Assessment of RF heating in the case of a mechanical default of an endoluminal coil

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Introduction

An endoluminal coil is schematically composed of a receiving part connected to a coaxial cable for sending NMR signal to the preamplifier. These coils are intended to be introduced in the patient body for a MRI examination. In an extreme case, the coil can be damaged and connection can be interrupted between coil and coaxial cable. For ensuring in this case the safety of the patient with respect to RF heating, one should verify that RF heating produced by the extremities of the cable will not burn the patient. The aim of this study is to investigate the heating at the tip of the coaxial cable when located in the center of the tunnel, and to find the maximal length of the cable for which the heating is not critical if the c is damaged into the patient body.

Methods

The influences of a coaxial cable (Axon P511068, Axon'Cable SA, France) position and length on heating were studied. The coaxial cable was placed in the middle of the MR table (Fig. 1a) of a 1.5 T MR Symphony system (Siemens, Erlangen, Germany) for the first experiment and its shape is straight and further termed "I-shape". In the second experiment (Fig. 1b) the coaxial cable has a "J-shape" to simulate its position when one of its extremities is close to the connector located in the MR table. This is, for example, the case when the connector is close to patient's head (as in 1.5T MR Symphony) and when imaging colon (patient head-first position). To assess the local concentration of electric field E, the temperature variation in a small pieces of gel (0.9 % NaCl, $\sigma = 1$, $\varepsilon_r = 73$) placed around the coaxial cable was measured. The measurements were started with a λ length wire, where λ is the wavelength in the coaxial cable (3.25 m for f = 63.7 MHz) of the RF B_1 field. The temperature measurements were made for multiples of λ/16 lengths of coaxial cable in the first case (between 0 and λ length) and for multiples of λ/32 in the second (between λ/4 and λ/2 length). The temperature sensor was placed at the tips located inside the tunnel. The temperature was measured with an optical fiber system (Luxtron Corporation, USA). The temperature sensors were mounted adjacent at the conductor and the shield of a coaxial cable with Teflon rubber. A 60 s True-Fisp sequence (TR/TE = 4.93/2.46 ms, α = 90°, in the first case and α = 20° in the second) was used to produce RF excitation. After each sequence, a λ/16 or a λ/32 length wire was cut off from opposite tip of measure.

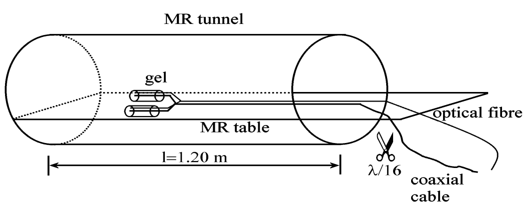

Fig. 1a. Schematic experimental setup for straight coaxial cable.

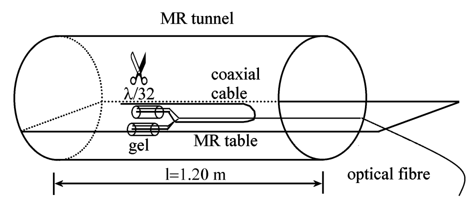

Fig. 1b. Schematic experimental setup for "J- shape" coaxial cable.

Results

Temperature variations of the shield and conductor as a function of length of coaxial cable are show in Fig. 2a for the "I-shape" (with 90° flip angle) and in Fig. 2b for the "J-shape" (with 20° flip angle). Using the same flip angle (90°) in the second case, leads to temperatures higher than 100 °C, exceeding the temperature range of Luxtron. Due to the fact that in the second case, the experiment with 90° flip angle was impossible to make, the flip angle was decreased in order to obtain about the same heating like in the first case. For "I-shape" the maximum heating is observed for lengths between 7λ/16 and 8λ/16 (Fig. 2a), a minimum at 9λ/16 and non significant temperature increase for lengths under 3λ/16. If the cable has a "J-shape", the temperature increases progressively with the coaxial cable length (Fig. 2b).

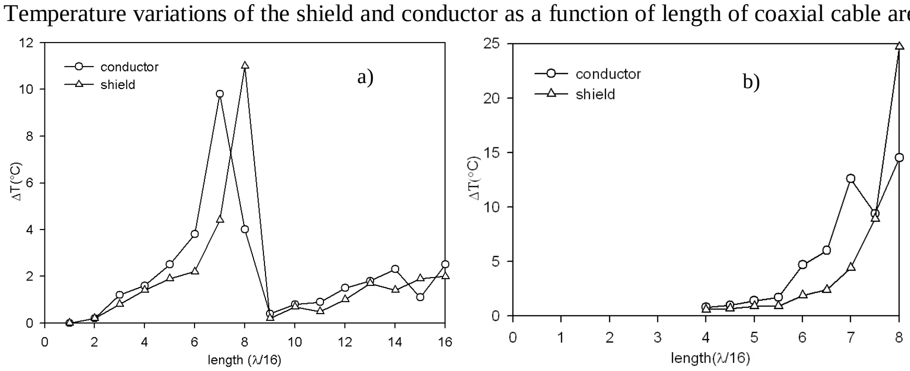

Fig. 2. Experimental measurements of the temperature variation as a function of the coaxial cable length: a). straight cable; b). "J-shape" cable

Conclusion

First, this experiment shows that in case of a mechanical default, temperatures inside the patient body can reach levels which are incompatible with patient safety. The parameters influencing the temperature are both the length and the path of the coaxial cable, for a given flip angle. Temperature increases to about the same level for very different flip angles. Thus, taking into consideration that $\Delta T \propto \alpha^2$, one should conclude that the "J-shape" will be much more dangerous in the case of a mechanical default. For a given MRI unit (body coil geometry and type), this shape is mandatory fixed by the connector location and the patient position. Secondly, these two experiments suggested that a maximum length of coaxial cable may be determined according to the shape of the cable when one extremity is connected to the unit and the other is located into the patient body. It is the reason why in many imaging systems RF traps are distributed along the connection cables. Finally, this study suggest that the safety of an endoluminal coil with respect to mechanical hazards should be assessed for each kind of MR unit (e.g. location of connectors) by taking into account the length of the cable and the position in the tunnel.