ASSESSMENT OF SAR DISTRIBUTIONS INSIDE 10, AND 70 DAYS OLD RATS EXPOSED TO 900MHZ RF

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Introduction:

Accurate determination of the specific absorption rate (SAR) is an important aspect in understanding the interaction between electromagnetic fields (EMF) and living matter. Influences due to dielectric properties, shape, and size of the exposed tissues have been considered to play an important role in the determination of SAR distributions in anatomical rat models [1-2]. Direction and polarisation of exposure were also considered to produce some effect on the SAR values. In order to highlight the effects of the dielectric properties of tissues on SAR values, we compute and compare the SAR distributions of anatomical rat models at different ages. Finite Difference Time Domain (FDTD) technique is used to simulate the models due to its ability to apply Maxwell's curl equations for solving complex microwave problems with reasonable computation requirements [3-5]. Complex FDTD rat models are created in the form of discrete voxels within a space region, based on Magnetic Resonance Imaging (MRI) scans of actual rats. The MRI scans are converted into the FDTD grid structure with 34 different tissue types [6]. Different rat age models are accomplished by resizing the original FDTD model diminutions (voxel sizes) and changing the their dielectric properties according to those measured and published in literature [7]. A FDTD code (used in Gajsek study [1]) is used to assess the amount of energy absorbed by the geometrically complex biological models during RF exposure. This code is used to predict localised and whole-body normalised SAR values (W/Kg per mW/cm²). SAR distributions inside the rat models are calculated by computing the local electric field strengths inside each given tissue type, and feeding these values into equation (1) below:

$$SAR = \frac{s\,|E|^2}{2r} \;\text{(W/kg)} \quad (1)$$

Where the conductivity (S/m) is given by (s), $|E|$ is the amplitude of the peak electric field (V/m), & r is the density of tissue (kg/m³).

It is worth noting the conductivity, and dielectric properties of each tissue type are dependent on the molecular structure, which is highly influenced by the water concentration of cells at different ages. These are also dependent on the EMF frequency [8-9]. In this paper, we determine the implications of permittivity values on predicated whole-body and localised SAR values by examining anatomical models of 10, and 70 days old rats with exposure to 900MHz radiations. The influences of changing tissue dielectric properties of the different organs of each model on SAR values are highlighted.

Methods:

FDTD anatomical model of the Sprague-Dawley rat (mass=334 g, space voxels = 51×22×114, body voxels = 36832), based on magnetic resonance imaging (MRI) data, is used in computing the SAR distributions [6]. Rats of 10, and 70 days old are modelled to examine the influence of aging on SAR data. For each of the rat models, the dielectric properties of tissue types are set similar to those reported earlier [1], however, other tissues influenced significantly due to aging were assigned accordingly (Table 1) [8]. Three different exposure orientations were processed, MEHK, MHEK, and

MKHE (Figure1). The M signifies the negative direction, E, and H represent the electric and magnetic field components respectively, and K represents the direction of propagation. Modelling of rats at different ages is achieved by setting the following:

10 days rat (Size A):
Mass = 16.49 g
Total space voxels = 51×22×114
Body voxels = 36832
Voxel size=0.715×0.715×0.789mm
Dielectric properties: (table 1.a – 10 days properties)

70 days rat (Size B):
Mass = 274.97g
Total space voxels = 51×22×114
Body voxels = 36832
Voxel size=1.827×1.827×2.015mm
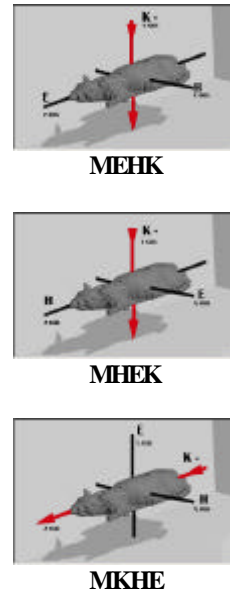Dielectric properties: (table 1.a – 70 days properties)

MEHK

MHEK

MKHE

Figure 1, Orientations of exposure

Results:

The normalised whole-body averaged SAR (W/kg per mW/cm²) of all exposure orientations were computed (Table 2.a). For each of the 10, and 70 days old models, it was noticed that the whole-body averaged SAR values vary depending on the orientation of exposure. The maximum averaged SAR was detected at the MEHK orientation. Variations of the SAR values due to orientation are considered to be a result of the coupling between the EM fields and the partly conductive body. The maximum possible coupling occurs when the size of the body is of the same order of magnitude as the wavelength of the field and when the body is aligned so that the long axis is in the direction of the electric field.

The whole-body averaged SAR for each of the 10 and 70 days old rats were in the MEHK orientation were 0.45, and 0.46 (W/kg per mW/m²) respectively. These SAR values are not notably affected by changing the dielectric properties of localised tissues, however, these can be significantly influenced if that tissue type occupies a large region of the body. Maximum localised SAR values (W/kg per mW/m²) of the 10, and 70 days old rats are presented in table 2.b. Alteration of the relative permittivity and conductivity properties of the different organs result in significant variations of their maximum localised SAR values. The influence of tissue conductivity and permittivity variations on localised SAR can be described by recalling equation (1). The SAR values are directly proportional to the conductivity of the tissues and to the square of the internal electric field strength. The electric field strength is inversely proportional to the relative permittivity of the material. However, SAR values are not always describable in terms of the local dielectric properties since the internal electric field strength distributions are significantly altered when changing the neighbouring tissues properties. This reflects the significant increase in the muscle SAR values (Table 2.b).

The SAR distributions inside the 10, and the 70 days old rats are shown in figure 2.

Organ	10 days old		70 days old	
	Relative permittivity e_r	Conductivity s (S/m)	Relative permittivity e_r	Conductivity s (S/m)
Bone	30.97	0.52	17.22	0.24
Brain	59.36	1.01	44.22	0.68
Muscle	61.93	1.18	49.02	0.89
Skin	39.76	0.76	30.38	0.53

Table 1. Influence of age on tissue dielectric properties (values used for dosimetry)

	10 days old			70 days old		
	MEHK	MHEK	MKHE	MEHK	MHEK	MKHE
Whole body averaged SAR (W/kg per mW/cm²)	0.45	0.06	0.03	0.46	0.24	0.38

Table 2.a. Normalised whole body averaged SAR for the 10, and 70 days old rats exposed to 900MHz from different orientations.

Organ	10 days old			70 days old		
	MEHK	MHEK	MKHE	MEHK	MHEK	MKHE
Bone	1.75	0.83	0.18	0.74	0.47	0.48
Brain	1.26	0.03	0.06	0.31	0.20	0.72
Muscle	3.19	2.06	0.38	5.55	1.76	3.77
Skin	6.70	2.33	1.21	2.52	1.85	2.44

Table 2.b. The maximum SAR in organs (900MHz exposure from different orientations)

(a) 10-days old model

0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 6.5 **Max. SAR (W/kg per mW/cm²)**
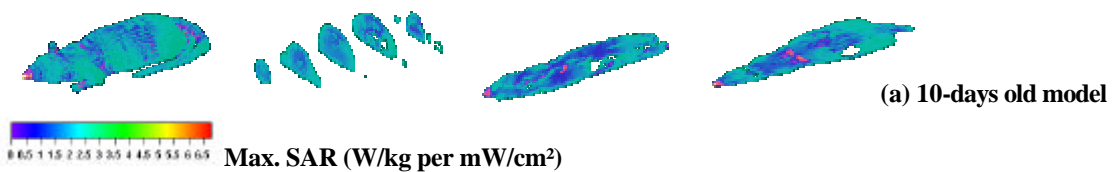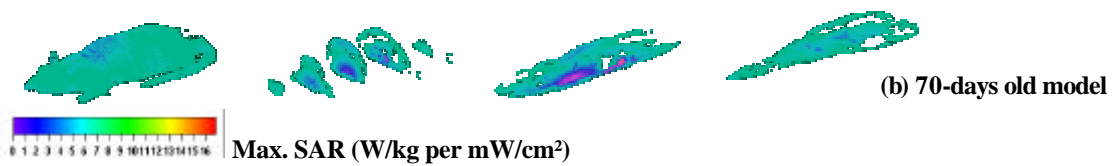
Fig.2, Distributions of the max. SAR (W/kg per mW/cm^2) for each rat model exposed to 900MHz. (MEHK)
Surface body, coronal, vertical and horizontal sagittal respectively.

(b) 70-days old model

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 **Max. SAR (W/kg per mW/cm²)**

Conclusions:

Finite Difference Time Domain (FDTD) technique was used to simulate rat models at different ages. Complex FDTD rat models are constructed from MRI scans, 34 different tissue types were assigned. Rat models at different ages were modelled by resizing the voxel sizes of the original MRI model, with changing the tissues dielectric properties. Results have highlighted the fact that localised SAR distributions can be significantly effected when changing their dielectric properties. It was also noted that changing the dielectric properties of neighbouring tissues could also influence the localised SAR values of unchanged tissue properties. The whole-body averaged SAR is not notably affected by changing the dielectric properties of localised tissues, however, can be significantly influenced if that tissue type occupies a large region of the body. Further SAR dosimetry is required to investigate the dielectric properties of wider range of tissues.

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