MR Imaging of Patients with Stents is Safe at 7.0 Tesla

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Introduction

MRI has seen a steady increase in magnetic field strength (B_0), yielding increased signal-to-noise. A prerequisite for acceptance of B_0-increases is assessment and validation of the intrinsic safety, and safety regarding implanted devices. Although extensively tested at lower fields, at ultrahigh field there are a relative lack of data concerning these safety issues[1], restricting subject scanning. However, it is not clear whether (subjects with) metallic implants are justifiably excluded. Metallic implants at ultrahigh field may have a length comparable to ½ wavelength at which dimension the coupling to the electric field of the transmit coil is maximum (due to resonance), resulting in maximum potential along the implant and subsequently heating of the stent tip and surrounding tissue. On the other hand, coupling is dependent upon the quality (Q) value of the potentially resonant implant in the particular tissue. Since tissue load increases with field strength, the Q-value can be very low in stents. In this study we assess our hypothesis that, based on the very low Q-value being the dominant factor, metallic implants are RF safe at high fields, by using both an experimental setup involving the measurement of RF heating of twenty stents around the resonance length at 7T, and by *in vivo* measurements.

Methods

Electrical characterization of wires and loops: Unloaded and loaded Q-values were measured using two small pickup probes. A non-insulated copper wire with an optimized length (resonant at 298MHz) was suspended in a container with deionized water; salt was then added for determining the dependence of Q on the solution conductivity. *Stent measurements:* The American Society for Testing and Materials (ASTM) standard F2128-11 was followed as closely as possible[2]. Twenty of most commonly-used clinical peripheral stent grafts were tested (range 20-100 mm). A custom-built two-channel unilateral RF coil for breast imaging was used[3]. Stents were individually embedded in phantoms with tissue-mimicking dielectric and conductivity values, and positioned in the coil at the position of highest heating. Scanning was performed on a 7T MR system (Philips Healthcare, Cleveland, OH, USA) administering a time-averaged RF power of 24W to the coil, i.e. a local SAR three times above safety standards, based on numerical simulations. Temperature was measured every second by four optical probes (Luxtron m3300, temperature resolution 0.1 Celsius) placed at both ends of the stent and parallel and perpendicular to the stent. Each measurement consisted of baseline recording (2 min.) followed by 5 min. of administering RF power. *Displacement measurements:* To further explore the safety of the stent grafts, magnetically-induced deflection experiments were performed according to the ASTM standard F2052-06[4]. All stents were individually placed in an apparatus that measured the attraction of the static magnetic field on the stent in comparison to the gravitational force. *In vivo measurements:* A tuned antenna, designed to form a quarter wavelength, monopole design, was inserted into the rectum of a healthy volunteer after obtaining written informed consent (study approved by the local ERB). A fiber-optic temperature probe was positioned at the antenna tip. The impedance was matched to 50Ohm to ensure full power coupling from the RF power source. MR images were obtained using the antenna as an MRI transceiver using a fast-field echo. Temperature was measured during a time-averaged RF power deposition of 4W for 10 min.

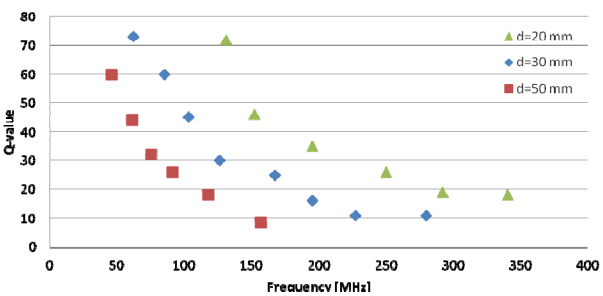

Figure 1: Quality factor of single loop coils resonating at frequencies ranging from 50 to 350MHz.

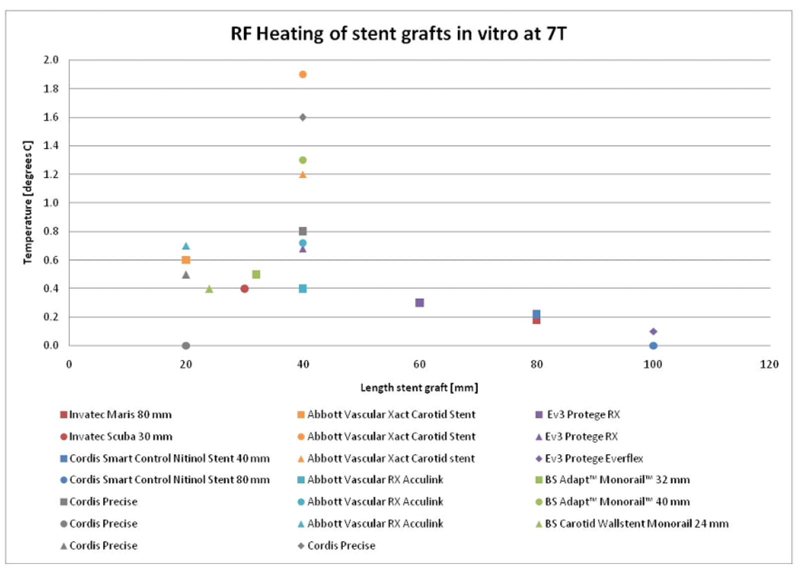

Figure 2: Temperature increases measured next to stents in phantoms while administering power which results in three times the federal SAR limit.

Results

Q-values for both a copper wire resonating at the Larmor frequency for a 7T field strength, and for three different diameter single loop coils at varying frequencies, decreased significantly when placed in a solution of 0.5S/m corresponding to human tissue (Figure 1). During stent measurements, none of the twenty clinical peripheral stent grafts produced a temperature rise of ≥ 2K while overriding SAR by a factor of 3. The maximum temperature increase was found for stents with a length of 40mm (Figure 2). During the deflection experiments, displacement of all stents due to the magnetic field was < 33°, which is below the 'safety limit' of 45°. During the *in vivo* experiment using a 10-min. scan with a total of 4W of RF power, < 0.5K temperature increase was measured.

Conclusion

The results of this study show that RF heating of implanted stents is not a safety issue for ultrahigh-field MRI. If federal guidelines for local and global SAR values are followed, none of the implanted stents will produce any significant additional heating in tissue beyond that which would be produced in the tissue itself from the energy deposited by the RF coil. Moreover, based on the very low degree of coupling at 7T, it might be possible that when considering electrical conductive implants, a field strength of 7T is more RF safe than lower field strengths, and patients with peripheral stent grafts should be allowed at 7T MRI.

References

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