SAR Comparison for "Head First" and "Feet First" Patient Loading at 3T MRI with Numerical Simulations

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INTRODUCTION: Numerical simulations of SAR have been widely used to investigate MRI RF safety. Although studies have covered multiple human models[1], imaging landmarks[2], and transmit body coil types[3], more clinical imaging scenarios remain to be investigated, such as patient scanned as "head first" or "feet first". Eddy current induced in conductive imaging subject by RF magnetic field is asymmetric even with a perfectly symmetric phantom and coil[4,5]. Human tissue heterogeneity and asymmetry add even more complexity to this phenomenon. In this work, we used FDTD numerical simulations to study a generic body transmit coil loaded with a digital human model. Simulations were performed for 11 imaging landmarks from head to toe, both "head first" and "feet first". Significant differences in peak local SAR were observed for two loading directions.

METHODS: All simulations were performed with xFDTD and the 39-tissue Visible Man model (both from Remcom, Inc., State College, PA) using a 16-rung high pass birdcage coil (diameter 61cm, length 62cm; RF shield diameter 66cm, length 122cm)[1,3]. The coil was tuned to 128MHz with appropriate end-ring capacitors to simulate 3T imaging. Quadrature drive was applied with two voltage sources (equal amplitude but 90 degree phase difference) in one end-ring (-Z side). The resultant polarization of the rotating RF transmit field B1 represents a main magnetic field B0 pointing toward +Z direction. Visible Man was loaded symmetrically in left/right direction, and the back was 13cm below the coil center to represent a typical patient couch position (Fig.1). Frequency appropriate tissue parameters (dielectric permittivity and conductivity) were applied. Simulations were performed with 11 imaging landmarks from head to toe, and both "head first" (head toward -Z) and "feet first" (head toward +Z) loading (Fig. 1).

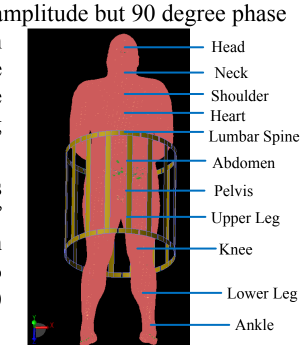

Fig. 1: All imaging landmarks studied with FDTD simulations. Visible Man is shown as "head first" loaded at pelvis landmark.

RESULTS: Fig. 2 shows whole body (WB) averaged SAR plotted as a function of imaging landmark. All data points were normalized to a fixed B1+ magnitude (1 microTesla) at the coil center. Switching from "head first" to "feet first" leads to increased WB SAR for 4 landmarks (head, neck, shoulder, and abdomen), with neck showing the maximum percentage increase of 11.3%. The other 7 landmarks all show decreased WB SAR, with the biggest drop of 12.2% observed for upper leg. Fig. 3 shows peak local SAR (calculated as 10 gram tissue average following IEC standard[6]) plotted against imaging landmark for two patient loading directions. All data points were also normalized to 1 microTesla B1+ at coil center. 4 landmarks (shoulder, heart, lumbar spine and pelvis) show increased peak local SAR from "head first" to "feet first", with heart showing the largest percentage increase of 37.5%. All other 7 landmarks show decreased peak local SAR, with the knee showing the largest percentage drop of 42.8%.

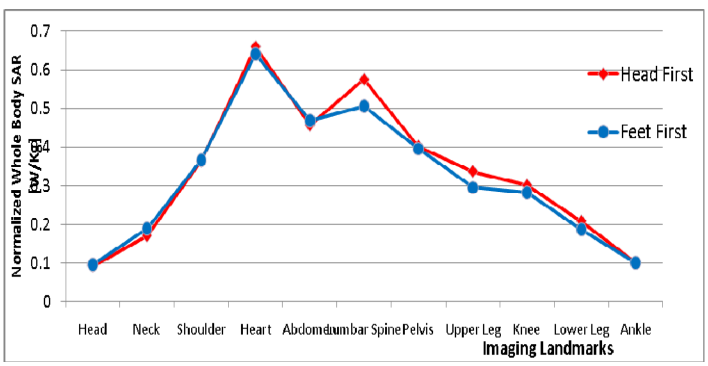

Fig. 2: Normalized WB SAR plotted for all imaging landmarks.

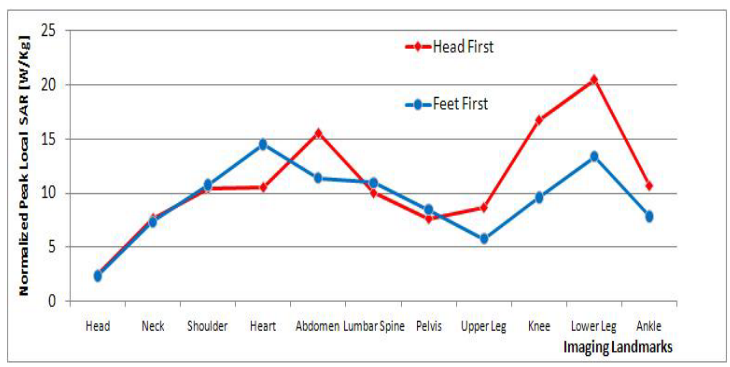

Fig. 3: Normalized peak local SAR plotted for all imaging landmarks.

DISCUSSION: Conductive imaging subject with high dielectric permittivity can significantly disturb the homogeneous B1 field produced by a quadrature birdcage coil. Even with a symmetric, uniform phantom, RF wavelength effect and circular polarization of B1 cause asymmetric eddy current, and resultant SAR and RF heating. Heterogeneity and asymmetry of human body tissue add even more complexity to this phenomenon. Patients are often loaded as "head first" for imaging upper body and "feet first" for imaging lower body. Although B1 field and whole body power deposition are similar for the two loading directions, their peak local SAR can have significant differences. Our results showed that for lower extremities (from upper leg to ankle), "feet first" loading has a significantly lower peak local SAR. It is noteworthy that "feet first" also leads to much lower peak local SAR for abdomen, a landmark that is often "head first." "Feet first" can also lead to a lower peak local SAR for head and neck landmarks, although the differences are not significant, and patient set up may not be practical.

REFERENCES:

1 Z. Wang et al., Proc. Intl. Soc. Mag. Reson. Med. 18: p.3880 (2010)
2 X. Chen et al., Proc. Intl. Soc. Mag. Reson. Med. 18: p.3879 (2010)
3 D.T. B. Yeo et al., Journal of Magnetic Resonance Imaging, 33: 1209-1217 (2011).
4 C. M. Collins and Z. Wang, Magnetic Resonance in Medicine 65: 1470-1482 (2011).
5 C. Koch et al., Proc. Intl. Soc. Mag. Reson. Med. 19: p.3775 (2011)
6 IEC, 60601-2-33, 3rd edition, 2010.