A Model of Noninvasive Radiofrequency Tissue Heating

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Introduction: Noninvasive radiofrequency (RF) tissue heating is frequently used for skin tightening and facial wrinkle reduction as alternative to invasive surgical procedures [1]. However, to ensure a safe and efficient therapy, the temperature of the skin and the subcutaneous tissue must be controlled in order to prevent tissue damage. For such purpose numerical modeling can be used as a tool to investigate the dynamics of the temperature increase in the deeper tissue layers.

Computational Methods: A model of tissue, heated by RF energy, consisted of a cylinder, which was divided into four concentrically arranged layers: skin, adipose tissue, muscle, and bone (Figure 1). On top and bottom of the cylinder, a model of an RF applicator and a neutral electrode were placed, respectively. The model of the applicator was built according to Cryo Derm (Iskra Medical, Ljubljana, Slovenia) device.

For the calculation of the electric field and the temperature increase two application modes were used, Electric Currents and Bioheat Transfer. To account for the frequency dependency of electrical properties of tissues, we included a mathematical model proposed in [2].

Results: The dissipated power in the tissue determines the rate of tissue heating. In the frequency range 68 kHz – 6.5 MHz, the maximum dissipated power is observed in the adipose tissue (Figure 2, left). This suggests that within this frequency range, it is possible to heat the adipose tissue at a higher rate than other tissues layers.

The time course of the increase in tissue temperature (RF frequency 1 MHz, voltage on the active electrode 1000 V) demonstrates that the maximum temperature is indeed observed in the adipose tissue (Figure 2, right; Figure 3).

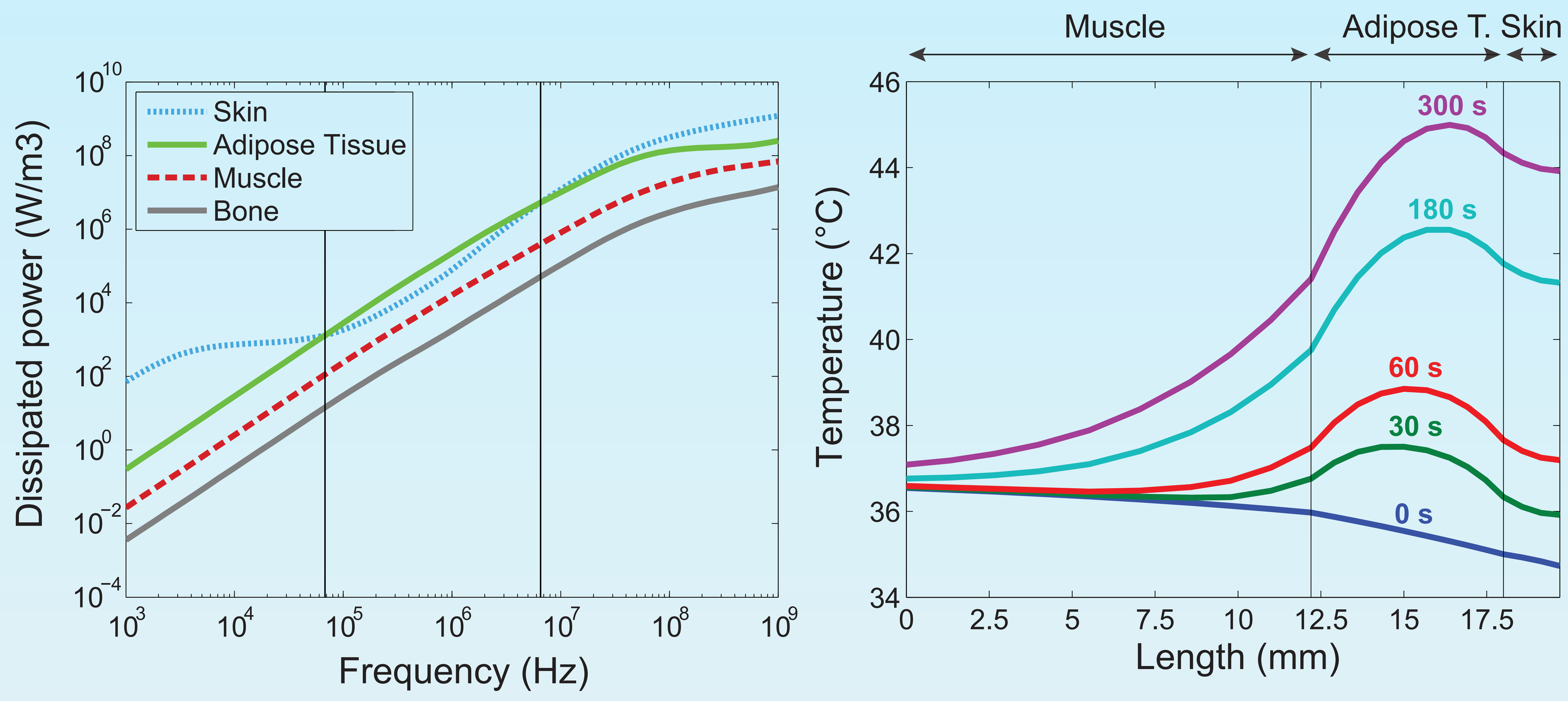

Figure 2. (*Left*) Maximum dissipated power in separate tissue layers for a wide frequency range. (*Right*) Temperature in separate tissue layers along a line beneath the applicator at different times after applying RF energy (1 MHz, 1000 V). Ambient temperature was set to 25°C.

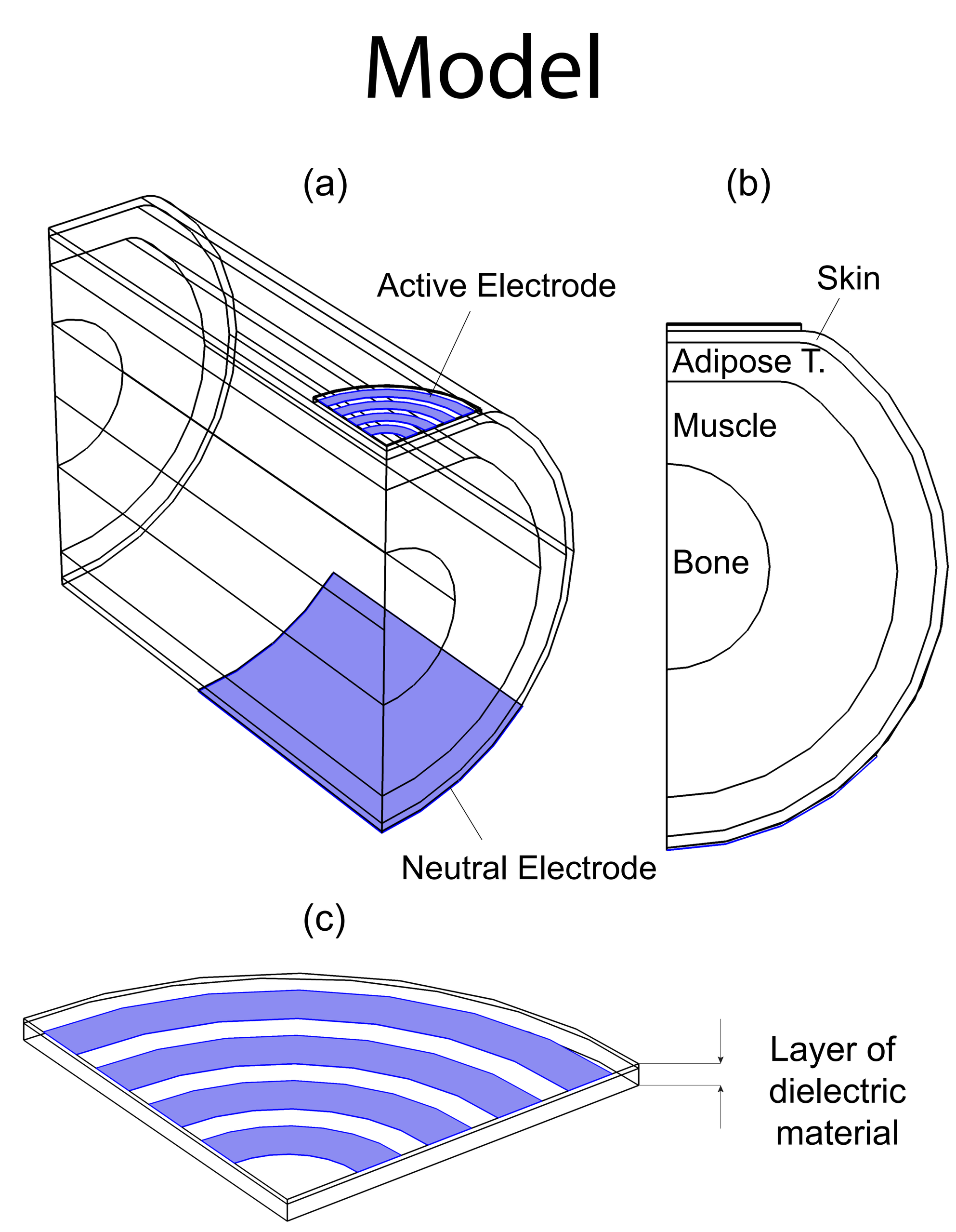

Figure 1. Tissue model. (a) 3D view. (b) Front view. (c) Model of RF applicator. The surfaces colored in blue are modeled as electrodes by assigning them an electric potential.

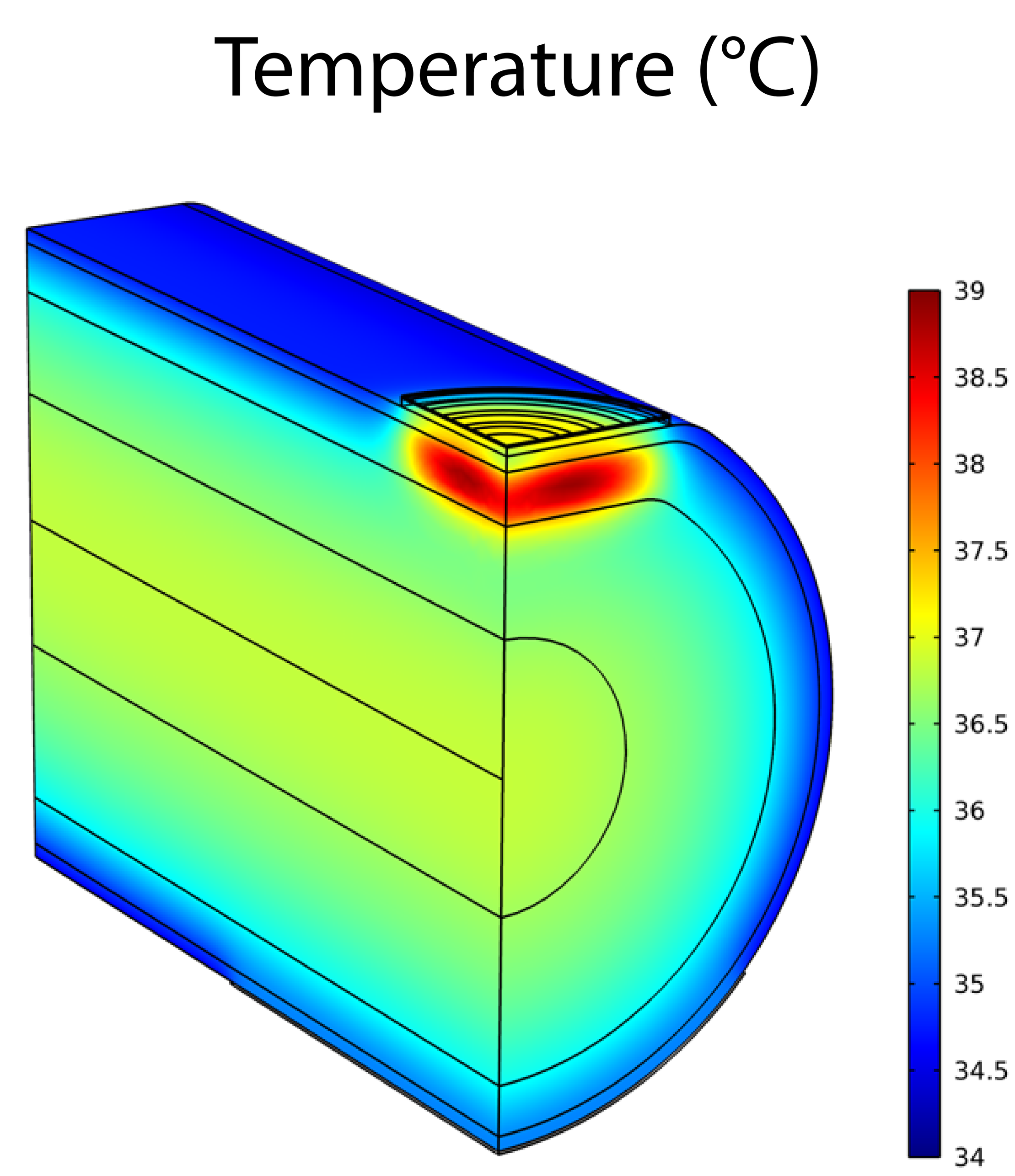

Figure 3. Spatial distribution of tissue temperature, 60 s after applying RF energy (1 MHz, 1000 V).

References:

1. Neil S. Sadick, Selective electro-thermolysis in aesthetic medicine: A review, Lasers Surg. Med., 34, 91–97 (2004)
2. Sami Gabriel et al., The dielectric properties of biological tissues: III. Parametric models for the dielectric spectrum of tissues, Phys. Med. Biol., 41, 2271–2293 (1996).

Conclusions: RF energy induces **targeted heating of adipose tissue** for a relatively wide frequency range of the applied RF signal. Numerical modeling can be used to **develop an optimal heating protocol** and to further **improve the RF devices**.

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