# An Investigation on IEC Head SAR Limit on Orbit Heating

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**TARGET AUDIENCE:** Audience who focus on understanding, implementing and/or improving MR safety standard.

**PURPOSE:** Significant portions of MRI examinations are constrained by the 3.2W/kg head SAR limit[1]. This limit is based on results from experimental sheep data[2] and simple models (spheres) of the head and eyes[3], but not human subjects. Subsequent numerical simulations[4, 5] investigated SAR and tissue temperature but with a truncated head model inside a Tx/Rx head coil. Recent studies[6] have utilized sophisticated thermal modeling, and anatomically accurate whole body human models to investigate thermal tissue damage threshold, but did not focus on brain imaging. Here we apply the same tools and models as in previous study[6] to investigate 3.2W/kg head SAR's thermal impact for brain imaging.

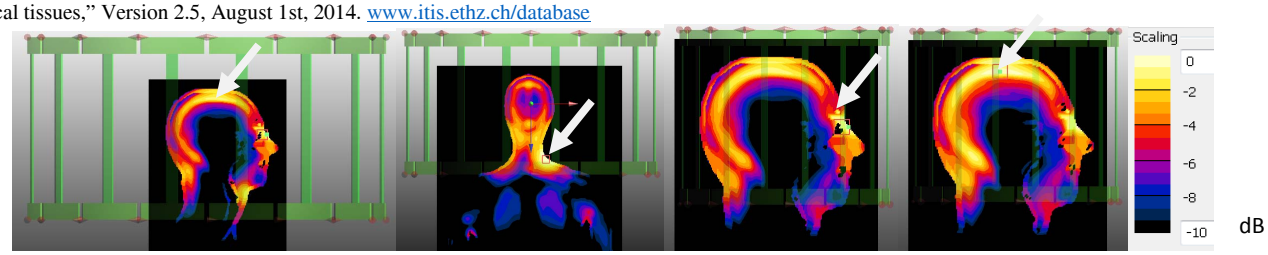
**METHODS:** FDTD simulations (SEMCAD X, v14.8, SPEAG) were performed with adult male model Duke[7] (IT'IS Foundation) and two generic quadrature birdcage transmit coils (75cm diameter/40cm length body coil and 30cm diameter/25cm length head coil). EM and thermal simulations (Pennes Bioheat) were performed with head at isocenter for 1.5T and 3T imaging (Fig.1). A 2mm isotropic FDTD mesh was used on the body model. Tissue parameters[8], with thermo-regulated skin, fat (including subcutaneous adipose tissue) and muscle[6] were applied. Thermal simulations started with 37°C initial tissue temperature and 25°C ambient air temperature. A 30min lead time (no RF heating) was applied to reach basal thermal equilibrium (no clothes). Consequently, temperature for external tissues (e.g., skin, eyes) were slightly below 37°C and above 37 °C for internal tissues just prior to heating. Continuous RF heating with 3.2 W/kg head SAR was then applied until transient temperature reached steady state.

**RESULTS:** SAR (averaged over 10g tissue[1]) and steady state temperature (per voxel) distributions are shown in Figs.1 and 2, respectively. At 1.5T, SAR hotspot is in skin/muscle in upper nasal bridge, and peak temperature is in CSF close to the top of the head, for both body and head coils. At 3T, SAR and temperature hotspots coincide in the muscle in neck/shoulder transition area for body coil, and with head coil they appear in two different locations in CSF. Hotspot tissue compositions are summarized in Table 1. Peak tissue temperatures were 38.6°C in all cases, and maximum temperature increase from thermal equilibrium is 1.6 °C. Temperature rise in eyes (measured at cornea for eye surface and at vitreous humor for internal eye) do not exceed 1°C.

**DISCUSSION:** For brain imaging, peak SAR and tissue temperature hotspots may not exclusively exist in skin, fat, or muscle as observed with other imaging landmarks[6]. In particular, results showed that hotspots may appear in CSF close to skull. CSF has high conductivity (2.06S/m at 64MHz and 2.14S/m at 128MHz), and is mainly distributed along the periphery of the head, therefore absorbing high RF power. Since CSF is bodily fluid, elevated temperature may have negligible effects on itself, and more thermal impacts are likely related to heat transferred to surrounding tissues. Since healthy brain is well perfused, no hotspots were observed inside the brain. Eyes have high conductivity and limited perfusion, and our results of temperature rise are consistent with previous studies.[2, 3]

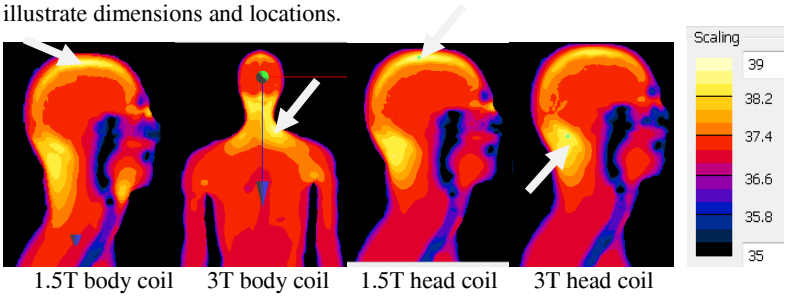
**CONCLUSION:** Simulations showed no significant SAR or temperature increases in the brain or eye tissues with 3.2W/kg head SAR. The other peak SAR and temperature rise elsewhere may require further investigations.

**REFERENCES:** [1] IEC 60601-2-33, 3rd edition, Geneva, IEC: 2010. [2] Barber BJ, et al. American Journal of Roentgenology 155, 1105-1110(1990). [3] Athey TW, Magn Reson Med 9, 177-184(1989). [4] Collins CM, et al. JMRI 19:650-656(2004). [5] Wang Z, et al. JMRI 26: 437-441 (2007). [6] Murbach M, et al. Magn Reson Med 71: 421-431 (2014). [7] Christ A, et al. Phys Med Biol 55: N23-38 (2010). [8] Hasgall PA, et al. "IT'IS Database for thermal and electromagnetic parameters of biological tissues," Version 2.5, August 1st, 2014. www.itis.ethz.ch/database




1.5T body coil 3T body coil 1.5T head coil 3T head coil

Fig.1. SAR distributions for the four cases studied. Peak SAR hotspots are indicated by arrows. Transmit coils are shown in the background to illustrate dimensions and locations.




1.5T body coil 3T body coil 1.5T head coil 3T head coil

Fig.2. Steady state tissue temperature for the four cases studied. Peak tissue temperature areas are indicated by arrows.

| | 1.5T body coil | 3T body coil | 1.5T head coil | 3T head coil |
|---|---|---|---|---|
| Peak SAR10g | Skin/Muscle | Muscle | Skin/Muscle | CSF |
| Peak tissue temperature | CSF | Muscle | CSF | Skull/CSF |

Table 1. Tissue composition for SAR and temperature hotspots.