Numerical evaluation of SAR within whole-body pregnant woman models in MRI birdcage coil

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Introduction

To ensure that the RF energy absorbed by human subjects during an MRI procedure does not cause hazardous body temperature increase, regulatory committees have developed limits on local and whole body average SAR[1]. These limits have been proven to be reasonable for adults. However, their applicability for a pregnant woman, fetus or child needs to be further investigated. Some previous numerical studies on pregnant women showed promising results as well as pitfalls[2-5]. For example, truncated body models [2,3] or anatomically simple geometries [4,5] had been used to define the fetus. These approximations have resulted in potential uncertainties in the SAR evaluation. It is also clear that whole-body pregnant woman models at different gestational stages should be adopted to evaluate the SAR variation. This paper describes the application of a set of pregnant woman models to calculate the SAR and compares the results with those obtained previously.

Method

This study has adopted three pregnant woman models, which represent the gestational stage at the end of 3, 6 and 9 months, respectively[6]. The original data sets were in 542x290x1631, 546x381x1631 and 553x420x1633, respectively, at $1mm^3$ isometric voxel resolution with 36 tissue types. They were resampled and adapted 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 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. For clinic whole body scan, the pregnant woman models were positioned with her torso inside the coil(top end-ring is just below the chin). And the back of the model is always placed 12cm away from the coil. The geometry of the coil and body are shown in Fig.1 with shield hidden. The pregnant woman models and the coil were meshed in $5mm^3$ resolution from the perspective of computer calculation time and memory. The central sagittal slices are given in Fig.2. With the increase of fetus size and the growth procedure at gestational phase of 3, 6, and 9 months, the belly becomes closer to the coil rungs and end-ring which may bring potential safety concern. The coil was driven in ideal case which means 48 current sources were placed in the end-ring elements with 15-degree phase-shift between each adjacent rungs. This method has shown practically identical results of driving the coil on resonance in quadrature at either two or four locations up to 128MHz[7].

Results & Discussion

Results were normalized to whole body average SAR=2W/Kg(normal mode)[1]. The local SAR_{1g} and SAR_{10g} were calculated subsequently. Since the pregnant woman models have different weight, organ shape, and fetus size at different stage, the absorption power and local SAR have obvious difference. The SAR distributions on the central sagittal and coronal plane passing through the center of the heart are shown in Fig.3. The axial plane passing through the fetus head is also given in Fig.3. Obviously, high induced SAR located in the arms, wrist and shoulder areas which close to the coil rungs and end-ring. The high-conductivity liquid surrounding the fetus can increase the power absorption as well. Therefore, higher SAR can be noticed in the liquid and partial fetal soft tissue. The detail comparison is listed in Table I. It is very interesting to see that the maximum local SAR does not increase as the gestational stage increase. This fluctuation could be further investigated by using more pregnancy stage and higher resolution models. On the other hand, the maximum local SAR within the fetus in all stages are below 10W/kg, which appears to be contradictory to the previous study[2]. This is probably because of the birdcage coil (high-pass, low-pass) difference and the pregnant woman position.

Reference

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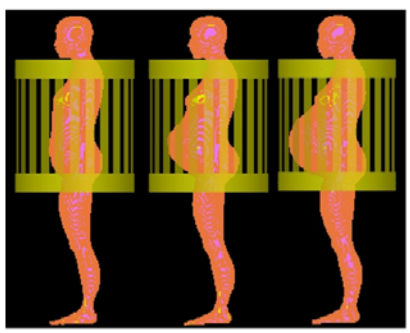

Fig.1. Coil geometry and pregnant woman at three gestational stage:3 months(P3, left), 6 months(P6 middle) and 9 months(P9 right)

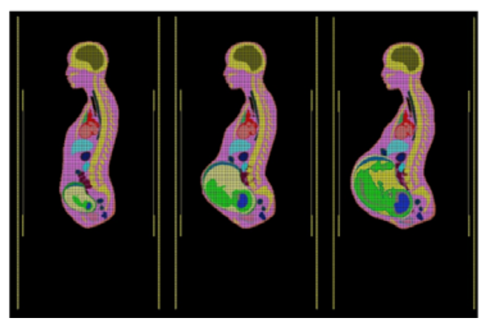

Fig.2.Central sagittal plane of three models:P3(left), P6(middle) and P9(right), respectively.

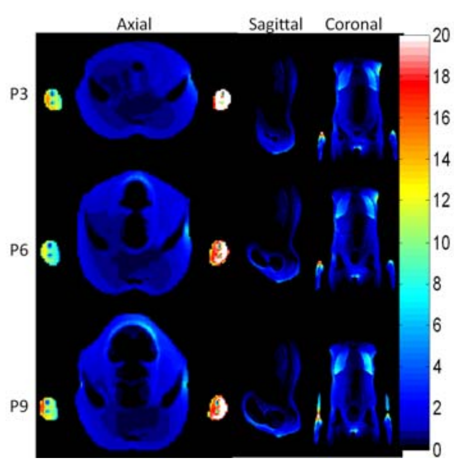

Fig.3. SAR distribution of central sagittal, coronal plane and axial plane passing through fetus head at different gestational stages.

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

Gestational Stage	Mass(Kg)	Absorption Power(W)	SAR_{1g} (W/Kg)	SAR_{10g} (W/Kg)
3 months(P3)	72.58	145.16	21.78	12.51
6 months(P6)	78.03	156.06	24.88	14.60
9 months(P9)	84.31	168.62	18.65	13.04