Comparative Analyses of MR-Induced Distal Heating in Novel Filtered Cardiac Pacing Leads Using Two Geometric Configurations

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Introduction

The exposure to RF fields associated with MRI can induce currents in long lead systems, as in those typically used for cardiac rhythm management. Band stop filters were used at the distal helices of the lead to restrict heating to levels below thermal injury. The heating induced on a control lead and a Band Stop Filter lead were evaluated in two physical arrangements.

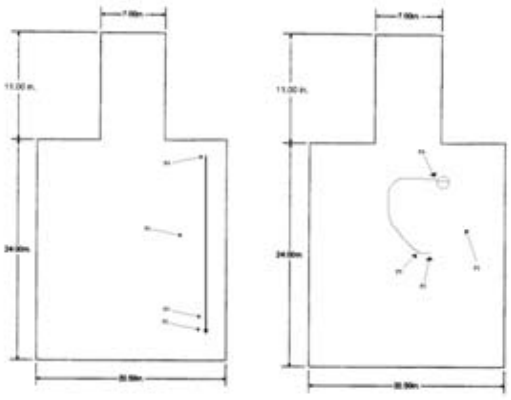

Figure 1. The figure on the left shows the lead geometry and probe position for the "straight lead" configuration in the test phantom. In this series of tests, the lead is moved progressively closer to the center of the phantom. The figure on the right shows approximated physiological lead configuration and temperature probe position.

Methods

A 46-cm control lead and a 46-cm optimized Band Stop Filter lead were evaluated in a 1.5 Tesla MR system using a transmit RF body coil at an MR system reported SAR value of 3.8 W/Kg. The leads were tested in a straight configuration over a range of distances from the phantom isocenter (Fig. 1, left). The heating in control and Band Stop Filter leads were also evaluated in an approximated physiological configuration using an empty IPG mock-up (Fig. 1, right). Fluoroptic temperature probes were placed at the distal helix, the anode ring and the proximal (IS-1) connector of the lead. A temperature reference probe was placed in the gelled saline filled phantom. Additional methods followed previously published reports (1, 2).

Results

A significant decrease in heating at the distal end was observed as the straight control lead was moved from the edge of the phantom to isocenter. The straight lead with a band stop filter decreased the heating even more. At 23-cm away from isocenter, the control lead heated to an absolute temperature of ~75˚C. In contrast, the Band Stop Filter lead heated to an absolute temperature of ~35˚C. As the control lead and Band Stop Filter leads were moved closer to isocenter, the amount of heating that occurs on both leads decreases. At ~18cm away from isocenter, the control lead heats to an absolute temperature of ~39˚C while the Band Stop Filter lead heats to an absolute temperature of ~25˚C (Fig. 2). In the approximated physiological configuration, the amount of overall heating on the control lead and Band Stop Filter lead were significantly lower than that found in the straight lead configuration. In the physiological configuration, the leads were placed closer to the center of the phantom and the effective lead length, relative to exposure to E_{tan} fields, were shorter resulting in decreased heating at the distal end. Overall heating at the distal end of the control lead is ~4˚C while the heating on the distal end of the Band Stop Filter lead is ~0.5˚C (Fig. 3).

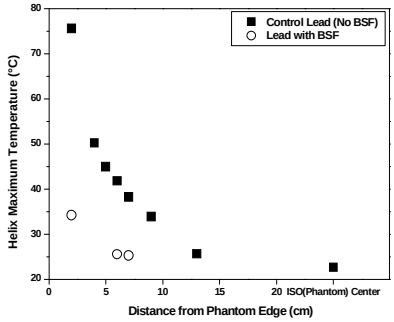

Figure 2. Temperature at the distal end of the Control Lead vs. Band Stop Filter Lead at a variety of distances away from the isocenter of the phantom.

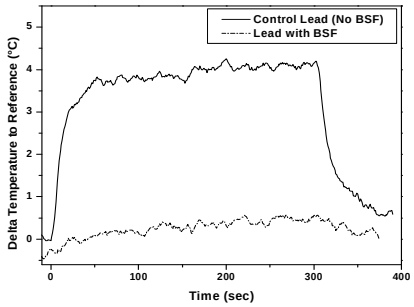

Figure 3. Heating at distal helix of a Control Lead vs. Band Stop Lead in approximated physiological configuration.

Conclusion

The use of a Band Stop Filter lead significantly decreases heating at the distal helix in straight configurations. Importantly, for physiological configurations, the indicated temperature rises were well below expected thermal injury levels.

References

(1) Shellock FG, et al. Cardiac pacemaker: in vitro assessment of MR safety at 1.5-Tesla.American Heart Journal, 151:436-443, 2006.

(2) ASTM F 2182–02a Standard Test Method for Measurement of Radio Frequency Induced Heating Near Passive Implants During Magnetic Resonance Imaging, ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA.