Skin injury Experienced During MRI Scans: measurements of body coil electric field

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Introduction: Although MRI is considered safe (~27 M procedures/ year in USA), it has nonetheless been associated with a number of adverse events, including skin injuries. Skin injuries resembling burns are relative rare but poorly understood. Some occur during skin to skin contact, while others occur when skin contacts the bore of the magnet. The aim of this study is to evaluate the incidence of skin injuries caused by contact with the bore of the magnet and to explore whether the electric fields (*E*) generated at the wall of the magnet-bore could be responsible for some of the observed injuries.

Methods: The FDA database known as the Manufacturers and User Facility Device Event Reporting System (MAUDE) was searched for events between January 1, 1998-2009. Key words in our searches included: burns, blisters, pain, redness, or erythema. Report identifiers included: event date, device name, model number, patient weight, location of burn, and event description. Injury reports that were judged to be not associated with an MR scan were excluded. Several of the recent events (6 cases) were followed up with to understand the relative location and circumstances of the skin injury.

To explore a possible mechanism of the bore-contact skin injury, the spatial maximum **(*E*)** distribution generated at the wall of a stand-alone body coil resonator was measured using three different devices. The body coil used was a low-pass type tuned to 63.7 MHz, with length of 113 cm and inner diameter of 62 cm. Each of the 16 rungs of the coil had two fixed capacitors at 1/3 and 2/3 of the length and two fixed matching capacitors one near each end-ring. The coil was driven by a power amplifier to generate a circularly polarized $\boldsymbol{B_1}$ in continuous wave (CW) mode. Incident power of up to 20 W was tested. The devices used to measure ***E*** were a) Holaday Industries Broadband probe (Edina, MD) model HI-3002 with probe model IME-009, b) SPEAG (Zurich, Geneva) DASY5 robot with ER3DV6 isotropic probe, c) SPEAG Robot with EX3DV4 dosimetry probe in saline and d) EASY4 with EX3DV4 isotropic probe in air. The saline measurements were performed with plastic bucket half filled with saline and placed on its side. The liquid body approximated a half-cylinder (36 cm length x 28 cm radius) touching the bottom of the bore, its axis parallel to the Z-axis of the bore (conductivity of 0.56 S/m).

Results: The incidence of skin injuries was found to increase from approximately 5 cases in 1997 to 67 cases in 2008, to a total 358 cases. In Figure 1, the reports have been sorted by the self-reported cause. A significant fraction (95 of the 358 cases) was caused. by simple contact of skin to the magnet bore. Almost all of the cases were reported at 1.5T. Since this is a voluntary reporting method the actual incidence may be greater. It was also found in interviews with patients/technologists that heating was not usually felt during the scan but a blister was usually attributed to the scan on the following day. During the follow-up interviews the blisters were regarded to be near the edge of the Body coil. The ***E*** measurements using the different probes in air at various points inside the bore showed peaks of ***E*** in the vicinity of the capacitors along the rungs of the resonator. The electric field values decreased non-linearly as a function of distance away from the capacitor. The maximum values measured with 20W (and scaled to 10 kW peak for a clinical MR system) in air were a) 3KV/m (1500 Kv/m) with Holaday device at the wall b) 0.95KV/m (475 Kv/m) with robotic probes at a distance of approximately 2 cm from the bore and c) 2.04 KV/m (1020 Kv/m) (SPEAG DASY5) with probe tip touching the wall. The maximum value in saline was found to be 0.039KV/m (19.5* Kv/m). An example of a ***E*** field plot in air along the x-axis starting at the wall of the coil, using the robot arm is shown in Figure 2 for power settings from 5 to 20W.

Discussion: The methods to make E-field measurements in air and saline were developed which demonstrated a strong peaking near the capacitors. Further studies during actual MRI scan will be needed to understand if the E-fields could be responsible for the reported skin injuries.

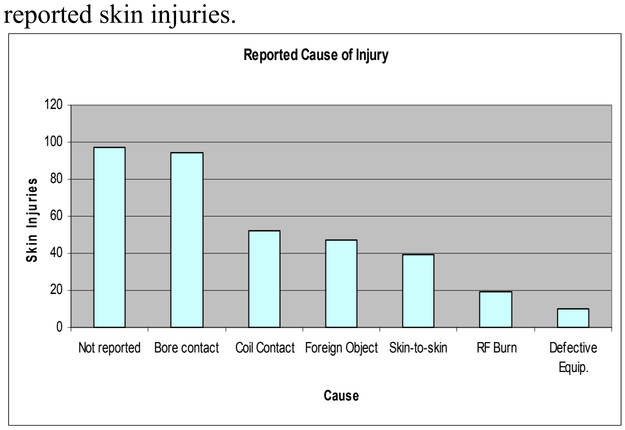

Figure 1: reported injuries versus cause

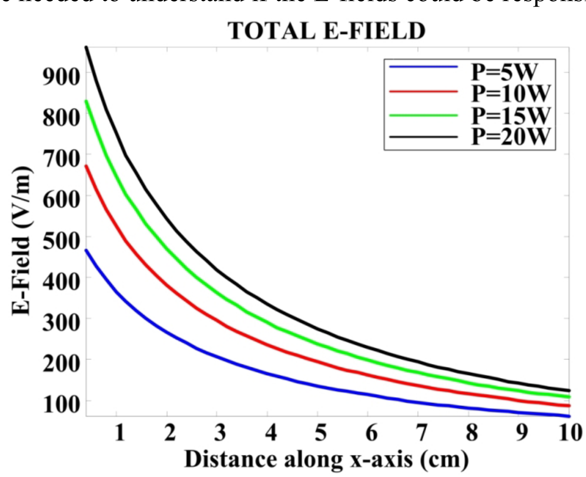

Figure 2: E-field in air as a function of x from the wall of the coil