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Case Report

MRI safety risks in the obese: The case of the disposable lighter stored in the pannus

H. Michael Gach, PhD^{a,b,c,*}, Stacie L. Mackey, AAS^d, Sarah E. Hausman, BS^d, Danielle R. Jackson, BS^d, Tammie L. Benzinger, MD, PhD^{b,e}, Lauren Henke, MD^a, Lindsay A. Murphy, BS^d, Jamie L. Fluchel, BS^d, Bin Cai, PhD^a, Jacqueline E. Zoberi, PhD^a, Jose Garcia-Ramirez, MS^a, Sasa Mutic, PhD^a, Julie K. Schwarz, MD, PhD^a

^a Department of Radiation Oncology, Washington University School of Medicine, 4921 Parkview Place, St. Louis, MO 63110, US

^b Department of Radiology, Washington University School of Medicine in St. Louis, 4921 Parkview Place, St. Louis, MO 63110, US

^c Department of Biomedical Engineering, Washington University in St. Louis School of Engineering & Applied Science, 6201 Forsyth Blvd, St. Louis, MO 63105, US

^d Department of Radiation Oncology, Barnes Jewish Hospital, 4921 Parkview Place, St. Louis, MO 63110, US

^e Department of Neurological Surgery, Washington University School of Medicine in St. Louis, 4921 Parkview Place, St. Louis, MO 63110, US

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ABSTRACT

Obese patients constitute 40% of the adult population. MRIs of obese patients are typically challenging because of the effects of a large field of view on image quality and the increased risk of thermal burns from contact with the bore. In this case report, the impacts of obesity on MRI procedures and safety are introduced. Then a case is presented of a 30-year old female cervical cancer patient who received an MRI simulation to verify the placement of a titanium tandem and colpostats for brachytherapy. A large magnetic susceptibility artifact was detected near the right pelvis during the MRI scout indicating the presence of ferrous material. The source of the artifact turned out to be a disposable lighter that was stored inside the patient's pannus. The finding highlights an unanticipated risk to MRI safety and image quality associated with large body habitus.

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* Corresponding author.

E-mail address: gachhm@wustl.edu (H.M. Gach).

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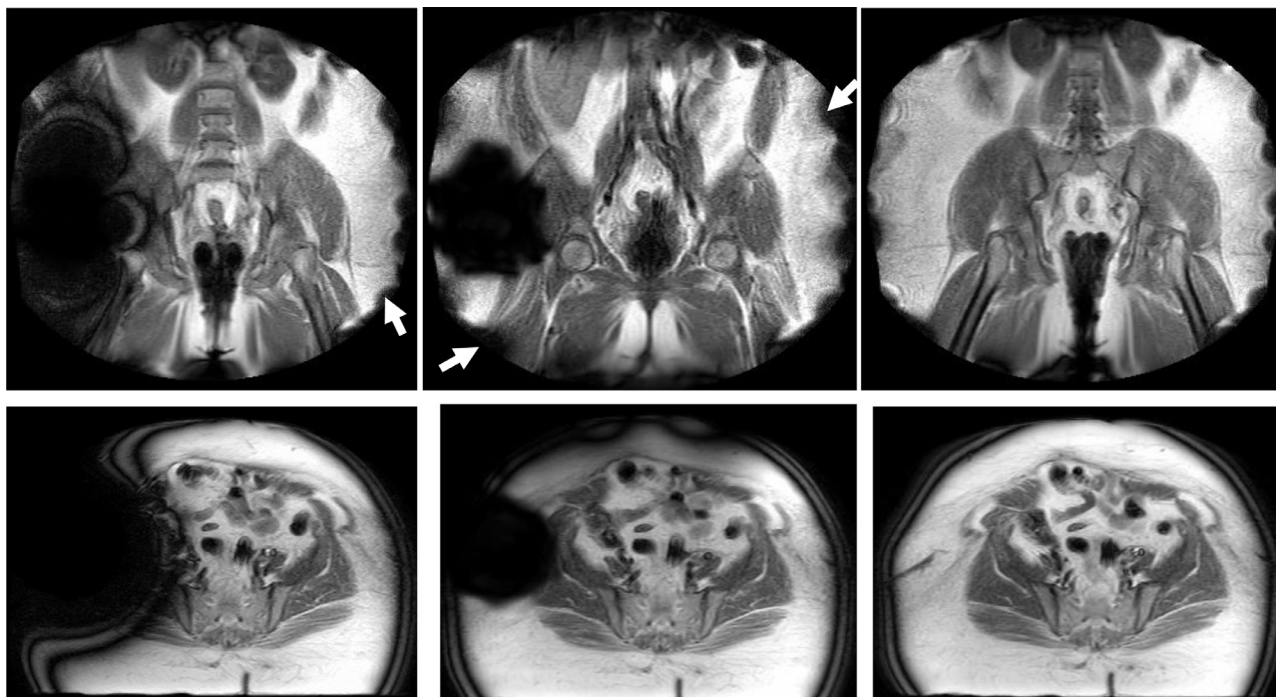


Fig. 1 – Ferrous lighter hidden in pannus. Scout MRIs are shown with (left column) and without (middle and right columns) the presence of the disposable lighter. The left column shows the effects of strong magnetic susceptibilities from the presence of the lighter. The center column was acquired after the removal of the lighter indicating that there was remaining ferrous residue. The right column shows the disappearance of the susceptibility artifact after the cover sheet was replaced. Top row: Coronal slice. Bottom row: Axial slice. The arrows show bite-mark artifacts caused by field inhomogeneities associated with the large field of view that are unrelated to the lighter.

Introduction

The risks of magnetic resonance imaging (MRI) procedures typically rise for the obese. Yet the literature has rarely addressed this important safety issue. In this report, we summarize the MRI safety risks that increase in the obese and present an unexpected risk: storage of objects in the large body habitus.

Case report

A 30-year-old female patient with malignant neoplasm of the exocervix was scheduled to receive an MRI simulation after implantation of brachytherapy titanium tandem and colpostats (Varian Medical Systems, Palo Alto, CA) to verify implant positioning [1]. The patient's weight was 190 kg and her height was 165 cm. Thus her body mass index (BMI) was 69.8 kg/m² and she met the criteria for being morbidly obese. This was her fourth brachytherapy fraction and the patient had successfully received MRI simulations in our department for the first 3 fractions without incident.

All MRI patients are required to wear only hospital gowns for their procedure and are screened prior to each MRI procedure. The patient was screened (interrogated) for MRI safety by

the MRI Technologist prior to transport into the magnet room. No other metal implant was identified during safety screening aside from the tandem and colpostats. The patient was brought into the magnet room and transferred from a gurney to the patient table using an MRI compatible HoverMatt Air Transfer System (HoverTech International, Allentown, PA) that is used for obese patients. For patient handling, MRI simulations are nominally staffed by a 2-person team consisting of the MRI Technologist and a Sim Therapist. For this patient, a 3-person team was used including a second Sim Therapist.

All MRIs were performed using a widebore (70 cm diameter) 1.5 Tesla Ingenia MRI system (Philips Healthcare, Netherlands) running software version 5.3. The patient was positioned on a flat table top and imaged using anterior/posterior receiver coils and a body transmit coil. A 3-plane gradient-recalled echo scout was acquired (TE/TR: 4.6/7.8 ms, flip angle: 25° degrees, field of view: 550 mm, slice thickness/spacing: 15/10 mm, receiver bandwidth: 359 Hz/pixel, 1.6 × 3 mm in-plane resolution). A large ferrous artifact was observed on the right lateral pelvis (Fig. 1).

The MRI Technologist and Sim Therapists immediately removed the patient from the MRI and inspected the proximity of the artifact. The patient remembered that she had a disposable lighter (Fig. 2) stored inside her pannus. To avoid a flying projectile, the patient was warned not to move. Instead, the MRI Technologist removed the lighter. The patient was reinserted into the bore and another set of surveys was



Fig. 2 – Disposable lighter (8 cm in length) removed from the patient's pannus.

acquired. The susceptibility artifact was reduced, but still significant. The patient was removed from the magnet and the cover sheet was replaced. The patient was reinserted into the magnet, the exam was successfully completed, and the patient was returned to brachytherapy for her treatment. The patient was instructed by the brachytherapists to remove the lighter before medical procedures.

Fortunately, no adverse impact to the patient occurred due to the presence of the lighter in the MRI. The patient was not wanded since the patient had implanted metal in her uterus near the location of the lighter. In a survey conducted in August and September 2017 of our MRI simulation patients ($N = 76$), 71% had metal implants (excluding tandems and colpostats) and 37% had metal in the imaging field of view. Wand-ing with a metal detector (Garrett Super Wand Model 1165800, Garland, TX) is not routinely performed for diagnostic MRIs or 1.5 T MRI simulations unless the patient is unsure about their history with metal. However, we routinely wand patients for MR-IGRT procedures. A hand magnet (Master Magnetics, Castle Rock, CO) is used in the event superficial ferrous metal is suspected.

The presence of a susceptibility artifact after the removal of the lighter was puzzling. Disposable lighters are composed of: (1) a plastic (Delrin) body and base; (2) an aluminum valve; (3) a brass jet; (4) a sparkwheel composed of zinc zamac alloy finger pieces and a serrated steel striker; (5) a “flint” made of ferrocerium; (6) a nickel-plated steel hood and guard; (7) a plastic fork; (8) two steel springs for the jet and fork; and (9) isobutane fuel. Ferrocerium is a synthetic pyrophoric alloy containing 21% iron. We suspect ferrocerium residue and possibly filings from the steel striker remained on the cover sheet during the second set of scout images thus producing the smaller susceptibility artifact.

After the MRI incident, it was discovered that the patient received cone-beam CT (CBCT)-guided external beam radiation therapy with the lighter present in her right pelvic pannus. The radiation therapists were not aware of the MRI incident and assumed the source of the CBCT metal artifact was located inside the body cavity due to its apparent depth (Fig. 3). The lighter was located in 1 of the radiation beam paths during 2 fractions, but the impact to treatment was minimal. A note about the patient's penchant for storing her lighter in her pannus was placed in her electronic medical record. The radiation therapists, brachytherapists, and simulation therapists were instructed to search for the lighter before subsequent treatments and simulations.

Table 1 – BMI distribution of 591 cervical cancer patients.

| Classification | BMI (kg/m ²) | % of patients |
|----------------|--------------------------|---------------|
| Underweight | <18.5 | 1.7 |
| Normal | 18.5-24.9 | 38.9 |
| Overweight | 25-29.9 | 18.8 |
| Obese | 30-39.9 | 26.4 |
| Morbidly obese | ≥40 | 14.2 |

Discussion

According to the National Health and Nutrition Examination Survey conducted in 2015-2016, the prevalence of obesity (BMI ≥ 30 kg/m²) in U.S. adults was 39.8% [2]. The prevalence of obesity was higher in middle-aged (40-59 years old) adults (42.8%) and seniors (60 years or older, 41.0%), that is, the age groups that are more likely to have chronic diseases requiring MRI procedures, versus younger (20-39 years old) adults (35.7%). The prevalence of obesity was 8% higher in adult women versus men although the difference was not statistically significant. In a recent study of our cervical cancer patients (most of whom received MRI simulations), 40.6% were either obese or morbidly obese (Table 1) [3].

Obese patients present challenges to the performance and safety (Table 2) of MRI exams. The first challenge is safely fitting the patient inside the bore. Widebore magnets with 70 cm diameter bores are widely available to accommodate most large patients. For MRI simulations used in external beam radiation therapy, the entire body must be imaged to ensure successful fusion with CT images for photon attenuation calculations and accurate treatment planning [4,5]. However, the MRI vendors typically limit the imaging field of view to ≤ 550 mm. MRIs using large fields of view are vulnerable to magnetic field and radiofrequency (RF) inhomogeneities, and gradient nonlinearities that can cause a variety of artifacts including anefact, poor fat saturation, and aliasing [6,7]. Larger fields of view also require longer image acquisitions assuming the image resolution is unchanged. Longer acquisitions in the body raise the risk of motion artifacts. At high fields (>1.5 T), dielectric artifacts become more pronounced since the RF wavelength inside tissue is comparable to the size of the imaging volume [8].

The risk of thermal burns rises for the obese due to their girth, the difficulty in preventing conductive loops between limbs, and the increased risk of high local electric fields forming around external tissue discontinuities like panni [9–11]. Heating effects from specific absorption rate are a major concern since the specific absorption rate rises quadratically with the radial distance from isocenter and with field strength. Since most MRIs use the body coil for RF transmission, one should assume that the electric field is highest at the surface of the body coil (or bore) [12]. In addition, the attenuation of RF by the lossy body habitus requires increased transmit (body) coil voltages and electric fields to achieve the desired flip angle in the center of the imaging volume [11]. Therefore, it is imperative to insulate the patient from the side of the bore to prevent burns [13]. Obese patients may also have more difficulty

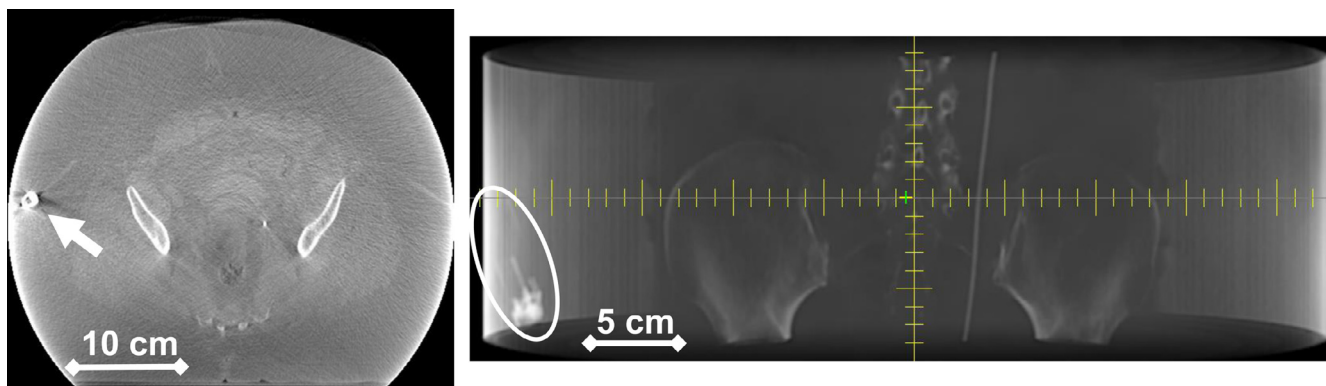


Fig. 3 – Lighter hidden in pannus during radiation therapy. Cone beam CT (CBCT) images acquired for image-guided radiation therapy setup. The axial image (left) and coronal projection (right) show the presence of the disposable lighter located inside the body periphery. The CBCT images (120 kVp, 100 mA) were acquired on a Varian Truebeam CBCT-Linac used in external beam treatment of the patient’s cervical cancer. Note: The lateral field of view was not reconstructed to include the entire body habitus so the lighter appears closer to the periphery than actual.

Table 2 – Safety threats and risks associated with MRI fields.

| Safety threat | Typical risks | Increased risks for the obese |
|---|--|--|
| Static magnetic field (B_0) | Metal projectiles [†] , torque on metal [†] , damaged implanted devices [†] , vertigo ^{†*} , nausea ^{†*} , phosphenes ^{†*} , metallic taste ^{†*} , magnetohydrodynamic effects ^{†*} , quench (exposure to cryogenics or suffocation) | None |
| Alternating magnetic field (dB/dt) [‡] | Acoustic noise [†] , peripheral nerve stimulation, alternating current heating, metal vibration, damaged implanted devices | Peripheral nerve stimulation, alternating current heating, metal vibration |
| RF field (B_1) | RF heating and burns [†] , damaged implanted devices [†] | RF heating and burns [†] |

[†] Risk increases with increasing field strength (B_0).
^{*} Symptoms tend to be observed only at high fields (>1.5 T).
[‡] Risks associated with dB/dt caused by movement through the magnet’s fringe field can increase with increasing field strength (B_0).

than thinner patients with thermoregulation thus exacerbating the risk of RF heating [14]. External receiver coils may not fit in the bore for some large patients. Therefore, the patient may require image reception with the body coil that will impact the quality of image acquisition, and increase the exam time and the risk of RF heating. Scan pauses may be required during the MRI exam to ensure dangerous temperatures are not achieved in or on the body.

The risks from alternating magnetic fields (dB/dt) associated with the magnetic field gradients, or interaction with the fringe field during insertion into the bore, will also increase in patients with a large body habitus. dB/dt associated with gradients increases with distance from isocenter, so larger patients will be subject to higher dB/dt at their periphery versus thin patients. dB/dt can cause peripheral nerve stimulation and alternating current heating in vivo [15]. However, the risks and effects of PNS (eg, pain) are usually mild. The risk of alternating current heating is usually small unless the patient has metal implants. Gradient switching can also cause metal implants to vibrate, although the effects are typically benign [16,17]. The vibrations are often perceived as heating sensations, despite no significant rise in temperature.

The phenomenon of a patient storing items in their body habitus (known as the “Human Couch”) was previously re-

ported for an obese ER patient who had an asthma inhaler, dime, paper towels, and a TV remote control hidden on the exterior of her large body habitus [18]. The disposable lighter stored on our patient was not detected by staff, despite extensive interactions with the patient’s habitus during brachytherapy implantation and MRI simulation setup. Therefore, this case highlights a new vulnerability in MRI safety screening. Unfortunately, the phenomenon and its risks are not restricted to MRI as we observed with the CBCT-guided external beam radiation treatments.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.radcr.2019.02.023.

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