COMPARISON AND EVALUATION OF LOCAL PEAK SAR IN REALISTIC HUMAN HEAD MODELS OF ADULT AND CHILDREN FOR MOBILE PHONES

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ABSTRACT

The controversy between Gandhi's and Kuster's groups on the dosimetry in children's heads for mobile phones is still inconsistent. With employing two Japanese children's head models, we calculated the peak SAR under the same conditions as those of the two groups. Comparing to the peak SAR in the adult head, we found a considerable increase in the children's heads when we fixed the output power of the monopole antenna, but no significant differences when we fixed the effective current of the dipole antenna. This finding suggests that the contradictory conclusions drawn by the two groups may be due to their different calculation conditions.

INTRODUCTION

The children's use of mobile phones is increasing, while the dosimetric results in children's heads are still inconsistent. In 1996, Gandhi et al. reported a deeper penetration and considerable increase in the local peak specific absorption rate (SAR) in children's heads by using two scaled child models. An increase of 50% in the one-gram averaged spatial peak SAR was found in a scaled 5-year-old child model for a quarter-wavelength monopole antenna mounted on a metal box [1]. On the other hand, Kuster et al. developed two child head models from magnetic resonance imaging (MRI) data in 1998, and conducted similar calculations. Their results revealed no significant differences in the peak SAR between adults and children for a 0.45λ dipole antenna, and this conclusion holds also when children are approximated as scaled adults [2]. To make this contradiction clear, we followed their calculations with two newly developed Japanese child head models.

HEAD MODELS

In general, a child head is not a simple scale of adult. The developmental changes in the anatomy of various organs follow a quite different course. To obtain a better approximation of the child head model from a scaled adult head, we used children's statistical database on external shapes of heads, as given in Table 1 [3], in the scaling process. For different parts of the head we employed different scaling factors. In such a form, we newly developed a 7-year-old and a 3-year-old child head models from an MRI-based Japanese adult head model [4]. Fig.1 shows these head models, each of which consists of 17 tissue types with a resolution of 2 mm. Comparing them with the adult head shows that the two children's models are acceptable representations for actual children's heads. Since there are no sufficient data of dielectric properties for children in the literature, we made no distinction between the adult and children. For both the adult and children's models, we therefore employed the same dielectric properties of tissues that were derived with the 4-cole-cole extrapolation from Gabriel's data [5].

CALCULATION METHOD

Using the finite-difference time-domain (FDTD) method together with the two children's head models scaled with statistical databases, we calculated the local peak SAR under the same conditions as those previously employed by

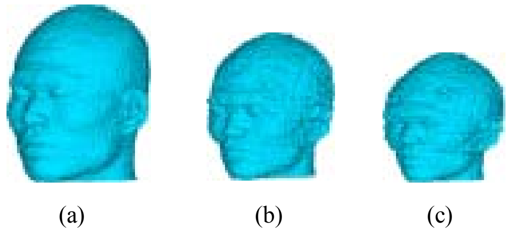

Fig.1 Head models. (a)Adult model, (b) scaled model with 7-year-old database, (c) scaled model with 3-year-old database.

Table 1 Statistical data for various parts of head

	Adult [cm]	7 years old[cm]	3 years old[cm]
Head length	18.8	17.3(92%)	16.2(86%)
Head breadth	16.0	14.9(93%)	13.9(87%)
Bizygomatic breadth	15.0	13.3(89%)	12.5(83%)
Bigonial breadth	11.6	9.5(82%)	8.8(76%)
Vertex-pupil height	11.5	11.1(97%)	10.5(91%)
Pupil-stomion height	7.5	6.0(80%)	4.2(56%)
Stomion-gnathion height	4.7	3.7(79%)	2.6(55%)

( ): scaling factor

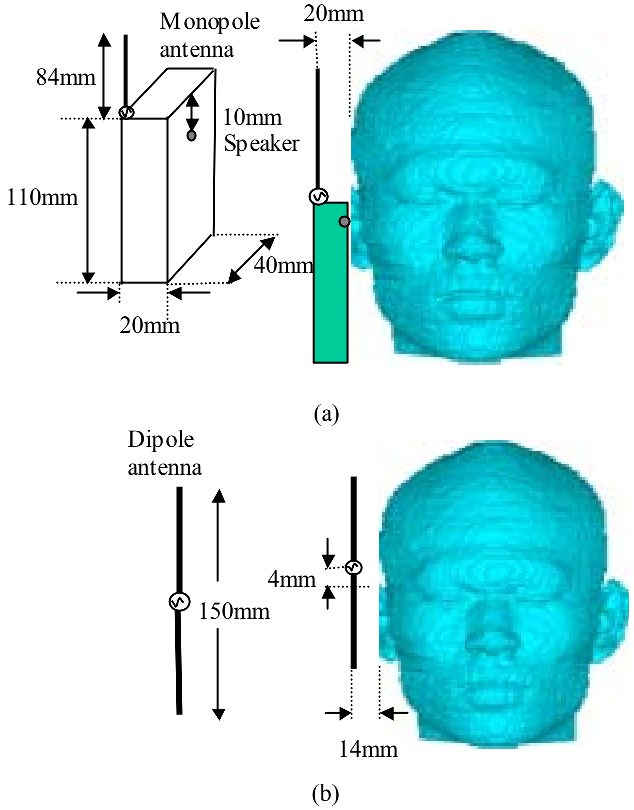

Fig. 2 Configuration of antennas for SAR calculation.
(a) λ/4 monopole antenna, (b) 0.45λ dipole antenna.

Gandhi's and Kuster's groups. Under the Gandhi's condition, a quarter-wavelength monopole antenna mounted on a rectangular metal box was employed as a mobile phone model. The SAR values were given for an antenna output power of 0.6 W. Under the Kuster's condition, a 0.45-wavelength dipole antenna was employed. The SAR values were given for an effective antenna current of 100 mA_{rms}. In both the two cases, the frequency was 900 MHz. The ear was pressed to simulate an actual use situation of mobile phones. Fig. 2 shows the details of arrangement for antennas and head models. It should be noted that our calculation conditions were quite identical to the Gandhi's or Kuster's ones, although there were some slight discrepancies such as that the frequency was 835 MHz in Gandhi's calculation but 900 MHz in ours.

In the FDTD calculations, we chose the size of cells equal to 2 x 2 x 2 mm. We fed the antenna using a sinusoidal voltage source, and calculated the current flowing through the voltage source cell by integrating the magnetic fields around the voltage source according to the Ampere's law. The input impedance of antenna was then derived from the ratio of the voltage and the current together with their phase difference. To absorb the outgoing scattered waves, we employed twelve perfectly matched layers (PML) at the boundaries of the calculation domain.

RESULTS AND DISCUSSION

Fig. 3 shows the one-gram and ten-gram averaged spatial peak SARs for the various head models under the Gandhi's condition. The one-gram and ten-gram averaged spatial peak SARs were derived by shifting a cube of 1 x 1 x 1 cm (1 cm^3) and a cube of 2.2 x 2.2 x 2.2 cm (10.6 cm^3), respectively, across the head volume and computing $\sigma E^2/2\rho$ (σ: conductivity; ρ: tissue density) averaged over the cubes at every position. More than 90% of the space was tissue in the above two cubes. As can be seen from Fig. 3, a considerable increase in the peak SARs was observed in the children's head models. For the 3-year-old head model scaled with the statistical database, we found an increase of 31.5% in the one-gram averaged spatial peak SAR and 21.6% in the ten-gram averaged spatial peak SAR compared to the adult head model. Fig. 3 also gives with closed bars the one-gram averaged peak SAR calculated by Gandhi's group for scaled head models. It can be found that our results are similar to Gandhi's ones. Moreover, Fig. 3 gives the effective antenna current I_a and the antenna input impedance Z_{in}. As can be seen in the figure, with the decrease of the head size, the antenna input impedance decreased and consequently the antenna current increased because we fixed the antenna output power at 0.6 W. The increase on the antenna current should yield stronger magnetic fields in the vicinity of the antenna. According to the energy absorption mechanism that the SAR in an exposed head is mainly related to the magnitude of magnetic near field [6], an increased peak SAR in the children's heads is understandable.

Fig.4 shows the one-gram and ten-gram averaged spatial peak SARs for the various head models under the Kuster's condition, which demonstrates no significant differences between the adult and children's models. The maximum differences between the adult and children were within 10% for both the one-gram and ten-gram averaged spatial peak SARs. These results are similar to Kuster's ones that are represented with closed bars in Fig. 4, and support their conclusion. Fig 4 also gives the antenna output power P and the antenna input impedance Z_{in}. As can be seen in the figure, the variation on the antenna input impedance and consequently the antenna output power were insignificant (within 4%) for different head models in this case. The phenomenon of the similar peak SAR levels between the adult and children's heads may attribute to the fixed antenna current and insignificant variation in the input impedance of the 0.45λ dipole antenna.

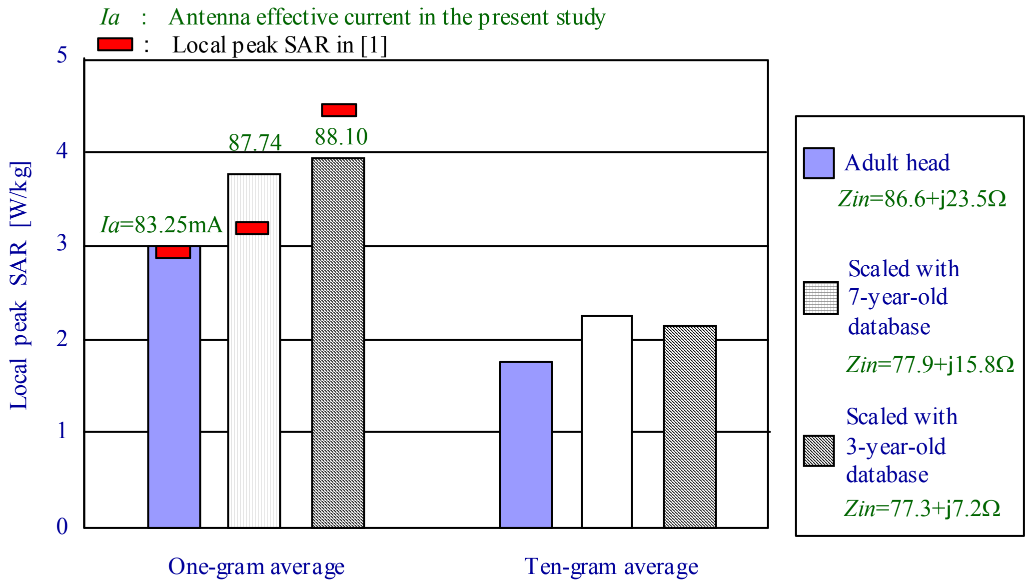

Fig. 3 Local peak SARs for the λ/4 monopole-type antenna with an output of 0.6W.

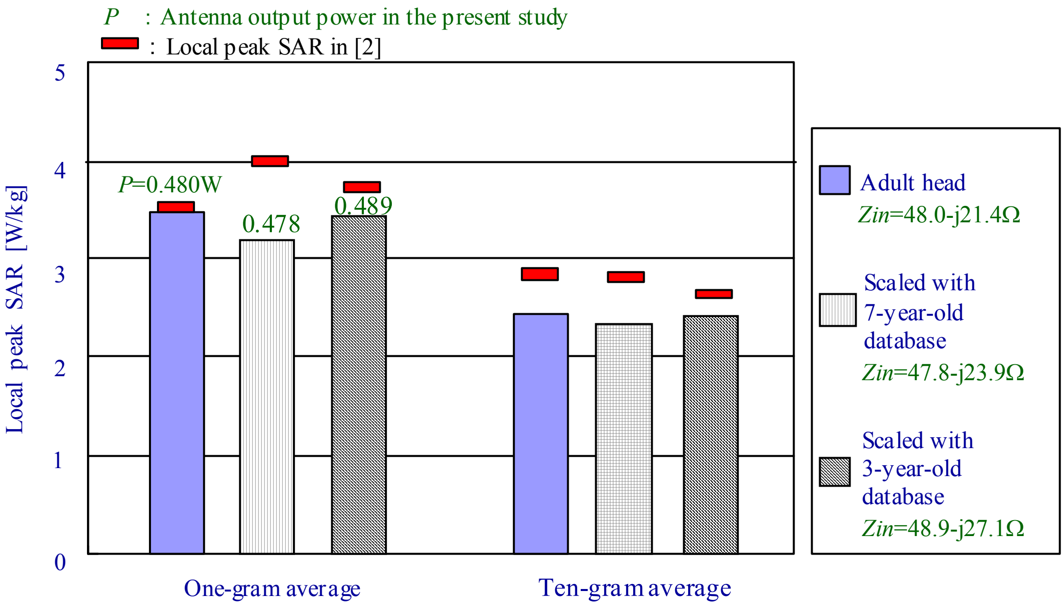

Fig. 4 Local peak SARs for the 0.45λ dipole antenna with an effective antenna current of 100 mA_{rms}.

CONCLUSION

In conclusion, in comparison with the local peak SAR in the adult head model, we found a considerable increase in the SAR for children's heads when we fixed the output power of the monopole-type antenna (Gandhi's conditions), but no significant differences when we fixed the input current of the dipole-type antenna (Kuster's conditions). This finding suggests that the contradictory conclusions drawn by Gandhi's and Kuster's groups may be due to the different conditions in their numerical SAR evaluations. A future subject is to elucidate the determinant for the local peak SAR evaluation of children.

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