INFLUENCES OF AGE DEPENDENT TISSUE PARAMETERS AND ANATOMICAL STRUCTURES ON SAR AND TEMPERATURE INCREASE IN THE HEADS OF CELLULAR PHONE USERS

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ABSTRACT

This study assesses the influence of the head anatomy and tissue properties on the energy absorption and temperature increase of mobile phone users. Anatomically correct head models from different age groups (children and adults) have been used, as well as age dependent dielectric tissue properties and typically used thermal parameters. The 10g peak spatial Specific Absorption Rate (SAR) and the exposure of subregions of the brain were analyzed. Results could not establish a correlation between the maximum 10g SAR and the age of the model for similar thicknesses of the pinna. However, the exposed functional subregions exhibited significant changes.

1. INTRODUCTION

The increasingly prevalent usage of mobile phones among young people in recent years has raised concerns about the possible health risks of these devices. The validity of current compliance testing standards using the SAM phantom [1, 2] for the smaller heads of children as well as possible differences in local exposure of certain brain regions due to anatomical changes during adolescence has been a subject of debate. The use of anatomically correct child head models has been indispensable to reduce the uncertainty of the numerical evaluation of the SAR distribution in children [3]. The impact of the size and shape of the head have been studied under many different exposure conditions, as reviewed in [4]. However, the dielectric properties of tissues are also a key parameter in determining the absorption in the near-field of transmitters [5]. Recent data based on measurements in animal tissue show that tissue properties exhibit a strong dependency on the age of the subject [6]. Thus, there is an urgent need to assess their influence on the SAR and the temperature distributions in children head models. This paper discusses the impact of age dependent tissue properties and head models on the SAR distribution. Thermal simulations and measurements are also introduced.

2. OBJECTIVES

The aim of this project is to evaluate the age dependent effects of the RF energy absorption in the heads of mobile phone users. Various age dependent head models and dielectric tissue properties are considered to:

- numerically assess the 10g spatial peak SAR in the head as a function of the head anatomy, in particular of the thickness of the pinna, and of age dependent changes of the dielectric tissue parameters
- evaluate the exposure of certain brain structures, such as hippocampus, hypothalamus, pineal body, etc.
- experimentally validate the peak spatial average SAR during mobile phone use with developed child head phantoms
- numerically and experimentally evaluate the temperature increase in adults and children due to mobile phone use

3. METHODS

3.1. Exposure Scenarios

Four different anatomical head models (3 children and 1 adult) were placed in the "touch" and "tilted" positions, according to [7]:

- a 3 year old girl model based on MRI images [3]
- a 6 year old boy from the Virtual Family project [8] (see Figure 1)
- an 11 year old girl from the Virtual Family project [8]
- the Visible Human model, based on cryosection images of a 38 year old male [9]

All heads were exposed to the radiation of three different telephone models (two generics and one commercial, Motorola T250 [10]) with integrated, helical and monopole antennas. The peak spatial average SAR and the brain regions exposed were evaluated for different tissue parameters (Section 3.2) under all exposure configurations, such that almost 200 different exposure scenarios were evaluated.

Figure 1 head model of the 6 year old child with the T250 phone in touch position

3.2. Tissue parameters

Every head model was assigned four different sets of dielectric tissue properties, each corresponding to one specific stage of tissue maturity:

- mature tissues: parameters set according to the Cole-Cole parametric model described in [11]
- young tissues: parameters based on tissue measurement of pigs of different age groups (body weights between 10kg and 250kg) [6]

The thermal properties of the tissues cover the range as specified in recent literature overviews [12, 13].

3.3. Computational methods

All the numerical evaluations were conducted using the Finite-Difference Time-Domain (FDTD) simulation platform SEMCAD X (Schmid & Partner Engineering AG, Switzerland). Non-uniform meshes were generated, using step sizes between 0.5mm and 1.5mm in the heads, which led to a simulation time up to 2 hours. For all the simulations, the power budget, i.e. the ratio of the radiated and absorbed powers on the input power, was more than 97%.

3.4. Experimental methods

Two experimental child head models were manufactured based on the external shapes of the heads of a 3 year old and of an 8 year old child. The heads were filled with standard simulating liquids and exposed to generic phones with monopole antennas (900MHz and 1800MHz) and the previously mentioned T250 phone (GSM900 and

GSM1800 bands) in the touch and tilted positions. Dosimetric evaluations were conducted using the DASY 5 NEO system.

4. DOSIMETRIC RESULTS

4.1. Spatial peak 10g SAR in the head

The maximum 10g peak spatial SAR in the head exposed to the FDA phone at 900MHz is presented in Figure 2. The results are normalized to 1W input power, which is approximately four times higher than the usual power of a standard mobile phone. Whereas the thickness of the pinna has a strong impact on the peak spatial SAR, a general correlation with age dependent changes of the tissue parameters or the size of the head could not be established. The maximum deviations of the peak spatial SAR observed were less than ±30% when the pinna thickness remained unchanged. They are therefore not larger than intersubject variations [7]. The simulations were validated experimentally using the child head phantoms mentioned above. The experimental assessment also revealed that the SAM phantom leads to a conservative peak spatial SAR evaluation with respect to children. The evaluation of the impact of the pinna thickness is ongoing.

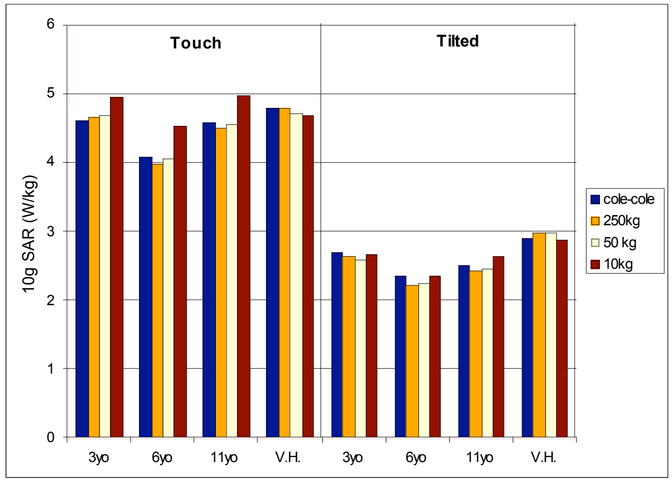

Figure 2 Maximum 10g SAR in the head exposed to a generic phone with monopole antenna at 900MHz (normalized to 1W input power).

4.2. Spatial peak 10g SAR in the brain

Depending on the characteristics of the current distribution of the phone, the exposure of the brain tissues of the 3 year old child exhibited significant changes when compared to the adult brain. A case study (Figure 3) shows an increase of the SAR in the brain tissue of a child model by more than 400% in comparison to the adult model, depending on the distance between the current maximum on the phone case and the cerebellum. In general, the distance between the current maximum and the exposed subregion of the brain is the most relevant parameter for the absorption.

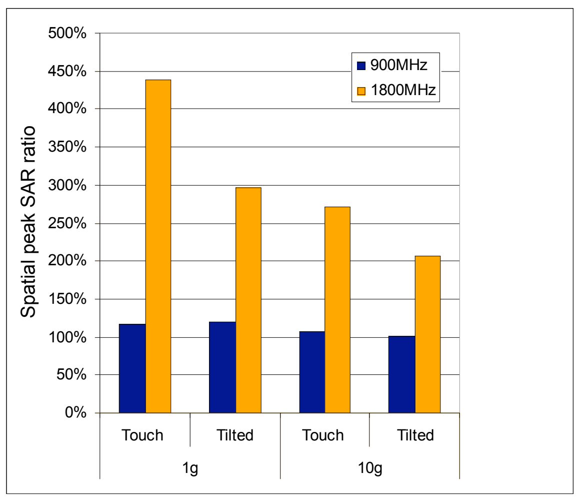

Figure 3 Ratio of the 1g and 10g spatial peak SAR of the 3 years old child to the adult exposed to a generic phone with integrated antenna. The location of the current maximum on the phone changes at 1800MHz leading to an increase of the exposure of the cerebellum of the child.

5. EXPERIMENTAL EVALUATIONS

In order to correlate the SAR with a possible increase of the temperature of the tissues of the head, thermal simulations and thermal measurements on volunteers were performed. The simulations relied on thermal tissue parameters from the literature [12, 13], arranged in three categories: average values, best case and worst case.

For the *in vivo* measurements, 16 adults (20 to 30 years old) and 16 children (6 to 10 years old) volunteers were used. The set-up consisted of two phones in the touch position, the generic phone on the right side and the T250 phone on the other side. Both phones operated at a frequency around 900MHz. To prevent heating of the phone due to losses in the battery and the electronic components, the generic phone was fed by an external amplifier. The input power was adjusted for a maximum peak 10g SAR of 2W/kg. The Motorola phone was set to its maximum power, which corresponds to 0.6W/kg maximum peak 10g SAR. One temperature probe was placed in one ear using an ear plug and a second one was taped to the cheek 4 cm from the ear canal. Following a detailed protocol, the phones were turned on and off for 7.5 minutes, twice on each side.

The measurements showed that the thermal heating due to increased handset temperature is much more significant than any temperature increase due to the absorption of radiation. The measured temperature increase in the auditory canal and on the cheek induced by the absorption of the electromagnetic fields was less than 0.3°C.

6. DISCUSSION AND CONCLUSION

As different exposure scenarios lead to a different impact on the SAR relative to the age of the head model and the tissue properties, it is not possible to establish a correlation of the maximum 10g SAR with age for similar thicknesses of the pinna. The thickness of the pinna as function of age is currently being assessed and the effect of the exposure, in particular on the functional subregions of the brain, will subsequently be evaluated. Based on current results, significant differences are expected. More complete data on the temperature increases will also be available in June.

7. ACKNOWLEDGMENTS

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