RF-heating effects on coated wires and pacemaker leads at 1.5T and 3.0T

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Introduction:

Heating effects induced by the RF-field are one of the concerns on safety of implants in MRI. High heating effects have been observed especially near long wires like pacemaker leads[1,2] and guidewires[3]. In addition, changing from a 1.5T to a 3.0T scanner the RF-power for identical pulse sequences will increase by a factor of 4 due to the increased RF-frequency. The need of more RF-power at 3.0T is often correlated with higher heating effects around implants. The purpose of this abstract is to evaluate whether heating around extended implants and wires are really higher in any cases compared with a 1.5T system.

Methods:

Temperature increases at the end of a coated wire of different length have been measured in a whole body 1.5T and 3.0T scanner (Achieva 1.5T, SW Rel 1.5 and Achieva 3.0T, SW Rel 1.2.2, Philips Medical Systems, Best, The Netherlands). Wires with different length have been placed in a 64x33cm^2 large Plexiglas tank filled with 20 liter of 0.45% saline water. TSE scans with the highest allowed SAR-value (4.0W/kg at 1.5T and <4.0W/kg at 3.0T) have been used.

Since it was known that at 3.0T the displayed whole body SAR is strongly overestimated by the used scanner software, SAR has been measured by using an agar-block doped with 0.45% salt, placed in right-left direction at the boarder of the tank. Temperature increase over a scan of 30min has been measured using four Luxtron fiberoptic temperature sensors placed in the agar phantom, but also in the saline solution.

In a second step the test has been repeated with a 58cm long active fixation lead (CapSure Fix 4068, Medtronic Inc, Minneapolis MN) and a dual chamber pacemaker (Kappa DR 731). In this case the lead was not shorten by cutting the lead, but by coiling it next to the pacemaker as presented in reference 1.

Results:

The calorimetric measurement of the SAR value in the used phantom showed that displayed SAR was in the 3T scanner about 4.7±0.7 times lower compared to the 1.5T scanner. Within the agar phantom local SAR values of 6W/kg could be found at 1.5T.

Using the latest scanner software release (Rel 1.5) on the 3.0T scanner, the whole body SAR is now estimated with 0.9W/kg which is in good agreement with measurements in the used tank. All following measurements at 3.0T will be corrected by the determined factor of 4.7 to show the results for a SAR of 4.0W/kg. At 3.0T such a sequence with a SAR value of 4.0 W/kg would exceed the limits for local SAR, and therefore it can not be performed.

The temperature increases at the tip of a coated wire are shown in Figure 1. The critical length at 3.0T was half of the length at 1.5T as expected from doubling the RF-frequency at the higher field strength.

In case of the used pacemaker system, the curves are broader and showed lower heating effects, than the one from the coated wire. At 1.5T the highest temperature increase could be seen at a length of 30±5cm with 14.5°C, which is in good agreement of reference 1. At 3.0T the measured temperature increase was 1.5°C (SAR=0.9W/kg) at length of 40±5cm. This peak is the peak at 3/4λ. A second small peak (λ/4) of 0.5°C could be seen at 15±5cm.

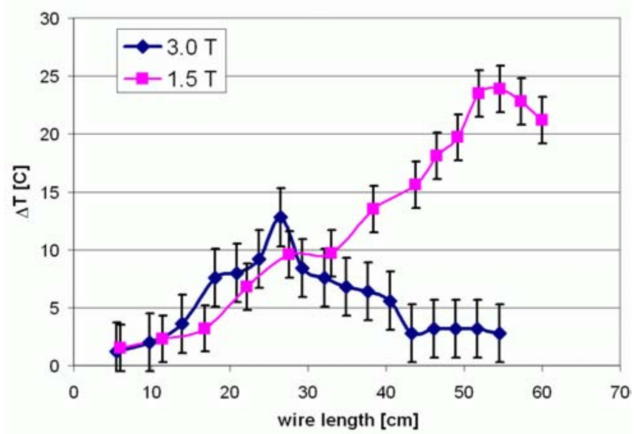

Figure 1: Temperature increase at the tip of coated wires of different length at 1.5 and 3.0T. The shown values at 3.0T were measured with a SAR-value of 0.9W/kg and corrected to 4.0W/kg.

Discussion:

High temperature increase could be found on both field strength. If both system would be limited to the same whole body SAR, on both field strength comparable heating effects could be seen for implants shorter than the critical length at 3.0T system. If an implant is longer, higher heating effects are expected in 1.5T scanner. Measuring the temperature increase at one length in both field strength may underestimate the highest heating in one of both scanners. For instance if in case of the coated wires (Figure 1) the measurements would be preformed at a length of 25cm, comparable heating could be found for both systems, but the maximal heating at 1.5T would be underestimate. On the other hand if the measurement would be performed around 55cm, nearly no heating could be found at 3.0T. Especially in case of flexible leads, but also external frames or longer implants, the anatomical situation will determine the length of the implants, which are often not implanted at full length, but coiled around the device as done with pacemakers or neurostimulators.

Due to a rather conservative SAR model in the used 3.0T scanner the heating is even after correcting with a factor of 4 lower than at 1.5T, since the maximal allowed whole body SAR was limited to 0.9W/kg for scans of the thorax using the body coil. However, this may not be true for other manufacturer, other anatomical regions (brain, lower extremities), and will probably also change in future software releases.

Limitations:

Even if in this study only comparable or even lower heating effects could be found at 3.0T, this work does not intend to recommend a limitation of heating measurements for safety evaluation only at 1.5T. The shown results allow not to exclude higher heating at 3.0T in special situations.

References:

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