Distribution of RF traps to reduce RF heating with endoluminal coils: an experimental study

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Introduction

If the benefit of endoluminal coil for the examination of the rectal wall has been shown ([1]), it is important to tackle a paramount issue regarding patient safety when using an endoluminal coil: Radio Frequency (RF) heating. RF heating is generated through spurious currents in the ground of the reception system. Thus, RF heating reduction device focus on reducing the intensity of these currents. Several architectures have been considered in the literature: passive devices (known as RF traps or coaxial chokes) using either an LC filter architecture ([2]) or a triaxial cable configuration ([3]) or real time control of the intensity of the spurious currents with a dedicated circuit (Zanghi 2010). Active RF traps showed great performance in RF reduction but they are not easy to implement and to use on a daily clinical routine. Thus, we investigated the historical solution of passive RF traps using a LC filter architecture: 1) to determine the necessary number of RF traps 2) to optimize the placement of the RF traps along the reception cable. We considered the particular case of a reception cable of length close to lambda (225cm for a lambda of 234 cm at 3T in air)

Material and Method

Experiments were performed on a DVMR750 3T system (General Electric Healthcare). The endoluminal coil is a double loop coil prototype (60 mm length, 6 mm width). It was placed in 1.5 % agar gel phantom, an adequate medium for heat propagation. Four optic fiber probes were taped on the endoluminal coil: 3 at the distal extremity and 1 at the proximal base where the intensity of the electric field is maximal at the extremities (cf Fig 2). These probes were connected to a temperature measurement device (Opsens Tempsens: 0.1 °C resolution, 0.357 Hz sampling rate). Heating effect was measured during a FIESTA sequence with following parameters: Acquisition time: 1min36, 35°flip angle, FOV :48×48 cm^2, matrix 128×128, 250 KHz Bandwidth, TE/TR : 0.99/2.7ms. The receiver cable was an RG 58 coaxial cable 225cm long incorporating between 0 and 5 RF traps. We started from 0 trap and gradually increased the number of RF traps starting by placing them at every maximum of the spurious currents along the reception cable (cf figure 1 [4]). Inside the MRI bore, the receiver cable path passed through the maxima of the electric field.We experimetally located these maxima using an electric dipole associated to a LED (Agilent HLMP 4015).

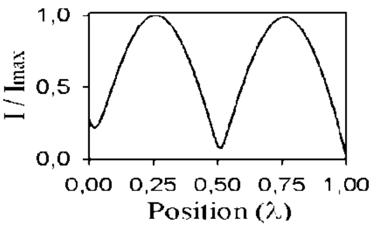

Figure 1 Simulation of the distribution of the module of the intensity of electric currents for a cable of length λ Units are expressed as a fraction of lambda. λ is the propagation wavelength of the electric field in air.

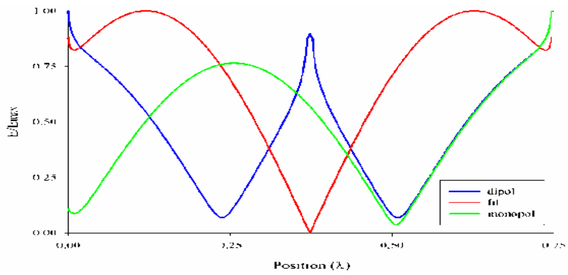

Figure 2 Simulation of the module of the intensity of Electric field 1cm away from a dipol (blue curve). Units are expressed as a fraction of λ (propagation wavelength of the electric field in air).

Results

With 2 RF traps placed at λ/4 and 3 λ/4, the increase in temperature caused by RF heating was limited to 1.6°C. The addition of additional RF traps does not significantly further reduce the temperature increase consecutive to RF heating (cf Fig 3).

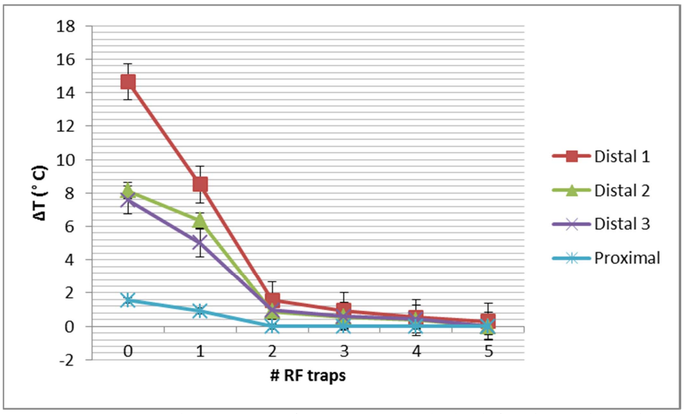

Figure 3 Measured increase of temperature (°C) defined as the relative difference of temperature between the end and the start of the FIESTA sequence in function of the number of RF traps. Measures were recorded at 4 different locations at both extremities of the endoluminal coil.

Discussion

It is important to be aware of the frame of this study: it is made for a fixed length of cable. Still, for other length of cable the same steps can be applied, it is only necessary to know the ditribution of the spurious currents. Furthermore, the maxima of the eletric field are determined manually: this may reduce the RF heating. Though, experiments conditions were set to achieve maximal RF heating: short TR sequence producing intense average electric field and reception cable going through several maxima of the module of the intensity of electric field.

Conclusion

The definition of the placement and the number of RF trap is of great importance in the RF heating reduction strategy. Our experiments tend to show that, for a cable of length λ, if an RF trap is incorporated into the reception cable at every maximum of the spurious currents, it is nearly sufficient to bring the level of RF heating down to an innocuous level (< 1.6 °C) wherever the temperature measurement is made.

References

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