Bayesian experiment planning applied to numerical dosimetry

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INTRODUCTION

To protect people from electromagnetic field, Basic Restrictions (BR) are defined [1]. These BR fix a limit to be not exceeded. The metric associated with these BR is the Specific Absorption Rate (SAR). Reference Levels (RL) are also defined since the BR are difficult to check in situ. These RL set the maximum allowed electromagnetic field. The compliance to RL guaranties the compliance to BR.

To evaluate the SAR in the human body, some anatomical models (phantoms) and numerical methods are used (e.g. Finite Difference in Time Domain). Based on this, studies show that for some configurations the Whole Body SAR (WBSAR) is close to BR. Other studies stressed the variability of the WBSAR due to the variability of human morphology [2].

Despite the computing resources development, the number of the phantoms is very limited. This limited number of phantoms does not allow using usual method such as Monte Carlo to assess the maximal threshold of the WBSAR for a given population. Hence the construction of a model of the WBSAR as a function of morphology is required. Nevertheless, the WBSAR is impacted by the external morphology (height and weight) and the internal morphology (proportion of fat, proportion of muscles…). But there is no statistical data concerning the internal ones.

In this paper, the external morphology is focused and the internal morphology is released by considering homogeneous phantoms.

A Bayesian sequential experiment planning is proposed. This method consists in refining the region of interest of the WBSAR statistical distribution for a given population. This region of interest is the threshold of the WBSAR at 95% ($WBSAR_{95}$). This study is conducted in the case of a plane wave vertically polarized and frontally oriented on phantoms. The incident power is equal to 1W/m². The frequency is fixed at 2.1GHz.

MATERIALS AND METHODS

In this study, an anthropometric database is used. This database gathers a sample of 3800 French adults. The morphological factors measured on this sample recently are height, front shoulder breadth, chest and waist.

The parametric laws estimating these factors are determined. The technique morphing is also used [4]. This technique allows us to obtain additional phantoms using the factors of the database.

A surrogate model is established using existing simulations. This model is written as follow:

$$\text{WBSAR} = \theta_1 \text{Height} + \theta_2 \frac{\text{chest}}{\text{front shoulder breadth}} + \theta_3 \frac{\text{waist}}{\text{front shoulder breadth}} + \theta_4$$

This model gives a good estimation of the WBSAR since the relative error is less than 7%.

To validate this model a design experiment is established. This design permits to choose phantoms that reduce the confident region of parameters $\Theta = [\theta_1, \theta_2, \theta_3, \theta_4]$. 6 experiences are initially chosen. The result obtained using this design are denoted $F_n = (x_i, y_i)_{i=1,..,6}$, ou x_i are the morphological factors and y_i is WBSAR. This experiment design allows us to validate statically the model.

The Bayesian sequential experiment design is based on the Bayes formula:

$P(\Theta \backslash F_n) = P(\Theta).P(F_n \backslash \Theta)$

Where $P(\Theta \backslash F_n)$ is the posterior law, $P(\Theta)$ non-informative prior law (Gaussian with mean equal to 0 and large standard-deviation) and $P(F_n \backslash \Theta)$ is the likelihood.

The principle of the experiment planning consist in sampling Θ using the posterior law $(\Theta_i)_{i=1,\dots,n}$. For each Θ_i a distribution of WBSAR can be obtained and the $WBSAR_{95}$ can be deduced. The set of the $WBSAR_{95}$ obtained for the entire sample $(\Theta_i)_{i=1,\dots,n}$ make a distribution of the WBSAR95. The principle of the Bayesian experiment design is to make sequentially a choice of candidates (phantoms) that allows us to reduce the variance of the WBSAR95 distribution. When the variance is sufficiently small, the value chosen for the $WBSAR_{95}$ is the mean value of the distribution.

RESULTS

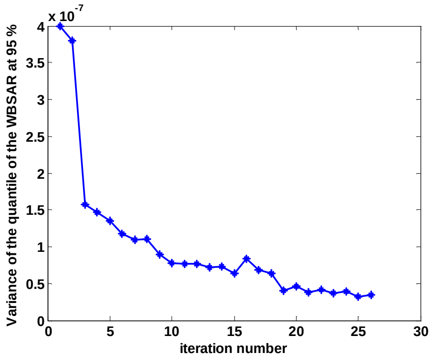

Fig1. Diminution of the variance of the WBSAR95

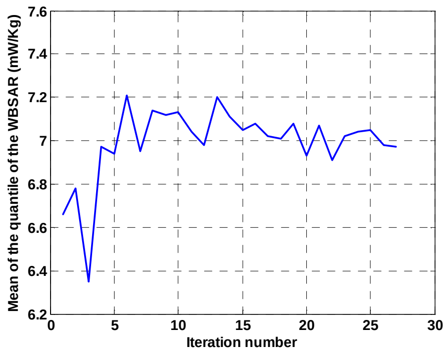

Fig2. Evolution of the mean of WBSAR95

Fig1. and Fig2. show respectively the diminution of the variance and the evolution of the mean of the $WBSAR_{95}$ distribution by adding new candidates. After 26 iterations the variance is stabilized. The corresponding mean is equal to 7mW/kg. In addition one phantom having this value of the WBSAR is found. The height of this phantom is equal to 1.47 m, his waist is equal to 65 cm and his chest is equal to 72.5 cm.

CONCLUSIONS

To obtain the threshold of the WBSAR at 95% for a given population, the Monte Carlo method is too much expensive mainly because of the lake of phantoms. The sequential planning experiment is proposed to determine this threshold. The threshold of the WBSAR is obtained after 26 iterations. In addition one phantom corresponding to this value is obtained.

REFERENCES

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