Impact of Imaging Landmark on RF-Induced Heating of Cardiac Pacemakers and Other Medical Devices in MRI

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Introduction: Increasing numbers of patients with implanted passive and/or active electrically conducting medical devices raise cumulative problems in MRI, as procedural risks can be exaggerated when performing MRI in these patients. Determination of specific low-risk imaging conditions might be feasible to allow MRI in such patients, even with devices which are not intrinsically MR safe. When considering MRI in patients with cardiac pacemakers, particularly safety concerns regarding exaggerated RF-induced tissue heating at the tip of the pacemaker lead are the focus of current discussion. Amongst other factors, imaging landmark has been shown to influence RF-heating [1]. Restrictions on imaging landmark might, therefore, be one possibility to increase procedural safety, and operating instructions of the just recently introduced first cardiac pacemaker officially labeled "MR conditional" [2] also define specific imaging landmarks. In the current study, the aim was to systematically investigate the impact of body positioning/imaging landmark inside the scanner bore (or, more specifically, inside the RF transmit coil) on potential RF-induced implant heating, and to clarify whether patient safety can be significantly increased by specification of imaging exclusion zones in patients with implanted conductive devices like cardiac pacemakers.

Methods: All experiments were performed in a head and torso phantom according to ASTM standard F2182-02a and filled with a saline fluid. It has been recently shown that MRI-induced implant heating is directly related to the RF-induced E-fields inside the body, which can, therefore, be used as a correlate for heating risk [3]. Accordingly, E-field distribution under varying imaging conditions was investigated in 3 different 1.5 Tesla MR scanners (Siemens Vision, Scanner 1; Siemens Avanto, Scanner 2; Philips Intera, Scanner 3) to allow for an estimation of how different hardware and software properties influence RF-induced heating dependent on imaging landmark, with the goal to determine possible exclusion zones for low-risk MRI. E-field distribution inside the phantom dependent on imaging conditions was determined shifting the E-field probe on a measurement grid consisting of 144 measurement points equally distributed over the fluid middle layer of head and torso inside the phantom fluid. For this purpose, the phantom was first centered in the scanner bore, later moved by table offset, and an E-field map acquired for each respective imaging landmark while running a standardized MR pulse sequence.

Results: Overall maximum E-field strength was generally found to follow the phantom walls, particularly the lateral walls in z-direction as described earlier [3]. Moving imaging landmark and, therefore, phantom along the z-axis in the head or hip direction resulted in a shifted E-field distribution inside the phantom. E-field distribution along the lateral phantom wall dependent on imaging landmark in a Siemens Avanto Scanner is shown exemplary in Figure 1. Shifting the imaging landmark toward either end of the phantom decreased peak heating in all scanners, but to a different extent. In Scanner 1, shifting the imaging landmark to +10 cm reduced peak E-field strength to 23%, at +20 cm by 37%, at +30 cm by 45%, at +40 cm by 69%, and at +50 cm by 84% of the maximum. In Scanner 2, imaging landmark dependent reduction of peak E-field strength was only 1.1% at +10 cm, 11% at +20 cm, 48% at +30 cm, 76% at +40 cm, >99% at +50 cm, and in Scanner 3 1.0% at +10 cm, 8% at +20 cm, 29% at +30 cm, 67% at +40 cm, and >99% at +50 cm.

Not only maximum values, but also locations of peak heating change under different imaging conditions. An example of overall E-field distribution in the phantom using different imaging landmarks is shown in Figure 2.

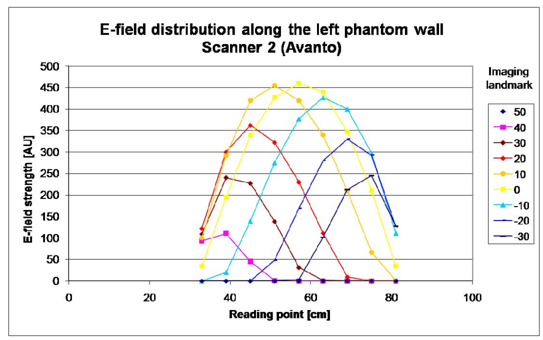

Figure 1: Z-directional E-field components along the left phantom wall in a Siemens Avanto Scanner (in arbitrary units, AU) dependent on imaging landmark (shifted in 10 cm increments, 0 = phantom center in z-direction).

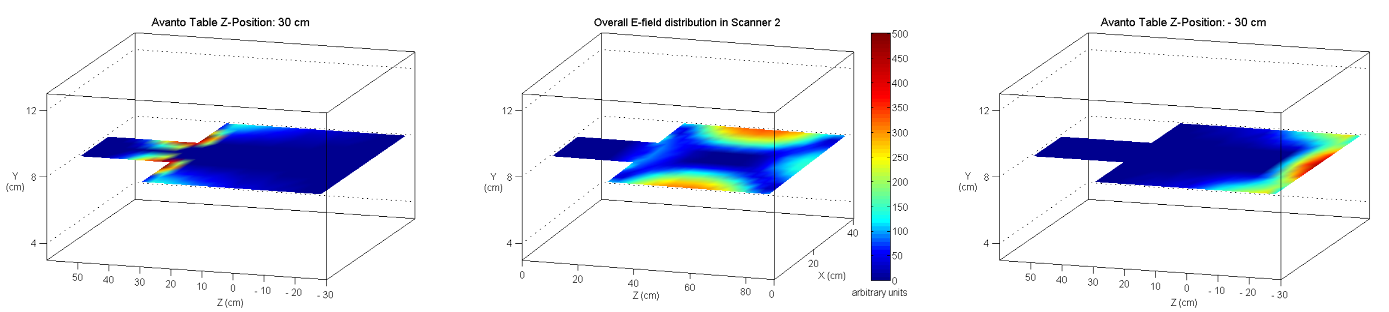

Figure 2: Relative E-field distribution in Scanner 2 (Siemens Avanto) dependent on imaging landmark. E-field distribution is shown exemplary for 3 imaging landmarks, ranging from -30 cm (~ hip) to +30 cm (~ shoulder). Relative local E-field strength (in arbitrary units, AU) is color encoded

Conclusion: We investigated the shift in E-field distribution as a correlate for potential unintended heating of electrically conducting implants in the body using varying MR imaging landmarks in three different scanners. The results show that implants far away from the imaging landmark have a lower overall potential to develop severe RF-related heating due to a highly significant decrease in local E-field strength with increasing distance from the imaging landmark. The exact E-field distribution is scanner dependent, which has to be taken into account even if scanners of the same vendor are considered. However, the quantitative impact on implant heating cannot be extrapolated from these data alone.

References:
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