Analysis of the SAR induced in the fetus at different stages of gestation exposed to plane wave at 900MHz

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INTRODUCTION

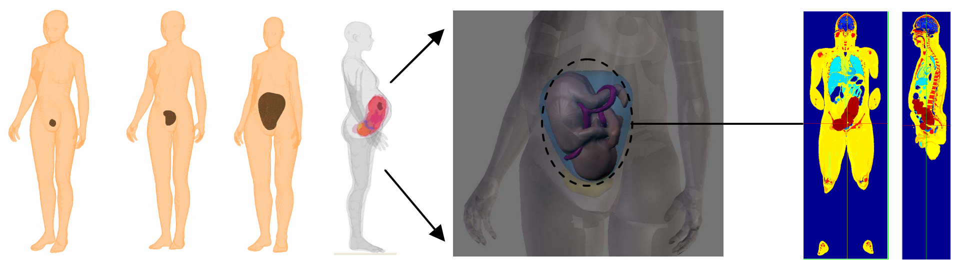
Many wireless systems are more and more present in daily life. More than 5 billions of people over the world are nowadays using devices emitting electromagnetic fields. This paper presents an analysis of the specific absorption rate (SAR) induced by an incident EM plane wave in different fetuses embedded in a homogeneous women model. Moreover, the influence of this homogeneity on the SAR induced in the fetus is assessed. The whole body SAR in the fetus and pregnant woman models are determined using the finite difference in time domain method. The source used for this study is a plane wave (vertical polarization) at 900 MHz.

MATERIALS AND METHODS

The aim of this study is to estimate the SAR induced by an incident EM plane wave in fetuses during pregnancy. For this purpose, we used nine fetus models at different stages of gestation (Tab. 1) and in different positions, in order to simulate several radiation dosimetry studies. Fetuses at the earliest stages of gestation (8 to 13 weeks, composed of only one homogeneous tissue [1]) are built from the segmentation of 3D ultrasound images, while fetuses at later stages of gestation (30 to 34 weeks, composed of 2 to 5 different tissues [2]) are created from the segmentation of magnetic resonance imaging (MRI) [3]. Fetus models are embedded within a synthetic and homogeneous woman model called Victoria (Fig 1.a), provided by DAZ Studio (www.daz3d.com). To analyze the influence of the model homogeneity on the SAR induced in the fetus, we also inserted the fetus at 34 weeks into the visible human (VH) model and the female model Naomi, without deformation (Fig 1.b).

Age (weeks)	8	9	10	13	30	32	32	33	34.5
Fetus weight (grams)	0.5	2.7	5.7	36.7	1719	1913	1053	1964	2659
# of tissues in the fetus	1	1	1	1	3	3	2	2	5

Table 1. Fetus model at various stages of gestation.



a. 9 weeks 13 weeks 30 weeks 34.5 weeks b. fetus in theVH model

Figure 1. A 3D fetus placed in the deformed virtual woman body and in the VH model.

RESULTS

The whole body (wb) SAR has been estimated for 9 fetuses at different ages from 8 weeks to 34 weeks embedded into Victoria. Table 2 shows that the whole body SAR is lower in the fetus than in the mother. The exposure does not increase with the age of the fetus. Differences observed in fetuses during the third trimester of pregnancy depend on the position of the fetus and on the fetus morphology. The mean ratio of the whole body SAR between the fetus and the pregnant woman is 0.35 with a standard deviation of 0.27. This means that the whole body exposure in fetus is 3 times below the whole body exposure induced in the maternal model.

Age (weeks)	8	9	10	13	30	32	32	33	34.5
SAR wb (mW/kg) (pregnant woman)	7.6	7.6	7.6	7.6	6.1	6.4	6.4	5.5	6
SAR wb (mW/kg) (fetus)	**5.5**	**7**	**1.5**	**1.7**	**1**	**1.6**	**2**	**1**	**1.1**

Table 2. SAR in the fetus and in the pregnant woman at 900MHz.

After the fetus positioning in the VH and Naomi, the fetus is exploited to mask the models and to define a volume called the “local fetus”. This volume is either heterogeneous (filled with the models organs) or homogeneous. Table 3 shows that considering a homogeneous model for the mother can underestimate the exposure in the fetus. When the model of the VH is heterogeneous, the variation on the SAR induced in the fetus considering either the heterogeneous local fetus or the homogeneous local fetus is not significant. When the VH is homogeneous, the variation on the SAR in the real fetus and heterogeneous local fetus is also not significant. The SAR wb in fetus at 34 weeks depends on the geometry of pregnant human model, on the morphology of the fetus and position of the fetus.

	SAR wb (mother + fetus) mW/kg	SAR wb (fetus) mW/kg
VH (heterogeneous) & heterog. local fetus	2,87	1.01
VH (homogeneous) & heterog. local fetus	2,33	0.291
VH (heterogeneous) & homog. local fetus	2,87	1.28
VH (homogeneous) & real fetus	2,33	0.334
Naomi ((heterogeneous) & real fetus	4.12	1.64
Victoria (homogeenous) & real fetus	6	1.1

Table 3. SAR in the fetus at 34 weeks and in the pregnant human model at 900MHz.

CONCLUSIONS

A comparison of the SAR induced in a pregnant woman at different gestational stages was performed employing an incident plane wave having a vertical polarization and operating at 900 MHz. The SAR was numerically estimated using the FDTD method. The results suggest that the fetus exposure depends on the fetus morphology, stage of pregnancy and position. The composition of the mother model, heterogeneous or homogeneous, can also induce an important difference on the whole body SAR in the fetus. Further work is needed for definitive conclusion since these simulations have been carried out only for specific cases (specific fetus models with homogeneous pregnant women and two heterogeneous models without deformation). The exploited pregnant woman models will be made freely available to the scientific community, in a near future.

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