Evaluating Radio Frequency Heating of Vascular Stents at 3 Tesla using a Gel Phantom

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Purpose

Many patients from our hospital had intravascular stents and could not be scanned in our 3 Tesla MRI facility due to safety concerns associated with radio frequency effects. Although descriptions of r.f. heating in straight wires are available [1], these measurements were done at 1.5T and do not address the complex geometry of intravascular stents. There was no 3T safety data available on these devices from vendors, MRI safety websites, or from the literature [2,3]. We initiated our own ex-vivo testing program, examining the most frequently encountered devices implanted at our institution, thereby allowing these patients to be safely scanned at 3 Tesla.

Methods

A variety of stents (Boston Scientific, Medtronic, AngioDynamics, Cordis) ranging in length from 20 mm to 60 mm have been tested in our Siemens Trio 3T scanner. Radio frequency heating was evaluated using an aggressive T2 weighted TSE multislice pulse sequence with a SAR=6 (reported by scanner for whole body). The tests were performed as described in ASTM publication F2182-02a. Implants were immersed in a (0.8g/L) saline/polyacrylic acid gel phantom having the approximate shape of a human head and torso. Temperature increases were monitored using an optical fiber/fluoroptic thermometry system (Luxtron FOB Lab Kit) with 4 sensors (STF). A MRI compatible stent holder was designed and constructed as illustrated in the Fig 1. A web of nylon fishing line was stretched across a horseshoe shaped Plexiglas support. The stent being tested was secured to this web with a rubber band, allowing unrestricted contact with the gel. The tips of the fluoroptic fibers were directed to positions within 1 mm of the stent (at locations where one might expect the largest heating effects). The fiber positioning system consisted of thin polyethylene tubing acting as guides, which were fastened to the horseshoe support system with adjustable plastic clamps. The entire assembly was then submerged in the gel and held in position with a Plexiglas rod and joint system. Temperature measurements were taken from each of the four fluoroptic sensors at one second intervals during a 15 minute scan and logged to a computer text file with Luxtron's True Temp software. An example plot is shown in Fig 2. Each trace represents the temperature rise of a fiber tip in the locations shown by Fig 1. Data were smoothed using a 30 point boxcar average with MS Excel software. The slope of the temperature rise vs. time for the end location on each stent was converted to a SAR value, and then plotted against stent length to give the graph shown in Fig 3.

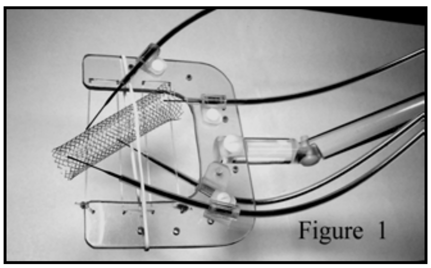
Figure 1

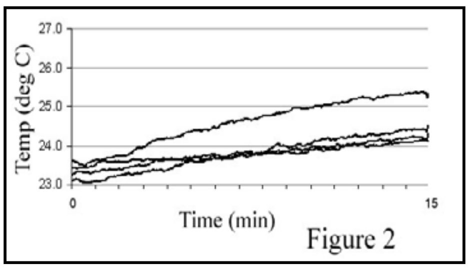

Figure 2

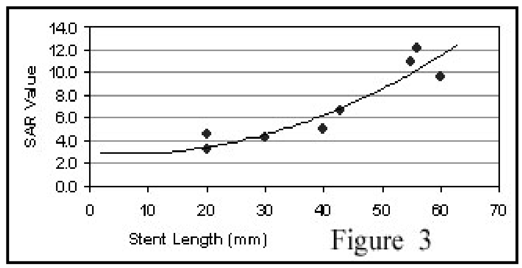

Figure 3

Results

No stent had significant static magnetic field interaction. The temperature increase for each stent was greatest at the ends, as documented by the top tracing of Fig 2. This trace is from the end location in a 60 mm stent, while the lower traces are for the midpoint, 1/3 down the length, and inside locations. Heat generation correlates with stent length as seen in Fig 3. It was not possible to determine the exact form of this function with the limited dataset. The trend line added in Fig. 3 is a second order polynomial. The SAR amplification (gain) effect, 4 in the long stents, is significantly lower than the gain of 60 observed in comparable short lengths of straight copper wire reported in reference [1]. The extra surface area of the stents could well provide additional heat dissipation lowering the gain factors reported here. The method of directing the tips of the thermometry fibers using the polyethylene guide tubing proved to be very convenient and allowed one to change test devices in a matter of minutes.

Conclusion

It was possible to safety test the most frequently encountered medical implants at our 3 Tesla MRI facility. Radio frequency heating, which was the primary concern associated with these implanted devices, was not significant except for the longest stents (55-60 mm) where temperature increases of 2.5 degree C were observed during a very aggressive 15 minute scan in the non-convecting gel. It is expected that blood flow would drastically reduce this temperature rise. All the devices we have tested to date have been approved as safe for 3 Tesla and lower field MRI scans.

References

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