Induction in ECG Leads Causes Fire in the MR bore - an Effect of the Electric HF Component

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Synopsis
Potential hazards exist when patients with attached or implanted long conductors are examined in MR scanners. Our observations demonstrate that coupling of the electric field to patient monitoring set ups is relevant, and that even with dedicated MR compatible devices hazardous situations may occur. To illustrate the potential of induction in a non-coiled long conductor we report on an incident with a patient who was examined in a 1.5 T MR scanner under ECG monitoring.

Introduction
While the presence of implanted structures is usually considered a potential contra indication for MR, physiological monitoring of patients in the MR scanner is performed on a routine base, applying equipment that is non magnetic and shielded against HF disturbance. If possible, optic wave-guides replace conducting wires. While ECG monitoring is still performed using galvanic conductors, in general practice it is considered safe if the set up is marked MR compatible and the electrodes are fixed in a proper way. However, recently it has been shown that long conductors couple with the electric component E1 of the HF field created in the transmit coil [1-5]. High voltages can be induced near the wire ends. This causes specific dangers.

Materials and Methods
An MR exam of the lumbar spine of a 57-year-old patient was performed in a 1.5 T scanner (Gyroscan Intera T15, Master gradients (30 mT/m, 150 mT/m/ms), Philips, Best, NL). Excitation was done with the standard body coil, for acquisition a five-element phased array coil (synergy spine) was used. ECG monitoring was performed using MR compatible equipment (Tesla plus, MIPM, Mammendorf, FRG). Three Ag/AgCl gelled electrodes were fixed onto the right upper hemithorax. ECG signals were guided through standard cabling marked as MR compatible, consisting of a 96 cm long three-wire twisted ECG cable and a 276 cm long shielded extension cable. The resistance of the ECG cable was 240 Ohm, and 828 Ohm for the extension cable. All cables were guided without loops through the caudal opening of the magnet bore.

Description of events
During a sagittal T1w TSE scan (TR 3.5 s, TE 120 ms, FW 90°, ETL 17, SAR 3.0 W/kg BW) the patient suddenly cried for help. The supervising anaesthesiologist noticed a flame of about 3 cm arising from the patient's shirt, near the ECG electrodes. He extinguished the flames with his hands from the head opening. The patient was immediately pulled out of the magnet bore. A subsequent examination revealed second to third degree burns at the position of the ECG electrodes. The wound was covered with a sterile bandage, and the patient recovered well from this incident. A closer inspection of the ECG leads revealed that the plastic clips connecting ECG lead and electrodes were deformed and partially molten (Fig. 1). The plastic foils of the electrodes were stained with soot, but not molten or perforated and remained intact.

Discussion
Subsequent experiments have shown that the applied spin echo sequences induced sufficiently high voltages into the ECG cables to induce sparking. Especially if the clip had loose contact with the electrode, sparks between clip and electrode emerged, even with the cable properly connected to the monitor. The findings after the incident indicate a significant heating at the lead-electrode contact, presumably caused by sparks. The released heat deformed the clips, and the sparks inflamed the surrounding cloth. This event also reveals that too little attention is paid to the effect of the electric HF component. While commonly there are warnings to avoid inductions due to the magnetic component of the HF field in current loops, in straight conductors induction caused by the electric HF field component is possible as well. This danger exists even with equipment that is specifically marked as MR compatible.

References

Fig. 1: Partially molten plastic clips.