Assessment of miniaturized RF traps for RF heating reduction and reception coil sensitivity profile restoration

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Target audience

Clinicians or physicists interested in RF-induced heating and in particular associated with an endoluminal MR examination of the prostate, sphincter or the bowel.

Purpose

It is well known that during a Magnetic Resonance (MR) exam, local RF-induced heating may occur close to the loop coil and along the signal cable. RF traps are an efficient way to suppress RF-induced heating as was demonstrated in numerous studies[1], [2]. RF traps were incorporated in the reception cable connecting the endoluminal coil to the MR scanner. In the prospect of an endoluminal MR exam, the endoluminal coil and the cable assembly should be small enough to avoid major discomfort to the patient. In the present study, the efficiency of miniaturized RF traps were assessed and compared with previously designed RF traps [3]. RF traps were positioned on theoretical maxima of the spurious currents with cable path chosen to be in the worst case scenario. The signal sensitivity pattern alterations in the absence of RF traps and its progressive restoration with the addition of RF traps was also studied.

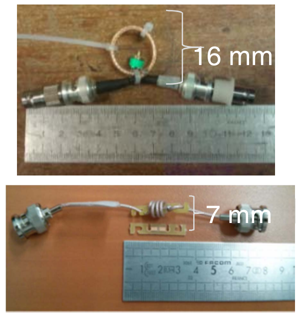

Figure 1 Photograph of a) miniaturized RF trap b) first generation RF traps

Methods

Experiments were performed on a DVMR750 3T system (General Electric Healthcare). The receiver coil was an endoluminal coil (60 mm length, 6 mm width) connected to the MR scanner via a 310 cm long coaxial cable. It was placed in a 1.5 % agar gel phantom, an adequate medium for heat propagation.

Temperature measurements: Four optic fiber probes were taped at the distal extremity of the endoluminal coil at maximum electric field intensity location (Fig 2). The probes were connected to a temperature measurement device (Opsens Tempsens: 0.1 °C resolution, 2.8s temporal resolution). Heating effect was measured during a FIESTA (balanced steady state) sequence with the following parameters: Acquisition time: 1min36, 90°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 310cm long incorporating between 0 and 5 RF traps (Figure 1). The initial set-up included no RF trap and the number of traps was gradually increased and placed at every maximum (odd multiples of $\lambda/4$) of the spurious currents along the reception cable. Inside the MRI bore, the receiver cable path passed through a maximum of the electric field experimentally located using an electric dipole associated to a LED (Agilent HLMP 4015). Temperature measurements with each trap configuration were repeated 5 times keeping positions of reception cable, coil and phantom identical.

Sensitivity: For each trap configuration, the signal sensitivity pattern of the endorectal coil was assessed by measuring the SNR profile extracted from high spatial resolution images acquired with a FSE-XL with the following parameters: TE/TR 14.4 / 1500 ms, slice Thickness: 3 mm, Echo Train Length: 4, matrix: 256 ×256, FOV = 60 × 60 mm^2.

Results

		0 trap	1trap	2 traps	3 traps	4 traps	5 traps
Temperature increase ΔT (°C)	Miniaturized RF traps	7±0.3	1.77±0.15	1.64±0.03	1.55±0.09	1.38±0.05	0.4±0.06
	Standard RF traps	14.7±1	8.5±0.25	1.56±0.45	0.94±0.09	0.52±0.03	0.3±0.03

Table 1 : Temperature increase (measured as the temperature difference between the end and the start of the FIESTA sequence) values yielded by standard and miniaturized RF traps. Statistics were performed on 5 repeated measurements.

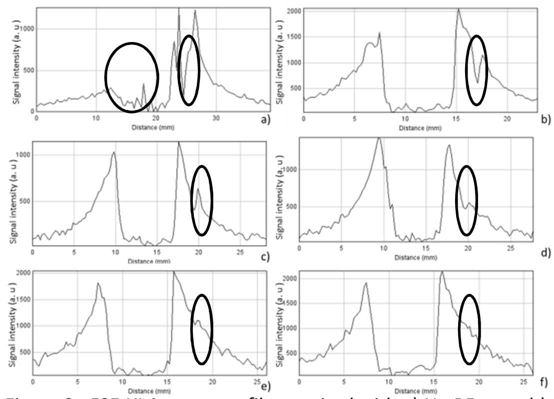

Figure 2 : FSE-XL images profile acquired with a) No RF traps b) 1 RF trap c) 2 RF traps d) 3 RF traps e) 4 RF Traps f) 5 RF traps

In both cases, the insertion of 5 traps reduced drastically RF-induced heating below authorized level (inferior to 1°C) (Table 1). Without any RF traps incorporated, the signal sensitivity pattern is strongly affected (Figure 2) and profile do not follow a monotone decrease with distance from the coil. The SNR profile small irregularities probably come from small air bubbles in the agar gel. With the addition of RF traps the expected signal intensity profile and overall pattern is progressively restored

Discussion

Though miniaturized RF traps were designed as standalone device comprising two BNC connectors, all 5 miniaturized RF traps may easily be integrated in a single 310 cm long RG178 cable. It is thus possible to suppress the BNC connectors,. For reproducibility purposes, this study was conducted at a fixed length of cable and a fixed position but other preliminary experiments yielded consistent results at different positions and for different cable lengths. Finally the study was performed on a gel agar phantom whose conductivity was set to be superior to biological tissues (in order to be in the worst case scenario).

Conclusion Miniaturized passive RF traps do prevent RF-induced heating and restore signal intensity pattern of the endoluminal coil. The reduced size of RF traps makes possible the integration of such circuits with the endoluminal coil for an introduction in natural orifices and allows the sage examination of the rectal wall.

References

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