THE SAR MEASUREMENT PHASE TRANSITION METHOD

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Introduction

During an MR procedure, the patient absorbs a portion of the transmitted RF energy, which may result in tissue heating and other adverse effects, such as alterations in visual, auditory, neural functions. The specific absorption rate (SAR) is the RF power absorbed per unit mass of tissue and is one of the most important parameters related with thermal effect and acts as a guideline for MRI safety. There are principally three experiment methods to measure SAR. One is using E-field probe to measure the electrical field strength, one is to measure temperature changes in tissue-equivalent phantom and the third one is the calorimetric method family. All these methods are not simple and present a lot of difficulties: E-field probes method refers to E-field values in tissue and requires to know the tissue density and conductivity function to obtain the SAR estimation; temperature measurements need non-interfering probes, adiabatic phantoms and, as for calorimetric techniques, requires to know the exact heat capacity of the system in measure, etc. The phase transition method is a new method to measure SAR in MRI which has the advantages to be very simple and to overcome all the typical calorimetric method problems. It does not require any temperature measurement, neither any specific heat nor heat capacity knowledge, but it requires only mass and time measurements.

The method

In a polyethylene phantom filled with a mass, M, of tissue-equivalent solution is inserted a glass test-tube with some ice in phase transition. The phantom is positioned at the isocenter of the transmitter coil. Normally, in absence of RF power, after a time Δt_1, a mass m_1 of bi-distilled water is obtained by the ice fusion. This mass of water is related to the thermal power released by the environment to the phantom solution, and by the phantom solution to the ice. So, for the mass m_1 of water, it is correct the equation:

$$\lambda\, m_1 = P_{Env1}\, \Delta t_1, \quad (1)$$

where λ is the fusion latent heat of the bi-distillate water. The time Δt_1 must be such that not all ice has fused.

If the same measurement is repeated during an MR sequence and if the time of measurement is Δt_2 and τ is the hold up of the sequence, as given by the scanner, there is a mass m_2 of fused water given by:

$$\lambda\, m_2 = P_{Env2}\, \Delta t_2 + P_{Seq}\, \tau, \quad (2)$$

where Pseq is the power released to the phantom by sequence; the time Δt_2 must be such that not all ice has fused. The equation (2) is based on the assumption that all the RF power is transferred to the test tube. In fact, it is possible to show that, due to the ice presence and the great gradient temperature between environment and ice, for typical polyethylene phantom, glass test tube and typical tissue-equivalent solution, all the RF power is transferred to the test tube for mean SAR values less than 10 W/kg (greater mean SAR values are not expected).

At this point, if the environment (gantry) temperature can be considered quite constant, generally it is, in every case it can be checked, it is possible to assume that $P_{Env1} = P_{Env2} = P_{Env}$, and so by using Eq. (1) into Eq. (2), one has:

$$P_{Seq} = \lambda\, (m_2 - m_1\, \Delta t_2/\Delta t_1)/\tau; \quad (3)$$

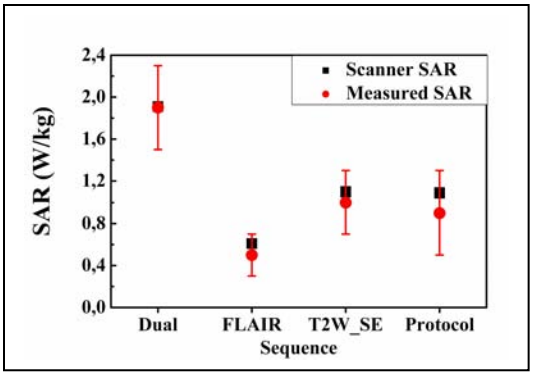
by which the SAR:

$$SAR = P_{Seq}/M. \quad (4)$$

Results

The method has been tested on a Philips Intera scanner at 1.5 T. A polyethylene phantom containing 2 kg of a tissue-equivalent solution (0.27% NaCl + 96.63% H_2O + 3% HEC) was used. The test tubes were in glass and contained about 40 g of bi-distilled water.

A clinical neurological protocol and three different sequences were chosen and for each sequence the SAR value reported on the scanner was registered. In Figure results are shown where SAR measured and SAR reported by the scanner are replicated. As can be seen measured values are consistent with the scanner reported SAR values.



Conclusions

A new method for SAR measurement in MRI has been presented. The method has the advantages of being very simple and not invasive of the scanner. Neither temperature measurement nor heat capacity knowledge is required. The method is based on the phase transition properties and consists in measuring the mass of bi-distilled water which changes state due to the effect of the RF power deposited in a tissue-equivalent solution. The phase transition method has been tested on a Philips Intera scanner at 1.5 T and results confirm that the method is reliable in order to measure SAR.