Numerical simulation of SAR for 3T whole body coil: effect of patient loading positions on local SAR hotspot

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INTRODUCTION: Local SAR levels (hotspots) are much higher than whole body average SAR [1-3] due to tissue heterogeneity, body habitus, and patient imaging position. This abstract extends previous chest and abdomen 3T hotspot ratio simulation analyses (ratio = maximum local 10g SAR/whole body average SAR) to five other common imaging positions. Results show that 1) the SAR distribution varies significantly between imaging positions, and 2) the local SAR hotspot ratios can be over 4x higher than previously reported [1-3]. While temperature increase is the key safety concern, understanding SAR distribution is an important factor in patient safety.

METHODS: Our simulations (v. 6.3 xFDTD + 23 tissue Visible Man human model, Remcom, Inc., State College, PA) use the previously presented 3T whole body coil [3] (24 rung high pass birdcage coil, 63cm diameter, 68cm shield diameter, 70cm length for both coil and shield length). The coil was driven at both end-rings with 48 voltage sources (128MHz) and phased to produce an ideal quadrature excitation for the birdcage coil at 3T [3, 4] in free space. The FDTD mesh resolution was 5 mm (isotropic) with overall dimensions of 1.11m(X)×1.11m(Y)×2.19m(Z). Simulation steady state was reached in 20000 time steps (approximately 24 cycles). Fig. 1 shows the coil and the visible man model. The back of the visible man was 10cm below [3] but otherwise aligned with the central axis of the coil for the head, shoulder, chest, abdomen, pelvis, knee, and ankle simulation positions. The whole body average SAR (WB SAR), maximum local SAR averaged over 10g tissue (SAR_{10g}) and ratio were computed.

RESULTS AND DISCUSSION: Fig. 2 shows the SAR_{10g} distribution at the coronal level with the maximum hotspot for the seven simulated imaging positions. Table 1 summarizes numerical SAR values. The SAR entries for each column are normalized to a constant 10 W/kg local SAR_{10g} maximum. The chest and abdomen results are consistent with [1-3]. The local SAR distribution varies significantly between imaging positions and the ratio generally increases as the torso moves out of the coil. Note that for extremities (knee or ankle) in particular, the RF power deposition is highly concentrated on the targeted small mass body part resulting in a very high local hotspot ratio, even though the whole body average SAR is low. It is possible that the unusual ankle hotspot is partially caused by the spread legs modifying the electric field distribution. The typical ankle imaging position is closer to isocenter, but we are not able to reposition individual legs with this version of the simulation software. These examples demonstrate why it is essential to control partial body SAR.

CONCLUSION: The present study extends the previous investigations of local SAR distribution and hotspot ratios at 3T with a whole body transmit coil to several other patient imaging positions. The results clearly show that the local SAR distribution and hotspot ratios are highly dependent on the imaging position. The extremity results show that the hotspot ratios can be up to four times larger than previously report hotspot ratios in chest/abdomen. These extreme hotspot ratios can be mitigated by the careful application of partial body SAR control factors.

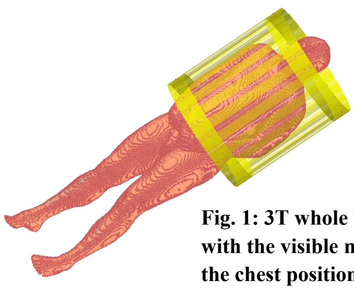

Fig. 1: 3T whole body coil model loaded with the visible man. The diagram shows the chest position, where the heart is approximately located at the isocenter.

REFERENCES

[1] C.M. Collins et al., Proc. Intl. Soc. Mag. Reson. Med. 14 (2006): p.2044.
[2] Z. Zhai et al., Proc. Intl. Soc. Mag. Reson. Med. 11 (2004): p.666.
[3] W. Liu et al., Appl. Magn. Reson. 29 (2005): pp 5-18.
[4] Z. Wang et al., Proc. Intl. Soc. Mag. Reson. Med. 17 (2009): p.4775.

Imaging positions	Head	Shoulder	Chest	Abdomen	Pelvis	Knee	Ankle
Max SAR_{10g} (W/Kg)	10	10	10	10	10	10	10
WB SAR (W/Kg)	0.52	0.82	0.96	0.79	0.74	0.23	0.19
Max SAR10g/WB SAR	19.1	12.2	10.4	12.7	13.6	44.1	51.7

Table 1: Simulated SAR values for different imaging positions.

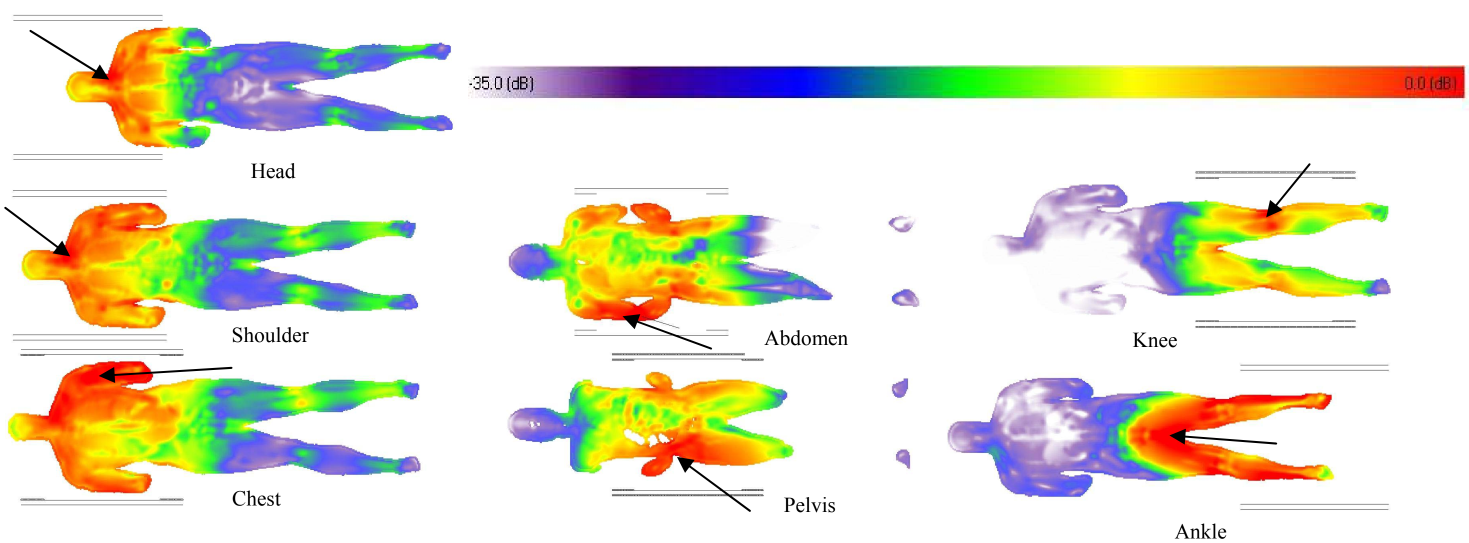

Fig. 2: SAR distributions for different imaging positions shown in coronal slices of visible man. The color represents a logarithm scale of the SAR strength, with the range from -35dB to 0dB. Maximum SAR_{10g} locations are indicated with arrows.