Poseable Male and Female Numerical Body Models for Field Calculations in MRI

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INTRODUCTION: Numerical models of the human body are used increasingly for engineering and safety assurance in MRI [1-8]. However, the different subject geometries [1] and different body positions can dramatically affect the SAR distribution. Due to limitations in available body model positions some researchers have resorted to removing portions of the arms to eliminate contacts between the hands and the torso [7, 8]. In this paper, we apply our recently-developed methods for making models poseable to investigate effects of arm position on the SAR distribution for thoracic imaging at 64MHz (1.5T) in a whole-body high-pass birdcage coil.

METHOD: Three-dimensional anatomical data was obtained from previous manual segmentations [1, 2] of the digital photographic data in the Visible Human Project (National Library of Medicine, Bethesda). To make the models poseable, each voxel is associated with a particular body segment, and joints throughout the body are identified. Desired angulation of all joints is defined on a digital stick figure in our "Varipose" (Version 1.2; REMCOM; State College, PA) interface, then the new position of each voxel in the anatomical dataset is calculated. Some simple algorithms are then applied to ensure continuity of tissues and skin in the new model. 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 male and female human models were positioned with the heart on the central axial plane of the coil and the back (patient bed) 10 cm away from the center of the coil. Field calculations were performed for three different positions of the male model as shown in Fig.1. Two different preliminary model positions for the female model are also shown in Fig. 1. Field calculations were performed using commercially-available finite-difference time-domain software ("xFDTD"; REMCOM; State College, PA). The coil was driven with 48 current sources was placed in the endrings and a 15-degree phase-shift was set between each adjacent rungs. This method has shown practically identical results to driving the coil on resonance in quadrature at either two or four locations at up to 128 MHz [2]. Results were normalized as to produce a 2μT average B_1^+ magnitude (corresponding to a 3ms 90° pulse) on the axial plane passing through the center of the heart.

RESULTS AND DISCUSSION: The SAR distribution (at model resolution: $5x5x5mm^3$) on the axial plane passing through the center of the heart and the whole body average SAR for three different positions of the male model are shown in Fig.2. As expected, having the arms at the sides results in notably lower SAR levels than when the hands are resting on the abdomen (with skin-to-skin contact), as in the "Original" position, and extending the arms above the head and out of the body coil results in significantly lower SAR than either of these other positions. Many other positions, including bending of the legs, neck, and fingers are also possible. We have begun work on making the female model poseable also, but this is not complete. Clearly, the ability to adjust the body position in numerical models can have tremendous value for field calculations in MRI engineering and safety assurance, including both coil and pulse design.

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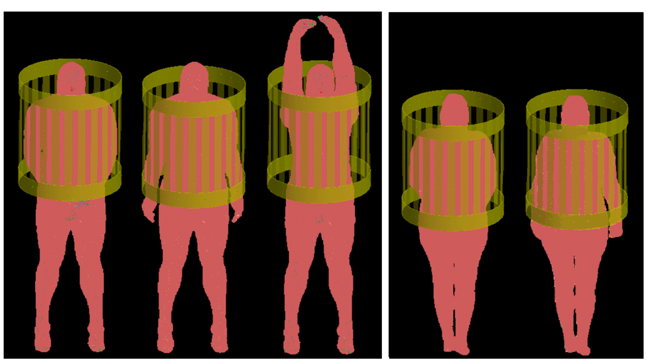

Figure 1 Male model (left frame) in "Original," "Arms at Sides," and "Arms Up" positions, and female model (right frame) in "Original" and preliminary "Hands at Sides" positions.

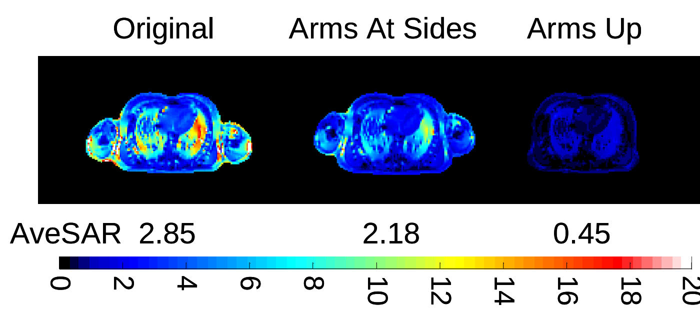

Figure 2 SAR distribution on the axial plane passing through the center of the heart when average B_1^+ magnitude on this plane is 2μT for three different body positions of the male model. Color scale is at bottom of figure, and whole-body average SAR for each position is given under the distribution plot. All values are in W/kg.