RF Power Deposition in the Human Body during MRI and Cardiac Pacemakers

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One of the important research issues in MRI of humans is a potential for excessive heating of tissues due to RF power. The problem is more pronounced for high magnetic field systems currently in use, typically 1.5 T, and for patients with cardiac pacemakers. Only a limited number of investigations have been reported for imaging of the human torso (O.P.Gandhi and X. B. Chen, Magn. Reson. Med., 41, 816-823,1999, H.S. Ho, J. Magn. Reson., 14, 472-477, 2001, C.M. Collins and M.B. Smith, J. Magn. Reson., 18, 383-388, 2003). None of the studies included a realistic model of a cardiac pacemaker *in situ*. Furthermore, resonant birdcage coils, which are used in practice, have not been modeled because of computational challenges that they pose.

Our study presents evaluation of RF power deposition, expressed as the specific absorption rate (SAR = $| Ei|^2\sigma/\rho$, where E is the electric field in tissue, σ is the tissue conductivity, and ρ is the density), in a heterogeneous model of the human body with and without a realistic model of the pacemaker. The model represents an average male (1.76 m, 76 kg) with over 30 organs and tissues identified and allocated corresponding electrical properties. The pacemaker model consists of a metallic box representing the generator implanted in the left upper clavicle under the skin and the lead treaded through the vein and terminating in the left ventricle of the heart. Two conductivities of the lead are considered, a perfect electrical conductor, and a representative value obtained as the average of over 20 leads measured. A large size, 0.7 m in diameter and length, birdcage coil is modeled in three configurations, namely non-resonant coil excited in 16 struts with a progressive phase shift (22.5^o) to obtain circular polarization, the same coil, but with capacitors in both terminating rings operating at resonance, and a resonant coil with four terminal excitation (90^o phase shift). All simulations are performed with the finite-difference time-domain (FDTD) method at 64 MHz, corresponding to 1.5 T systems. The resolution is 5mm, and a time-shifted Gaussian pulse is used for excitation.

The most important findings can be summarized as follows. Previously performed evaluations of SAR values performed for non-resonant coils give significantly higher results than those for used in practice resonant coils; the differences are of the order of 5 to 10 fold. The coil excitation (4-port vs. 16-port), and position (rungs vs. terminating rings), ad the body position influence the SAR, but the differences are smaller than those associated with the coil operating in resonance. Cardiac pacemaker leads enhance SAR at their ends, however the SAR increases are relatively modest because of the location of the lead terminals inside the body, where the unperturbed SAR values are lower than those on the body periphery.