EXPOSURE ASSESSMENT FOR EPIDEMIOLOGICAL STUDY ON POSSIBLE RISK OF HEAD DISEASES DUE TO MOBILE PHONE USE

Masao Taki[(1)] and Kanako Wake[(2)]
[(1)]Department of Electrical Engineering, Tokyo Metropolitan University
taki@eei.metro-u.ac.jp
[(2)]Communications Research Laboratory
kana@crl.go.kp

ABSTRACT

We discuss the appropriate metric for the epidemiological studies on the possible link between brain tumor and mobile phone use. SAR in the brain could be an appropriate measure even in consideration of non-thermal mechanisms. Distribution of SAR in the head exposed to microwaves from a phone suggests that most part of the brain is exposed less than 1 % of the maximum local SAR in the head, especially when the frequency is above 1.5 GHz. Various factors affecting the exposure are summarized to clarify the issues to be considered in the procedure of exposure assessment in the epidemiological studies.

INTRODUCTION

Epidemiological studies are ongoing in a number of countries to investigate possible association between brain tumor incidence and the use of mobile telephones. These studies are performed as an internationally coordinated project. One of the key issues in these studies is the assessment of the exposure due to the mobile telephone use [1][2].

Appropriate metric of exposure should be established to make reliable exposure assessment. The metric should represent the gradient of exposure to electromagnetic fields (EMF) from mobile phones as exactly as possible. The data for the exposure assessment are collected by the questionnaire, which mainly provide information of the duration and frequency of use, and on the type of devices and systems. The exposure assessment needs careful consideration of the physical and biological interaction of EMF with human body. It also needs consideration on the characteristics of mobile phone devices and the systems.

First question to be answered is what physical quantity is relevant to represent the dose that may be related with the risk of cancer. Then we need to consider various factors that influence the actual exposure. The factors include the types of the telephone devices as well as the pattern of the use such as use in rural /suburban region, moving/stationary condition, and so on. In this paper we discuss the appropriate physical quantity for the exposure metric and various factors that should be considered in the exposure assessment.

PHYSICAL QUANTITY FOR EXPOSURE ASSESSMENT

There is no identified hazard of exposure to microwaves except the effect of heating. The energy of EMF from mobile phones does not produce hazardous temperature rise. So biology does not tell us what physical quantity is essential to represent the exposure which might lead to possible risk of cancer in head. Hence we need to hypothesize some possible scenario for electromagnetic field to act as a cause of tumor, although it is very hard to delineate it explicitly.

One of the favorable hypotheses is that the strongly exposed location is likely to be the primary location of tumor. We do not know, however, what exposure parameter is most essential among specific absorption rate (SAR), internal electric field strength, magnetic flux density, and so on. The exposure guidelines to protect human health limit the maximum local SAR in the head during the use of mobile telephones. This restriction was derived mainly on the basis of thermal effect as SAR was an indicator of heat generation in tissue. In consideration of diffusion of heat from the exposed part to other parts of the body any significant temperature elevation to a hazardous level is not likely to occur by the exposure from mobile phones with small radiation power.

One possible path to cause some effect of thermal origin is that a subtle change of temperature may cause some sensation or change in physiological environment of cells in tissue, which could be enhanced by some kind of positive "biofeedback" to lead a significant change. This might result in subjective symptoms of various kinds including

headache. The effect might possibly be related with generation or growth of tumor though the gap of knowledge is extremely wide. This hypothesis, however, supports the use of SAR as a physical quantity of exposure for the study because it assumes the effect essentially of thermal origin.

We should also consider possibility where some non-thermal mechanism is involved. In this case SAR is not necessarily an appropriate quantity but electric field and/or magnetic flux density in tissue would be more significant quantities to be related with the disease. As the SAR is closely related with the square of internal electric field in tissue, it could be used as a quantity which represents the strength of electric field. We should note, however, that magnetic flux density is not represented by SAR value in general. Fortunately the energy absorption in the head exposed to the field from a mobile phone occurs dominantly through magnetic near-field from the device [3]. In addition incident magnetic field is not significantly disturbed by the presence of the head. Hence we could expect that the internal magnetic flux density is also well correlated with the SAR in the head near the antenna. These considerations suggest that the local SAR at the point of interest should be an appropriate physical quantity to evaluate the local exposure to the EMF from mobile phones even if the internal electric or magnetic field is the essential physical quantity for the possible effect.

Thus evaluation of SAR especially at the primary location of the tumor is considered essential in the exposure assessment for the study whichever of a thermal or a non-thermal mechanism should be involved in the process of possible risk elevation.

TEMPORAL FACTOR

Another question is how to take the temporal duration of exposure into account in the exposure assessment. It is natural to consider that the longer duration of exposure is likely to have potentially the more effect than shorter exposure if the SAR is the same. However, it should be controversial to assume that time integration of the magnitude of exposure is the essential dose metric. For example, we have no evidence to explain that an exposure of twice duration with half strength has the same effect as an exposure of unit duration with unit strength. It is natural that there should be some threshold of the effect in strength and some time constant of the phenomenon in consideration of the known characteristics of the interaction between EMF and body. The problem is that we have no idea of the quantities of the threshold and the time constant as we are dealing with unidentified hazard. As a result we have to implicitly assume both parameters to be zero. This implies that a stochastic-type dose-effect relationship is assumed for the possible non-thermal effect involved in the tumor incidence. We should note that there is no plausible delineation of this assumption but it is only introduced because we have no picture of the mechanism of hazard of non-thermal effect. Considerations of the temporal factor in other ways should further be considered.

SPATIAL FACTOR

It has been recognized that the SAR distribution in the head is highly inhomogeneous during the exposure to the EMF from a mobile phone near the head. So the SAR at the location of tumor is strongly dependent on the location relative to the position of the radiating structure of the device.

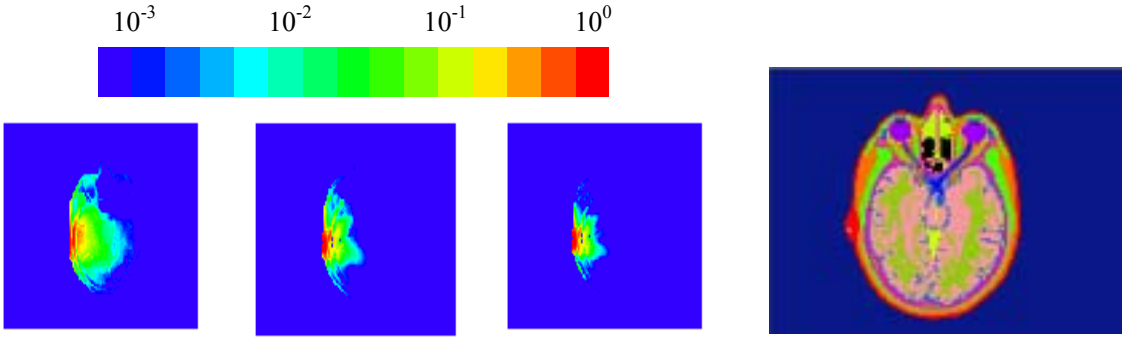

Fig. 1 Calculated SAR distributions in the head during the use of a mobile phone operating at frequencies (*a*) 900 MHz, (*b*) 1,500 MHz, and (*c*) 2,000 MHz. Calculations were made by FDTD method with a numerical head model of 2 mm resolution shown in (*d*).

Figure 1(*a*) - (*c*) show SAR distributions in the head during the use of a mobile phone. They were obtained by numerical simulations at three different frequencies using finite-difference time-domain (FDTD) calculation with a numerical model provided by Brooks Air Force Base (Fig. 1 (*d*)) modified to 2 mm resolution, and a simple phone model of a metal box with a monopole antenna on the box. As is well recognized, larger SARs appear near the ear-base and the SAR decreases quickly as the depth becomes larger into the head. The SAR is more localized for higher frequencies as the penetration depth in tissue decreases with frequency.

Figure 2 shows the relative value of cumulative numbers of voxcels *in brain* with various SARs normalized by the maximum SAR of 10-g average in the head. The result indicates how much volume of brain is exposed at a comparable strength to the maximum local SAR defined in the standard procedure of measurement [4], or the maximum local SAR averaged over any 10-g of tissue. About 7 % volume of the brain is exposed at higher SAR than 10 % of the maximum SAR at 900 MHz and only 2 % and 1 % volume of the brain is exposed more than 10 % of the maximum SAR at 1,500 and 2,000 MHz, respectively. It should be noted that as much as 62 %, 87 %, and 94 % of brain is exposed by less than only1 % of the maximum SAR at 900, 1,500, and 2,000 MHz, respectively.

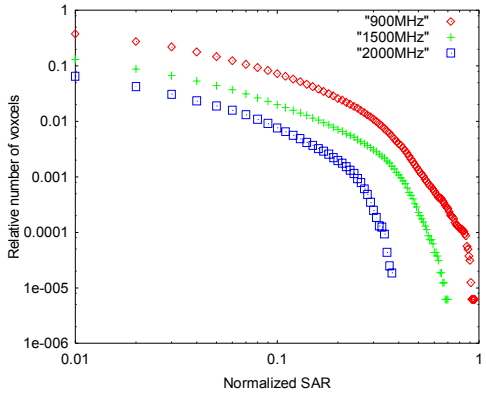

Fig. 2 Cumulative number of voxcels in brain relative to the total voxcels in brain as a function of SAR normalized by the maximum local SAR of 10-g average. The data are derived from the same calculation as those in Figure 1.

DEVICE FACTOR

SAR distribution is dependent on the difference in the design of the individual devices. Each device has its own position and type of antenna, and its own shape of chassis (e.g. flip or non-flip). Phones may be used in different conditions of antenna with extended or retracted. The SAR distribution significantly varies depending on these factors represented by external features or technical specifications. Invisible factors can also affect the SAR distribution such as current flow path in the printed circuit and in the keyboard.

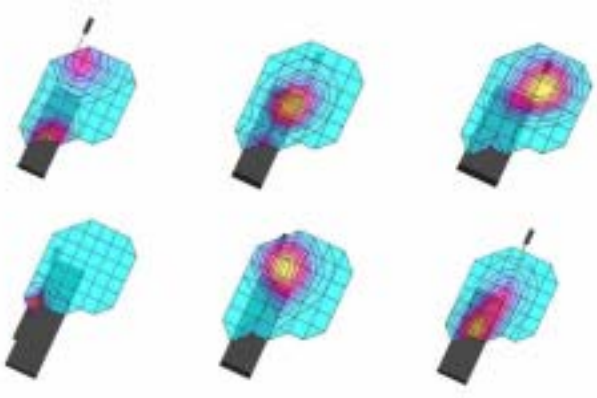

Fig. 3 Typical patterns of SAR distribution for the telephones used in Japan. The data were measured according to the standard procedure of SAR measurement.

Figure 3 shows examples of SAR distributions near the surface of the head obtained by measurement with a standard procedure [4]. The distributions could be categorized into several groups. The category of SAR distribution could be related to the external views of the devices in part [2] but it is not possible to classify the patterns only by the external views.

SYSTEM FACTOR

The SAR value of a device is specified by the measured value at the maximum output power of the device according to the standard procedure. In actual use, however, the output power is controlled depending on the signal strengths and other communication conditions. These characteristics are not recognized by users but we could estimate the pattern depending on the condition of the use. Software Modified Phones (SMP) have been developed and been provided by some manufacturers or an operator (e.g. NTT Docomo in Japan) to record the detailed sequence of power control and other conditions of communication. Data have been collected by volunteers. These data will be taken into account in the exposure assessment. We should note that contribution of power control to the SAR of the user is very significant and may critically affect the exposure assessment. This issue was discussed by Wiart et al. [5].

CONCLUSION

The local SAR in the brain is considered most appropriate quantity to represent exposure of EMF from mobile phones in the epidemiological study on mobile phone and cancer. Several factors should be considered to constitute a metric which relevantly represent the gradient of exposure. These factors include temporal factor, spatial factor, device factor, and system factor. Some of these factors could modify the resultant metric of exposure, though not yet established, more than hundred times. This fact indicates the significance of the analysis of these factors, in addition to the analysis of the quantities of the duration and frequency of the phone use reported by the questionnaire.

REFERENCE

[1] Ardoino L, Bowman JD, Cardis E, Mann S, Vecchia P, Wiart J (2001): Radiofrequency exposure of mobile phone users: The activity of the INTERPHONE study group, Proc. EBEA 2001, pp.90-92.

[2] BenDjebra N, Wiart J, Tabbara W(2001): Statistical analysis and characterization of absorbed power spatial distribution for GSM mobile phones, Proc. EBEA 2001, pp.83-85.

[3] Kuster N and Balzano Q (1992) Energy absorptionmechanism by biological bosies in the near field of dipole antennas above 300 MHz. IEEE Trans. on Vehicular Technology, 41 (1), pp.17-23.

[4] Association of Radio Industries and Businesses (1998): ARIB STD-T56 "Specific absorption rate (SAR) estimation for cellular phone".

[5] Wiart J, Dale C, Bosisio AV, LeCornec A.(2000): Analysis of the influence of the power control and discontinuous transmission on RF exposure with GSM mobile phones. IEEE Trans. EMC, 42 (4) pp.376-385.