RF heating of pacemaker leads: Do open MR systems perform better than close bore systems?

R. Luechinger[1], V. A. Zeijlemaker[2], B. Mengiardi[3], and P. Boesiger[1]

[1]Institute for Biomedical Engineering, University and ETH Zurich, Zurich, Switzerland, [2]Medtronic Bakken Research Center, Maastricht, Netherlands, [3]Imamed, Liestal, Switzerland

Introduction:

Magnetic resonance imaging (MRI) has evolved to be an important diagnostic tool in medicine. However, patients with cardiac pacemakers (PM) and implantable cardioverter-defibrillators (ICD) are usually precluded from MRI examinations due to safety concerns. Potential risks include heating of the lead tip, force and torque on the pacemaker, fast pacing, and inhibition [1].

Nevertheless, at some MR sites patients with pacemakers underwent MR examination at different field strengths [2,3]. It is well accepted that for such investigation, lower field strength (e.g. 0.5T) are preferable over higher field strength (1.5T).

Theoretically, an open MR system with a main magnetic field should orthogonal to the feet-head axis of the patient should even be more favorable, since in such a scanner the E-field of the B1-field is mainly not in parallel with the a pacemaker lead, as computer simulation of the empty body coil from the 1T Panorama scanner (Philips Healthcare) showed [4]. E_{tan}, important for the RF heating [5], should therefore be strongly reduced.

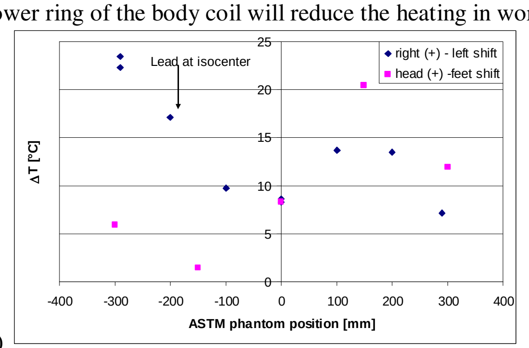
The aim of this study was to verify these simple assumptions on the potential risks of RF heating at pacemaker lead tips at 1-Tesla in an open MR scanner with vertical main magnetic field.

Methods:

Temperature increases at the tip of a 58cm long active fixation lead (CapSure Fix 5076, Medtronic Inc) connected to a dual chamber pacemaker (Kappa DR 731, Medtronic Inc) placed in the ASTM human shaped tank field with PAA-Gel (30l distilled water, 300g PAA and 39.6g NaCl; conductivity of the gel 4.8±0.1 mS/cm). Different lead configurations have been evaluated: linear near the boarder of the tank, linear at the center of the tank, half circular configuration and anatomical configuration. In addition the whole tank with fixed pacemaker system placement has been moved in the left-right and feed-head up to ±29cm in the 1T Panorama MR scanner (Software Rel 2.5.3). As a MR sequence a TFE sequence with TE=1.39, TR=2.79, flip angle 90°, TFE-Factor 142, NEX=16, matrix 144x142, FOV=500x500mm^2, whole body SAR 1.31W/kg, forward average power 249±10W, B_{1rms}=25.15uT^2 and scan duration 32.9s was used. Research settings have been used, since in the clinical configuration, no whole body SAR above 0.6W/kg are allowed due to limitation to 10 W/kg local SAR by the manufacturer.

Results:

High heating could be seen in case of the linear configuration at the boarder of the ASTM phantom (Fig 1a). In the linear configuration in the center of the ASTM phantom strongly reduced heating could be found (Fig 1b). Heating in anatomical and but also in half circular position at different locations with MR scanner showed also only limited temperature increase (half circular conf.: 6°C, anatomical conf.: 3°C). For all these measurements the phantom was directly placed on patient table. Adding the foam as used for patient will move the tank about 4.5cm away from the lower ring of the body coil will reduce the heating in worst case position (-290 right-left) from 24°C to 11.1°C.

a)


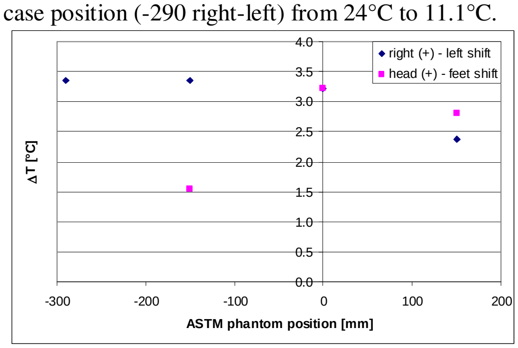
b)


Fig. 1: *Temperature increase at the lead tip with the lead a) 18cm right from the centerline of the tank and b) along the centerline of the tank. The tank position in a) with the lead in the center of the body coil in right-left direction is marked with an arrow. In feet head direction highest heating could be seen in case the lead part next to the lead tip is mostly within the body coil.*

Discussion:

The results show very nicely the strong influence of the phantom around the pacemaker lead. With the lead at the same position relative to the body coil of the scanner shifting the tank 18cm relative to the lead will increase the temperature from about 3.5°C to over 15°C. The results show clearly the strong influence of the used phantom and the position within the tank leading to strongly increased heating in some cases.

In worst case situations temperature increases of over 20°C could be seen (SAR 1.3W/kg instead of the maximal allowed 0.6W/kg, as low and eccentric as possible). These increases are of the same order as seen in a close bore 1.5T scanner (corrected for a SAR of 1.3W/kg). However, due to the strong limitation of the SAR on the used scanner and the low heating seen in more physiology placement, the authors think that the open magnets may show lower safety risks with respect to RF-heating as high field close bore systems. Therefore, more research would be of interest for a better understanding of the effects.

References:

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