.

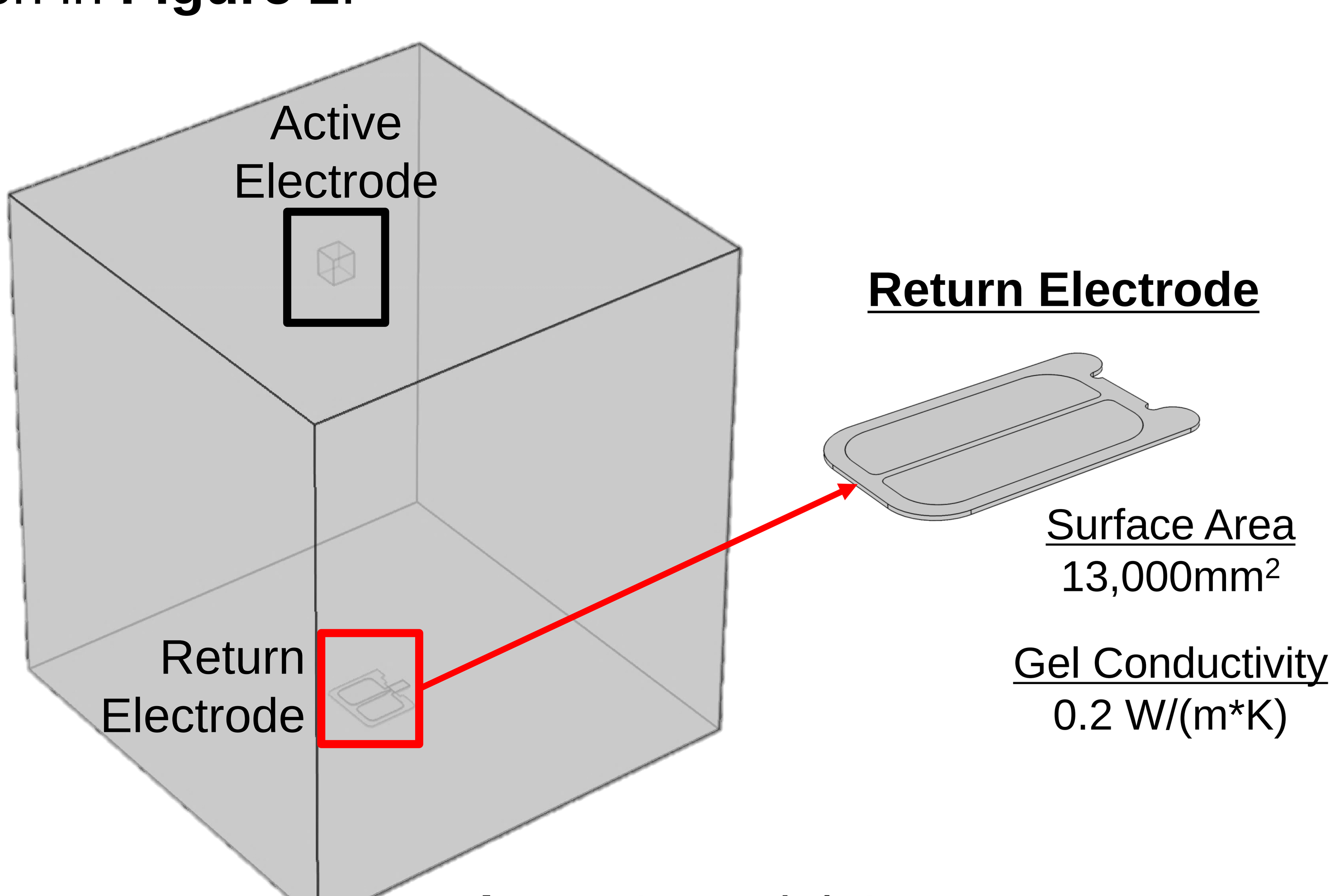

Figure 2. Model Geometry

The AC/DC module and Heat Transfer Module were used to evaluate this model. A frequency transient study was done with the frequency set to 460 kHz. The system was also modeled for voltage and power control using the Events Module. During simulations, the model monitored the voltage, current, and power being applied through the RF terminal. When these values exceed their defined limits, an implicit event is triggered that restricts the flow of RF energy to safe levels. Each simulation was run for 10 minutes at constant current levels ranging from 0.1 A to 0.9 A.

Results: The results were analyzed at 1 minute time intervals for each current level. The maximum temperature rise was seen at 10 minutes with a current of 0.9 A.

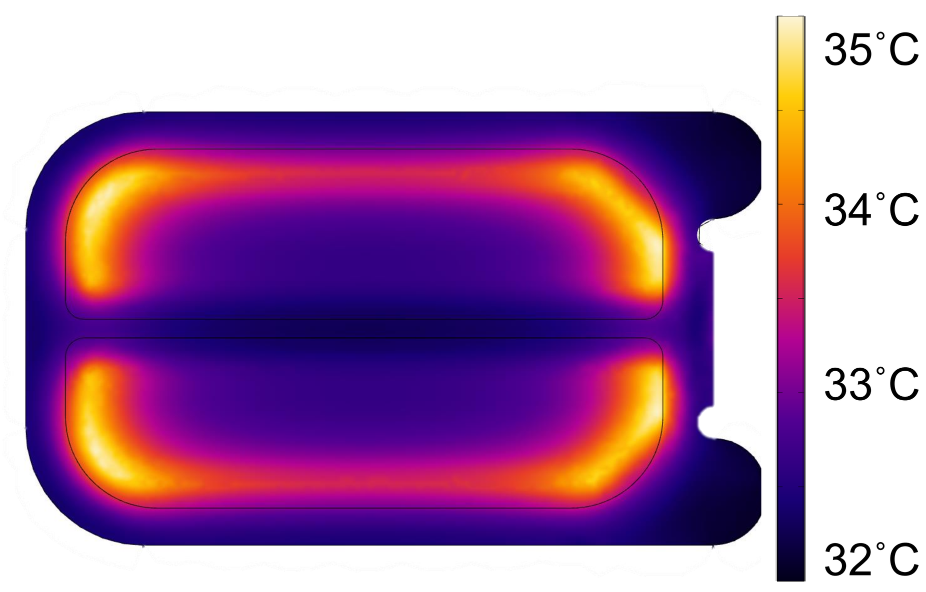

Figure 3.
Temperature Distribution at 10 minutes, 0.9 A

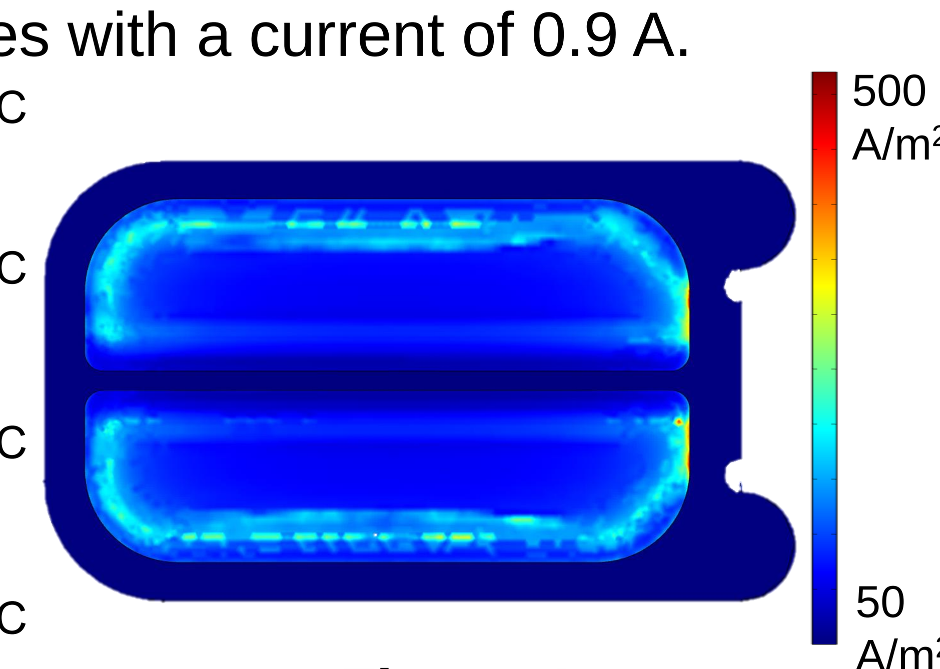

Figure 4.
Current Density at 10 minutes, 0.9 A

Figure 3 and **Figure 4** show the temperature and current density when a current of 0.9 A is applied for 10 minutes. The highest regions of current density occur along the exterior of the dual gel pads and align with the highest regions of thermal rise.

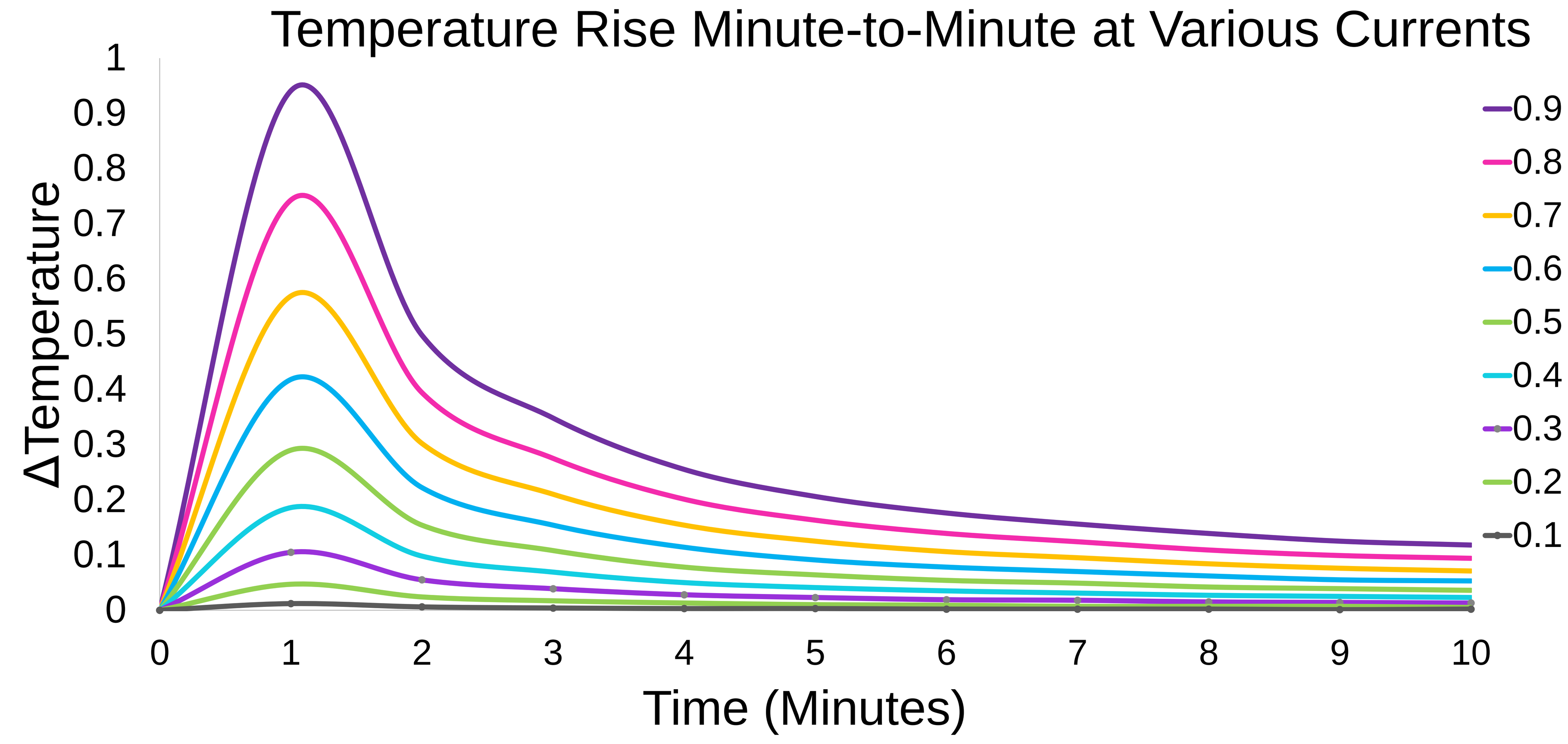

Figure 5: Temperature Rise Minute-to-Minute at Various Currents

The highest temperature rise for all current levels (0.1-0.9 A) occurs around the first minute of the procedure. After three minutes the thermal rise plateaus and the temperature increases significantly less past the five minute mark. A visual representation of this is shown in **Figure 5**.

Conclusions: The largest temperature rise for all applied currents (0.1-0.9 A) occurs around the first minute of the procedure. The temperature continues to rise as time continues, however the magnitude of the temperature rise significantly decreases. It can be concluded that when a constant current is applied, the largest thermal rise will occur around the first minute of testing. As expected, the highest temperature regions occur along the exterior of the dual gel pads. Further bench-top studies should be performed to confirm the accuracy of the model.

References:

1. C. Gabriel, A. Peyman, E.H. Grant, Electrical conductivity of tissue at frequencies below 1MHz, Phys. Med. Biol., 54, 4863-4878, 2009
2. T. J. C. Faes, H. A. van der Meij, J. C. de Munck, R.M. Heethaar, The electric resistivity of human tissues (100Hz-10MHz) a meta-analysis of review studies, Physiol. Meas., 20, R1-R10, 1999