BURNS FROM ECG LEADS IN AN MRI SCANNER: CASE SERIES AND DISCUSSION OF MECHANISMS

Abdel-Rehim S., Bagirathan S., Al-Benna S., O'Boyle C.*

Department of Plastic Surgery, Nottingham City Hospital Campus, Nottingham University Hospitals, UK

SUMMARY. Iatrogenic burns are rare and preventable. The authors present two cases of burns from ECG leads, sustained during magnetic resonance imaging (MRI). Common features included a long duration spinal MR scan (120 and 60 minutes) and high patient body mass index (BMI >30). Both patients were discharged within 24 hours of admission, but required a period of outpatient burn care. The causation of these injuries remains unclear but there are several possible mechanisms including: electromagnetic induction heating, antenna effects and closed-loop current induction. The authors provide a description of the injuries, discuss possible mechanisms that may lead to burn injury in the MRI environment and suggest ways to reduce the risks of such injuries.

Keywords: burns, ECG leads, magnetic resonance imaging (MRI)

Introduction

Burns sustained in magnetic resonance imaging (MRI) scanners are rare.[1-2] Clinicians are aware of absolute contraindications for MRI, but may not be familiar with other hazards of these devices, including burns.[3-6] The authors describe two unusual cases of burns from ECG leads, sustained within MRI scanners, and discuss possible mechanisms of energy transfer within this environment that may give rise to burn injuries.[6-8]

Methods

Patients who sustained burns from ECG leads within the MRI scanner were identified from burns dressings clinic records. We performed a retrospective analysis of the patient case notes. Data collected included patient demographics, mechanism of burn, site and severity of the burn, treatment and clinical outcome.

Results

Case 1

A 59-year-old female, BMI 32 (Weight: 86kg, Height: 1.64metres), underwent a 120 minute MRI scan of the brain and spinal cord to investigate lower limb paraesthesia, under general anaesthesic, using a Philips Intera 1.5 Tesla scanner. The scan proceeded with full anaesthetic monitoring and MRI-compatible ECG cable and monitor (braided coated carbon fibre leads and GE Healthcare Patient Monitor). Upon recovery, the patient immediately complained of burning abdominal pain. A red blistering line was noted from the xyphoid to the peri-umbilical area, in the position of the patient's ECG cable.

Following first aid, the patient was transferred to an adult burns unit. Laboratory investigations, including urinary myoglobin, were unremarkable. The patient received analgesia and topical silver sulphadiazine and gauze dressings. Several areas within the burn progressed to full-thickness skin necrosis (*Fig. 1*). Due to their small size, conservative treatment was maintained. The patient was discharged within 24 hours of admission and the wound healed 4 weeks after injury.

Case 2

A 44-year-old male patient, BMI 34 (Weight: 120kg, Height: 1.88metres), and chronic back pain underwent a 60 minute spinal MRI scan. Due to claustrophobia, the scan was performed under general anaesthesia, using the same scanning device and monitoring as described above. Before scanning, a 2.5cm thick cotton wool strip was placed between the patient and ECG cable. Upon recovery, the patient complained of peri-umbilical pain. Examination revealed an erythematous, blistered line, 8cm in length, on

* Corresponding author: Mr Ciaran O'Boyle, Consultant Plastic & Burn Surgeon, Department of Plastic, Reconstructive and Burns Surgery, City Hospital Campus, Nottingham University Hospitals NHS Trust, Hucknall Road, Nottingham NG5 1PB, United Kingdom. Tel.: +44 (0)115 969 1169; fax: +44(0)115 962 7839; e-mail:Ciaran.O'Boyle@nuh.nhs.uk

Fig. 1 - Case 1: Full thickness abdominal burn following MRI scanning.

Fig. 2 - Case 2: Partial thickness burn seen after scanning.

the anterior abdomen (*Fig. 2*), corresponding to the position of the ECG cable during the scan. First aid was provided. The wound was treated conservatively and healed 10 days after injury.

A Hospital Trust Incident Advisory Report concluded that the burn locations and patterns were indicative of magnetic or electric field coupling (most likely the latter) between the braided ECG cable and patient's skin. The large size of these patients, which reduced convective cooling by restricting air flow through the scanner, and long scan durations were regarded as contributory factors. The failure of insulating material between skin and ECG cables was also cited. The MRI manufacturers recommend the use of sheets or blankets between the patient and ECG cable. Although these patients did have bed sheets and wore gowns, they became excessively sweaty within the scanner. This moisture reduced the fabric's electrical and thermal insulation. It addition, it was suggested that partial unravelling of the ECG cable may have increased induced currents in cables, leading to heating.

Discussion

A recent review of MRI-related burn injuries included only one case out of 150 which was due to ECG leads.[9] Published descriptions of all other ECG-related burns refer to direct skin contact with metal electrodes, as opposed to contact with insulated ECG leads, as in these cases. This raises questions about how electrically-insulated leads could cause burns and what methods may be employed in order to prevent injury.[3,10]

Unlike CT scanners, MRI devices do not produce ionising radiation.[11-21] In MRI, a static magnetic field aligns the magnetisation of hydrogen nuclei (protons) in water. Radio frequency electromagnetic fields cause the quantum spin of aligned protons to flip. When this field is turned off, the nuclei fall back into alignment, releasing photons which can be detected by receiver coils and interpreted to produce an image (*Fig. 3*).[22-23]

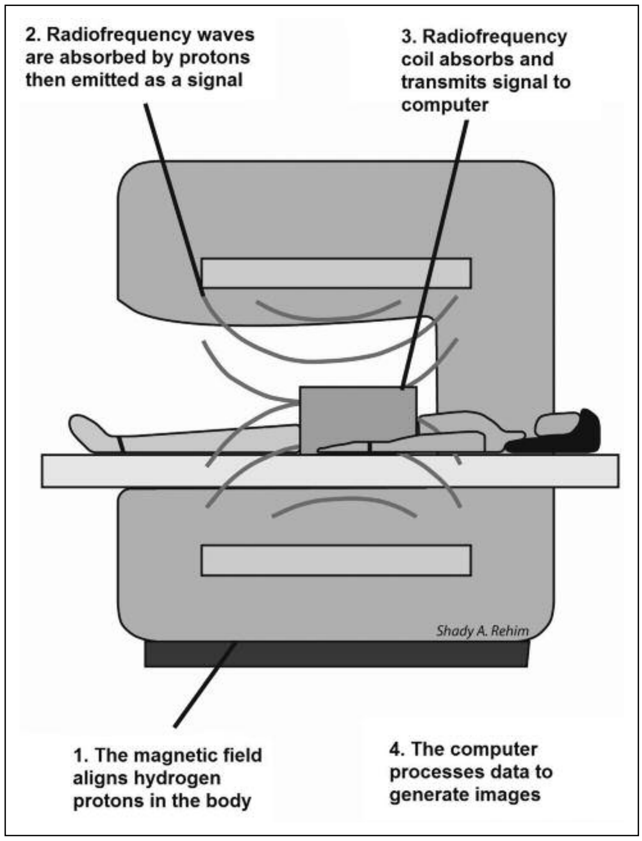

Fig. 3 - MRI scanner and mechanism of action.

Both patients in this series had BMI (Body Mass Index) >30 and spent a considerable time in the MR scanner (120 minutes and 60 minutes).[24-25] Similar patient characteristics and scanning duration have been observed previously.[9] Direct conduction of thermal energy through ECG cables or electrodes may seem the most logical mechanism of injury.[3-4] However, heating during MRI may arise through several mechanisms.[9,26]

1) *Electromagnetic Induction Heating*: Changes in flux of the magnetic induction through a fixed circuit gives rise to an electromotive force (EMF). This EMF creates electric currents that cause heating of the conducting specimen.
2) *Heating due to Antenna Effects*: Transmission of an electric current along leads, with maximal density of heat concentrated at the tip of the lead, which resembles conduction of radiofrequency electromagnetic energy in an antenna.
3) *Current Induction*: In an electrically conductive loop, intercepting a changing magnetic field may

result in development of an electric current in the loop. If body tissues complete an electrical circuit with ECG leads, as a result of capacitive coupling at the site of contact between the body and lead, then an electrical injury could result. If current flow within the lead generates sufficient heat, thermal injury may be produced.

In the absence of a proof of mechanism, it is imperative to examine these mechanisms in order to minimise risks to other patients.[3-5,24,27-35] In both patients, injury patterns strongly suggest altered ECG cable interactions with the variable MRI magnetic field. Increased loop size created by opening out of ECG cables may increase induced currents in the cables, leading to heating and injury. Increasing the distance between ECG leads and the patient would provide an obvious solution, reducing the risk of injury by all three outlined mechanisms. However, in MRI scanners, space is at a premium and it may be impossible to satisfactorily direct leads away from a patient. Use of a thick non-ferromagnetic substance, like cotton or foam wadding, may provide a space between leads and the patient, which is sufficient to dissipate charge or heat and prevent injury. Nevertheless, despite the use of a 2.5cm thick insulating cotton wool strip, a patient still sustained a burn. In each case, patient size was regarded as contributory. The scanner's internal diameter was 60cm (188.5cm circumference). As a result of these incidents, patient circumferences are now measured before scanning and if found to exceed 188.5cm, i.e. consistent with a 60cm diameter, the patient will be scanned at another hospital, which has a scanner of 70cm internal diameter.[36-37]

Patients undergoing whole spine MR scanning appear to be a susceptible group to MRI-induced burns for several reasons.[9,26] Firstly, patients suffering from disabling spine conditions are often less mobile or immobile.[24] The reduced mobility contributes to increased body weight, high BMI and difficult positioning in the MR device.[24] Another risk factor to be considered is the length of time spent by the patient within the MRI device. A relatively long duration (over 40 minutes) of MR scanning is required to obtain images of the whole spinal column. This may predispose patients to a greater risk of injury due to loss of thermal and electrical insulation by excessive sweating, contributing to increased risk of radiofrequency-associated burns.[24,38] Although most published reports highlight the effects of magnetic field and MRI radiofrequencies; patient weight, body habitus and duration of scanning should be taken into account and regarded as risk factors for MRI-related burns.

Conclusion

MRI-induced burns are rare, but the lack of ionizing radiation may lull clinicians into a false sense of security regarding other risks of MRI scanning. This report sheds light on the proposed mechanisms of injury and describes some patient characteristics that may pose higher risks for burn injuries from MRI scanners.[3-5] Increased staff awareness, communication and adherence to pre-procedure safety checks are required in order to minimize these risks.[3-5,39-46]

RÉSUMÉ. Les brûlures iatrogènes sont rares et évitables. Nous présentons deux cas de brûlures subies au cours de l'imagerie par résonance magnétique (IRM). Dans les deux cas, il s'agissait d'une analyse de longue durée de la moelle (120 et 60 minutes) et des patients avec un indice de masse corporelle élevé (IMC> 30). Les deux patients ont recu leur congé de l'hopital dans les 24 heures suivant l'admission, mais ils ont eu besoin d'une période de soins ambulatoires. La causalité de ces blessures reste imprécise mais plusieurs mécanismes sont possibles, y compris : le chauffage par induction électromagnétique, les effets de l'antenne et l'induction de courant à boucle fermée. Nous donnons une description des blessures, discutons des mécanismes possibles qui peuvent conduire à des brûlures dans l'environnement IRM et proposons des moyens pour réduire les risques de telles blessures.

Mots-clés: brûlures, dérivations, l'imagerie par résonance magnétique (IRM)

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