RF SAFETY AND THERMAL CHARECTERISTS OF PORCINE HEADS AFTER EUTHANASIA

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Introduction Human geometries, tissue types, and blood flow characteristics are needed to measure radiofrequency (RF) heating and develop appropriate bioheat thermal models relevant to RF safety of humans at ultra-high fields (≥ 3 tesla (T)). This is so since sub-degree accuracy of RF heating measurements and models are required to determine non-uniform RF heating, local hot spots, and the maximum, safe *in vivo* temperature change of 1 ^{0}C in a human head. (1-3) The use of the maximum safe temperature instead of the maximum allowable specific absorption rate (SAR) to determine safety is prudent since cellular thermogenic hazards are related to *in vivo* temperatures and temperature-time history – not to maximum SAR.(4) The use of unpreserved, fresh, perfused cadavers may be useful as appropriate models to humans to study RF heating at the highest fields.

Four human sized porcine models were used to study the thermal characteristics of the porcine head right after euthanasia and after 11 hours of death. This was done to quantify the change in thermal behavior within 11-13 hours of death. Human sized porcine models were used as approximate models to human cadavers. This was appropriate since porcine models have human comparable body mass, surface area, blood pool, thermal properties, and thermo-physiologic mechanisms.

Experiment design and Methods Temperatures were measured as a function of time for up to 13.5 hours after death in the brain and surrounding cutaneous layer of four human sized, euthanized swine (mean animal weight = 53.6 kg, SD = 7.7 kg). Brain temperatures were recorded using three fluroptic probes placed at 5 mm, 10 mm, and 15 mm depths from the dura inside the brain. An ~18G hole was drilled into the anesthetized animal's cranium to place the probes. Skin temperature was recorded using a separate fluroptic probe placed in the head cutaneous layer using an 18G catheter. The animals were kept anesthetized during the placement of the probes using 2-3% Isoflurane in 50% air – 50% O_2. The animals were euthanized to measure their thermal behavior over time. The room temperature and humidity were recorded every 30 minutes. The number of animals was chosen as N = 4. This was so because a minimum of N = 3.16 animals was required to have >90% power with P<0.05 (two-sided). The animal experiment protocol was approved by the Institutional Animal Care and Usage Committee of the University of Minnesota.

The measured absolute temperature response was normalized such that the maximum brain temperature was 1 and the ambient temperature was 0 (normalized temperature Tn = (absolute temperature T – room temperature Tamb)(maximum brain temperature Tmax,brain – Tamb)$^{-1}$). The normalized temperature response is a function of the initial temperature at time t=0, thermal diffusivity (thermal conductivity/(density *specific heat at constant pressure)), and a convective heat transfer coefficient from the skin in an animal when the animal is exposed to the ambient. The time rate of change of the thermal response is a function of the thermal diffusivity alone. To quantify alteration in the thermal properties, the thermal responses over time between the 0.5 hours – 2.5 hours were compared to the thermal responses between the 11.5 hours – 13.5 hours. The 0.5 hours of wait time after euthanasia was appropriate to diminish the thermal effects of resettling blood.

Results and Discussion Figure 1 presents typical non-dimensional thermal responses between 0.5 – 2.5 hours and 11.5 – 13.5 hours after death in the head-skin and brain in an animal. Figure 2 presents the % difference between the two thermal responses. The measurements demonstrated that the maximum thermal response variation with in 13.5 hours of death was ≤ 15%. Further, the variation in the thermal responses over time (i.e., in the thermal decay time constant which is a function of the thermal diffusivity alone) was ≤ 15 %. The results are significant since they suggest that the thermal responses obtained with in 12 hours of death in fresh, perfused cadavers may closely mimic the responses in live humans.

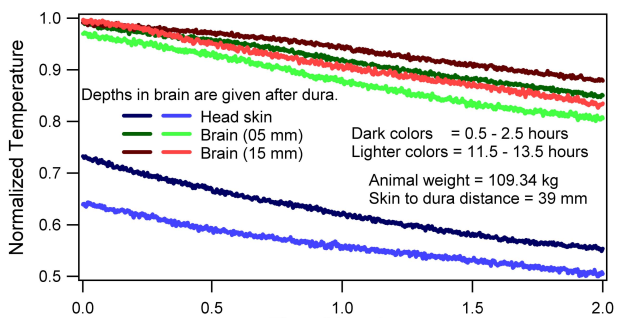

Figure 1

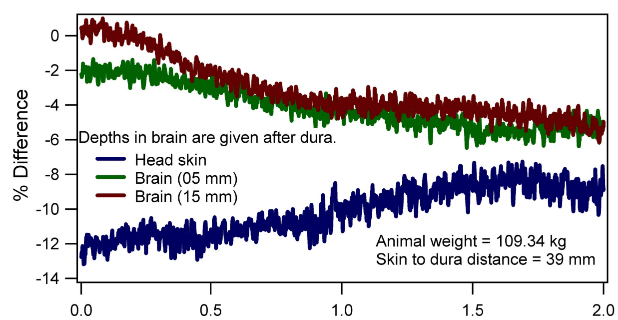

Figure 2

Summary Thermal response right after the euthanasia was within 15% of the thermal response obtained after 11 hours of death in the heads of human sized porcine models. RF heating related temperature measurements obtained with in 12 hours of death in fresh, perfused cadavers may closely mimic RF heating in live humans.

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