Comparing SAR Calculated in Multiple Human Body Models at 1.5T

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Introduction:

For SAR modeling and numerical calculation, most results have been obtained from one human body model (Visible Human Project (National Library of Medicine, Bethesda, MD)) [1,2]. For engineering and safety assurance in MRI, there is a need for a more diverse set of high resolution heterogeneous human body models to better represent the diverse population of patients. In this paper, we utilize six currently available human body models to investigate the effects of body geometry on SAR distribution at 64MHz (1.5T) in a whole-body high-pass birdcage coil.

Method:

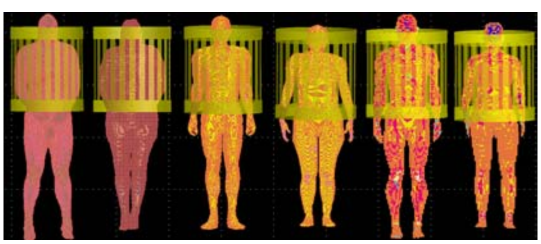
Anatomically-based models “NORMAN” and “NAOMI” [3,4] are often used in SAR calculation for radiological protection applications. NORMAN has the size of 277x148x871 at 2mm isometric resolution with 37 tissue types. NAOMI has the size of 294x124x791 at 2mm isometric resolution with 40 tissue types. Also, the IT'IS foundation [5] has recently created the “virtual family” models which include adult male and female. Models at four resolutions (0.5mm, 1mm, 2mm and 5mm) with up to 84 tissue types are provided. At 5mm resolution, for the male model “Duke” the size is 122x62x372 and for the female model “Ella” the size is 106x60x336. Adding the visible man (116x67x377) and woman (108x61x347) with 39 tissue types at 5mm isometric resolution, we currently have six adult human models (three male and three female models). Models were modified to adapt to commercially available finite-difference time-domain software “xFDTD” (REMCOM; State College, PA). A Four-Cole-Cole extrapolation technique was used to determine values for the dielectric properties of the different human tissues. For this study, a 24-rung body size (63 cm coil diameter and 70 cm length, 68 cm shield diameter and 140 cm length) high-pass birdcage coil was modeled at 64MHz and the human models were positioned with the heart in the middle of the coil. Considering calculation time and memory, the human model and the coil were meshed at 5mm isometric resolution. The geometry of the coil and six models are shown in Fig.1 with the shield hidden. Anatomy on the central sagittal slices is given in Fig.2. The coil was driven with 48 current sources placed in the end-rings and 15-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 & Discuss:

Results were normalized to have a whole body average SAR of 2W/Kg [6]. Since the different models have different mass, posture and tissue types, the absorption power and local SAR have obvious differences. The SAR distributions on the sagittal plane passing through the center of the heart are shown in Fig.3. For detailed comparison, we also give the maximum local SAR_{1g} and SAR_{10g} in Table I. For the visible man and woman, the maximum SAR_{1g} and SAR_{10g} are smaller than other models, perhaps because they have a greater percentage of body fat, which results in lower SAR levels. The higher maximum local SAR values in the other four models may also be due to the discontinuity of tissues and non-complete skin cover. On the other hand, the visible man and woman's hands are in contact with the body which may create current paths not typically available in practice. This contact has been shown to increase local SAR [7]. We plan to apply some algorithms to remedy the models and increase the resolution to better understand SAR distribution in the future. From the figures and Table I, NORMAN, NAOMI, Duke and Ella have similar SAR distribution since their size and posture are similar. These models may be preferred for SAR prediction in slim people. In addition, the highest local SAR occurring in NAOMI is probably because the arms and wrists are very close to the coil end-ring and rungs. 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.

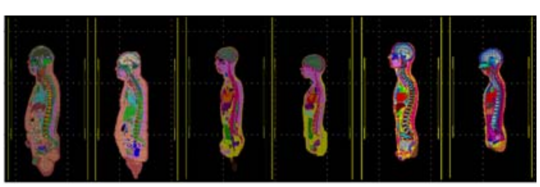
Reference:

[1] CM Collins *et al*., Magn Reson Med 2001;45:692 [2] W. Liu *et al*. Appl. Magn. Reson. 2005;29:5-18 [3] P. Dimbylow, Phy. Med. Bio. 1997;42: 479-490 [4] P. Dimbylow, Phy. Med. Bio. 2005;50:1047-1070 [5] www.itis.ethz.ch/index/index_humanmodels.html
[6] IEC 60601-2-33, 2006-02 [7] Z. Wang, Proc. ISMRM, 2008, p. 75



Visible Man   Visible Woman   NORMAN   NAOMI   Duke   Ella

Fig.1. Human body models inside the birdcage coil

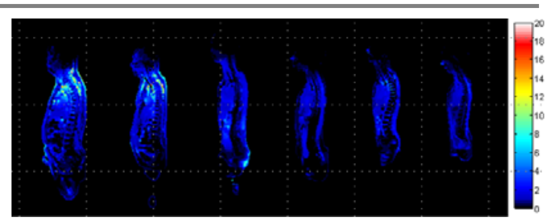


Visible Man   Visible Woman   NORMAN   NAOMI   Duke   Ella

Fig.2. Central sagittal plane for different human body models

Table I. Comparison of mass, absorption power and maximum local SAR (normalized to whole body average SAR=2W/Kg)

Human Models	Mass(Kg)	Absorption Power(W)	SAR_{1g} (W/Kg)	SAR_{10g} (W/Kg)
Visible Man	119.88	239.76	30.03	15.74
Visible Woman	96.05	192.09	35.28	17.90
NORMAN	71.78	143.57	29.71	29.16
NAOMI	64.84	129.67	65.59	43.27
Duke	71.86	143.73	37.63	27.06
Ella	58.70	117.40	52.04	26.22



Visible Man   Visible Woman   NORMAN   NAOMI   Duke   Ella

Fig.3. SAR distribution at central sagittal plane for different human body models