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Specific Absorption Rate and Temperature Rise in the Abdomens of Pregnant Woman Models Exposed to a Smartphone Radiation

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Abstract

Today, public concerns regarding the influence for the human body exposed electromagnetic (EM) waves have been increasing. Smartphones have been spreading rapidly in recent years, and they are used for many purposes such as a voice communication and a data communication, unlike the conventional type of mobile phones. Therefore, the dosimetry of EM radiation from the smartphone held at near the human abdomen is necessary. Particularly, the situation when pregnant women use smartphones close to their abdomen was very important issue, because their abdominal structure changes significantly according to the progress of the gestational weeks, and fetus is in their uterus. In this study, we estimated specific absorption rate (SAR) and temperature rise in pregnant and their fetus when they use smartphones in front of the navel by computer simulation. As a result of this study, SARs in the maternal body increased with gestational progress. SARs in the fetus were changed regard of the positional relationship between the smartphone and the fetus. Temperature rise at the both the maternal body and the fetus were affected by strongly cooling of the placenta. Moreover, we confirmed both of SARs and temperature rise at fetus were much lower than that at maternal body.

1. Introduction

In recent years, smartphones are one of the most popular mobile phones. They have become indispensable devices to improve a convenience of our lives, a quality of works and a lot of other things. However, some people are concerned with the influence for the human body owing to the electromagnetic (EM) exposure from smartphones, because our lives become largely dependent on smartphones. Therefore, the dosimetry of EM radiation from the smartphone is today's important issue.

Smartphones have a greater number of functions compared with conventional types of mobile phones. Conventional types of mobile phones are mainly used for the voice communication near the head. On the other hand, smartphones are used for data communication held at near the torso. Heretofore, most studies evaluated the specific absorption rate (SAR) when the EM source was placed at closed to the human head. Therefore, we constructed a realistic computational smartphone model in previous study [1], and then we evaluated the 10-g-averaged SAR in Japanese male and female adults by numerical simulation when the smartphone was placed in front of the torso. As a result of the previous study, we confirmed that the SAR in the human body was lower than the limiting value (2 W/kg) established by the International Commission on Non-Ionizing Radiation Protection [2]. Moreover, we confirmed that the SAR was varied dependent on tissue structures close to the placement of the smartphone.

When we assume the utilization of smartphone close to the human abdomen, EM exposure for pregnant women and their fetus are interesting issue, because the abdominal structure changes significantly, and the safety guidelines of the SAR for fetuses has not been determine yet. In this study, we estimated specific absorption rate in pregnant and their fetus when they use smartphones in front of the navel. However, the limitation value applied to the exposure of fetuses has not yet defined. SAR finally achieve temperature rise of the human body. Temperature rise above 1 K in the fetuses of many animals is known to be a cause of adverse effects such as growth retardation [3]. Therefore, we calculated temperature rise in the pregnant and their fetus in this study.

2. Computational model

In this study, we used computational whole body pregnant woman models for gestational ages of 13, 18, and 26 weeks (Fig. 1) developed by Nagaoka et al. [4, 5], and a computational smartphone model (Fig. 2) developed in our previous study [1].

Computational pregnant woman models are composed of 2 mm cubes and 56 types of tissues and organs. Body dimensions of the abdomens of each model are suitable for those of averaged Japanese pregnant women and masses of fetal tissues are also suitable for radiological protection reference values [6].

Computational smartphone model was developed based on a commercially available smartphone with a third generation communication system. The validity of the computational smartphone model was confirmed through the comparison of the SAR distributions between the actual smartphone and the computational smartphone model.

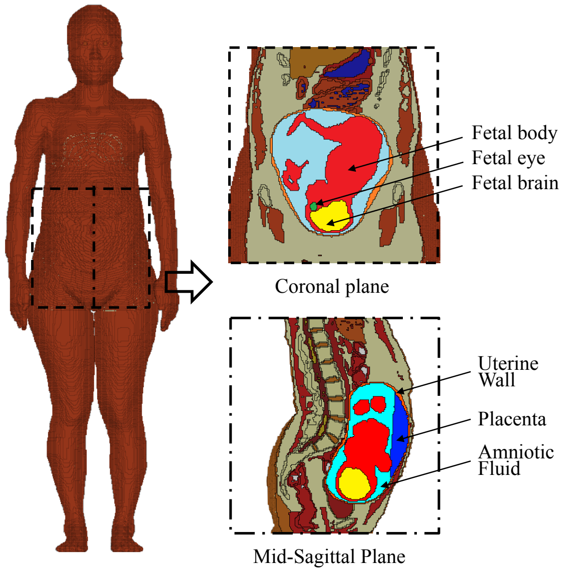

Figure 1. Computational pregnant woman model for 26 weeks gestation.

3. SAR and temperature rise evaluation for pregnant woman and fetus

3.1 Calculation model

Calculation model was shown in Fig. 2. The smartphone model was placed horizontally at the front of the navel of the pregnant woman models. The shortest distance between the surface of the body and the surface of the smartphone was fixed at 10 mm. A perpendicular bisector of the short side of the smartphone corresponded to the median line of the body. Operating frequencies of the smartphone were 900 MHz and 2 GHz, and the maximum radiated power was fixed at 0.25 W in consideration with the maximum power of the third generation mobile communication system.

We calculated the SAR and temperature rise in the calculation model using XFdtd ver. 7.5 (Remcom Inc., State College, PA, USA). Calculation region was divided into approximately 200 million cuboids varying from 0.2 mm to 1 mm each edge. Properties of each tissue and organs in voxel models were taken from [7].

3.2 Results and Discussion

Tab. 1 shows peak 10-g-averaged SAR values in pregnant women and their fetus. 10-g-averaged SAR values in the non-pregnant woman [1] were also shown in Tab. 1. The peak 10-g-averaged SAR at maternal body increased with progress of pregnancy. They were the highest at 26 weeks pregnant. On the other hand, 10-g-averaged SARs in fetuses were the highest at gestational weeks of 18 weeks. Peak SARs at the maternal body and the fetus were confirmed at different gestational weeks. However, SARs in fetuses were up to one forth of values at maternal body.

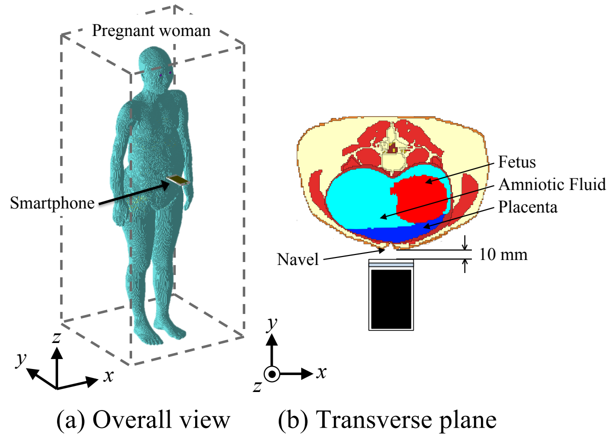

Figure 2. Calculation model intended for using the smartphone for data communication.

In this study, the placement of the smartphone was determined on the basis of the navel of maternal bodies. In the case of 18 weeks gestation, the distance between the smartphone and the fetus is closest. Therefore SARs in the fetus are the highest at 18 weeks gestation. Moreover, SARs at 900 MHz were higher than that at 2 GHz in fetuses, in contrast to SARs at maternal body were higher at 2 GHz. The reason for this difference is mainly penetration depth of the EM waves.

We compared the 10-g-averaged SAR of the smartphone and the results of other terminals [8, 9]. SAR values in the pregnant woman due to the smartphone were lower than those due to other terminals. Similarly, SARs in the fetus due to the smartphone were lower than those due to other terminals. This is because of the difference of the radiation pattern between other terminals and the smartphone. Moreover, unlike the results in this study, SAR in the fetus was the highest at 26 weeks gestation in [8, 9]. In previous studies, positions of terminals were determined in relation to the height of the fetus's head. Thus, the positional relationship between the fetus and the EM source was different between this study and previous studies. We considered that this difference is a reason why the SAR in the fetus due to other terminals were the highest at 26 weeks gestation.

Tab. 2 shows peak temperature rise in pregnant women bodies. The maximum temperature rise due to exposure from the smartphone was 0.06 K (18 weeks, 2 GHz). Fig. 3 shows distributions of temperature rise on mid-sagittal plane of pregnant women for 18 weeks and 26 weeks gestation due to EM exposure from the smartphone operated at 2 GHz. Temperature rise in the fetuses were the highest at the 18 weeks gestation as well as results of SAR. Likewise, temperature rise in the fetuses were highest at the 18 weeks. We also considered that the placenta provide strongly cooling effect. Therefore, when we evaluate the temperature rise in the fetus, positional relationship between the smartphone, placenta, and fetus is considerable important. Finally, we confirmed that temperature rise in the fetuses are lower than that in the maternal body in all of the results.

Table 1. Peak 10-g-averaged SAR values due to EM exposure from the smartphone [W/kg]

@ Mother (@ Fetus)	Non-pregnancy	13 weeks	18 weeks	26 weeks
900 MHz	0.12 (-)	0.115 (0.004)	0.133 (0.035)	0.154 (0.012)
2 GHz	0.19 (-)	0.256 (0.001)	0.219 (0.025)	0.330 (0.006)

Table 2. Peak temperature rise in pregnant women due to EM exposure from the smartphone [K]

	13 weeks	18 weeks	26 weeks
900 MHz	0.025	0.030	0.017
2 GHz	0.053	0.057	0.043

4. Conclusion

We estimated the SAR and temperature rise in the pregnant women and their fetus when they use smartphones close to the abdomen in this study. As a result, 10-g-averaged SARs in the maternal body increased with gestational progress. SARs in the fetus were changed regard of the positional relationship between the smartphone and the fetus. Furthermore, maternal SARs when the smartphone was operated at 2 GHz were higher than that at 900 MHz, however, SARs in fetuses at 900 MHz were higher than that at 2 GHz because the 900 MHz EM wave could deeply penetrate the maternal body.

We considered that temperature rise at 18 weeks gestation were higher than that at 26 weeks gestation, because the placenta provided strongly cooling effect for both the maternal body and the fetus. It means positional relationship between the smartphone, the placenta, and the fetus is considerable important.

Finally, we found that 10-g-averaged SARs in maternal bodies were much lower than the ICNIRP safety guidelines. Maximum temperature rise in maternal bodies was 0.057 K, and then temperature rise in fetuses was lower than that in maternal bodies. Therefore the temperature rise in fetuses were the lower than 1 K significantly.

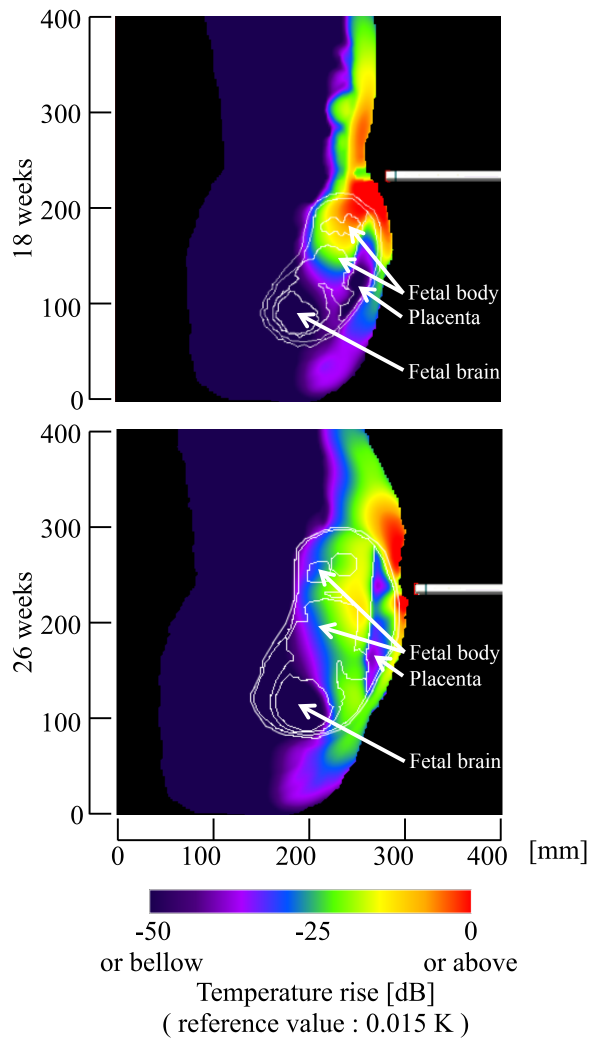

Figure 3. Distributions of temperature rise on the mid-sagittal plane of pregnant women.

5. Acknowledgement

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6. References

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