SAR Comparison for Multiple Human Body Models at 1.5T and 3.0T

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Introduction: In numerical calculations and SAR evaluations of RF fields for MRI, until recently most results have been obtained using models based on segmentations of the NIH Visible Human Project [e.g., 1, 2]. Although comparison of results from multiple human body models has been performed previously [3], the low resolution (5mm) may induce uncertainty, especially near tissue boundaries [4]. In this paper, we utilize six currently available human body models at 2mm isometric resolution to investigate the effects of body geometry and position on SAR distribution at 64MHz (1.5T) and 128MHz(3T) in a whole-body high-pass birdcage coil.

Method: Anatomically-based models “NORMAN” and “NAOMI” [5, 6] are often used in SAR calculation for radiological protection applications. NORMAN has the size of 277x148x871 at 2mm isometric resolution with 37 tissue types. NAOMI has the size of 294x124x791 at 2mm isometric resolution with 40 tissue types. Also, the IT'IS foundation [7] has recently created the “virtual family” models which include adult male and female. At 2mm isometric resolution, the male model “Duke” has the size of 271x142x903 and the female model “Ella” has the size of 253x140x818 with up to 84 tissue types. Adding the visible man (293x170x939) with 39 tissue types at 2mm isometric resolution and visible woman (interpolated to 266x143x864 at 2mm resolution) models, we currently have six adult human models (three male and three female models). Models were modified for use with commercially available finite-difference time-domain software SEMCAD (SPEAG; Zurich, Switzerland). A Four-Cole-Cole extrapolation technique was used to determine values for the dielectric properties of the different human tissues. For this study, a 16-rung body size (610 mm coil diameter and 620 mm length, 660 mm shield diameter and 1220 mm length, as in a typical product coil) high-pass birdcage coil was modeled at 64MHz and 128MHz. The human models were positioned with the heart in the middle of the coil. To model a typical patient table position in a scanner, the backs of the body models were placed 170mm away from furthest rear coil rung. With the acceleration hardware support (CIB 1000, SPEAG; Zurich, Switzerland), the human model and the coil were meshed at more than 42 million voxels and the running time is less than 4 hours for each calculation. The geometry of the coil and six models are shown in Fig.1. The coil was driven with 32 current sources placed in the end-rings and 22.5-degree phase-shift between adjacent rungs. This method has shown practically identical results to driving the coil on resonance in quadrature at either two or four locations up to 128 MHz [2].

Results & Discussion: Results were normalized to have a whole body average SAR of 2W/Kg [8]. Since the different models have different mass, shape, posture and tissue types, the absorption power and local SAR have obvious differences. The SAR distributions on the central sagittal and coronal plane are shown in Fig.2 and Fig. 3, respectively. For detailed comparison, we also give the maximum local SAR_{1g} and SAR_{10g} in Table I. In every case, the maximum SAR_{10g} exceeds the first level controlled mode exposure limits [8]. A hot spot can be seen in the area of neck and shoulder where the current distribution is constrained to flow in a small cross-section with interfaces between tissues with high contrast in dielectric properties, such as skin, fat, muscle, and bone. Due to the normalization keeping the whole body average SAR at 2W/Kg, the 1.5T results show higher SAR value than 3.0T results in some locations. However, 3T results always have higher SAR value than those of 1.5T in the outside coil tissues, particularly in head and legs. NAOMI has the highest maximum SAR because her arms are very close to the birdcage coil rungs. The hands of the visible man and woman are in contact with the body, which creates current paths not typically available in practice. This contact increases local SAR which can be noticed in Fig.3. The human body shape, position and dielectric properties of the body tissues have significant effects on the SAR distribution. Therefore, use of multiple numerical models should provide more realistic representations of a diverse patient population in calculations for MRI engineering and safety assurance, including MR coil design.

References: [1] CM Collins *et al*., Magn Reson Med 2001;45:692 [2] W. Liu *et al*. Appl. Magn. Reson. 2005;29:5-18 [3] Z. Wang *et al.* Proc. ISMRM,2009, p.1861 [4] Z. Wang *et al.* Proc. ISMRM,2009,p.1857 [5] P. Dimbylow, Phy. Med. Bio. 1997;42: 479-490 [6] P. Dimbylow, Phy. Med. Bio. 2005;50:1047-1070 [7] www.itis.ethz.ch/index/index_humanmodels.html [8] IEC 60601-2-33, 2006-02

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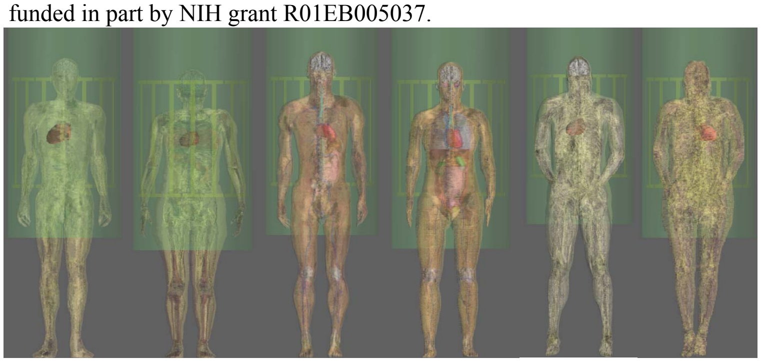
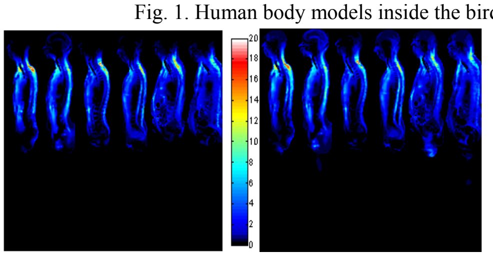


NORMAN NAOMI Duke Ella VisibleMan VisibleWoman

Fig. 1. Human body models inside the birdcage coil

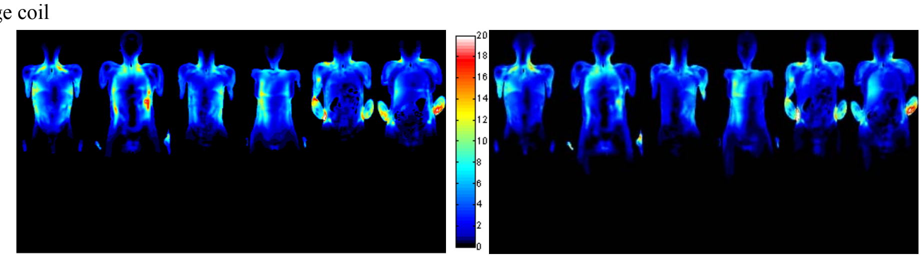
Table I Maximum SAR_{1g} (W/Kg) and SAR_{10g} (W/Kg) for human models at 1.5T and 3.0T (normalized to whole body average SAR=2W/Kg)

			1.5T		3.0T	
	Mass(Kg)	Height (cm)	SAR_{1g}	SAR_{10g}	SAR_{1g}	SAR_{10g}
NORMAN	71.97	174.20	45.23	31.09	51.63	35.91
NAOMI	64.42	158.20	59.89	37.44	108.80	70.56
Duke	72.34	180.40	35.32	23.18	31.90	25.51
Ella	58.14	163.40	58.84	31.33	51.08	27.75
VisibleMan	105.71	187.60	41.20	24.70	53.31	30.66
VisibleWoman	82.80	172.50	39.94	26.55	42.53	29.66



1.5T 3.0T

Fig. 2. SAR1g distribution of human models at central sagittal plane. Order of models, from left to right, is as in Fig. 1.



1.5T 3.0T

Fig. 3. SAR10g distribution of human models at central coronal plane. Order of models, from left to right, is as in Fig. 1.