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The Dangers of Fabric in MRI

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Thermal burns are the most common injury sustained during MRI. Textiles such as clothing and blankets, and most recently fabric face masks are emerging as key factors when considering such thermal injuries. Fabric can trap heat and sweat close to the body and fabric containing metallic fibers can interact with MRI's RF waves to induce burns, which represents the majority of reported fabric-related thermal injury cases. This may be exacerbated by a lack of comprehensive labeling when fabrics contain trace amounts of metals. This review outlines case reports and makes suggestions that may reduce the frequency of these burns. The single most effective way to reduce the danger of fabric-induced MRI burns is to require all patients to change into MR-safe clothing, such as approved hospital gowns, prior to imaging.

Introduction

MRI is a vital imaging modality, performed millions of times per year in the United States alone.[1] It is ideal for imaging soft tissue and is relatively safe due to its non-invasive and non-ionizing nature. However, MR imaging has inherent risks. As the number of MR procedures increases every year, so does the number of adverse events.[2, 3] Although the fraction of MR procedures with adverse events is low, these events can have devastating consequences[1]. Risks to patients and radiological staff include thermal injuries, nerve/muscle stimulation, and unwanted forces that can increase the potential for launched projectiles.[2,3]

Thermal injuries to patients are recognized as a primary threat, constituting 59% of adverse events[2]. Investigations into the causes of such injuries[4,5] have shown that skin-to-skin, bore, and foreign object contact can form conductive loops; MR's radiofrequency (RF) waves can induce an electrical current in such conductive pathways and resistively heat tissue, potentially causing a burn[2](4). Foreign, metallic objects involved with these burns include electrocardiogram (ECG) leads[6,7] and adornments such as zippers, clasps, buttons, and mask nose clips. However, textiles such as blankets, clothing, and non-woven fabrics such as face masks have also been linked to burns.[8–15] The propensity for thermal events stemming from fabric may be exacerbated by the relatively recent trend of employing metallic thread in exercise clothing and face masks, which has resulted in corresponding MRI safety guidance from the ACR and FDA.[15,16] Although such guidelines are in place to prevent thermal injuries due to fabric interactions during MR imaging, incomplete labeling, failure to heed safety guidelines, and a lack of awareness still contribute to their occurrence.

This review outlines unintentional thermal injuries caused by fabric during MR imaging. It encompasses thermal injuries and elevated temperature related to fabric including masks, undergarments, pants, shirts, socks, gowns, and blankets. Several safety recommendations are made to address concerns raised throughout the literature. Of these suggestions, the most imperative is that all patients change into approved garments before undergoing MRI.

Review of Reported Events

As of December 2020, at least six pertinent case reports have been published. Additionally, warning articles from the Cumulative Index of Nursing and Allied Health Literature (CINAHL) and AuntMinnie.com are outlined. Finally, an unpublished case was identified from a local institution.

Thermal Events Due to Metallic Fibres

Burn from jogging pants

In Japan in 2019, a 40-year-old female patient was imaged using MRI to evaluate the thigh muscles.[10] She was visually screened, verbally screened, and examined using a handheld metal detector to ensure safety prior to entering the MRI suite. She entered the MR scan room wearing a white t-shirt and jogging pants. The jogging pants were labeled as 100% polyester and had vertical lines running along the lateral side of each thigh. Artifacts were noted bilaterally on the thighs during the MRI, with a pattern matching the decorative lines running lengthwise along the pants. The patient did not complain of discomfort or pain - imaging continued for a total duration of 15 minutes. Afterward, bilateral thigh redness and swelling appeared. Seven days later the reddened regions blistered, and the injuries were diagnosed as second-degree burns. The burns were treated

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with a steroid ointment and improved gradually. Unfortunately, radiography was not able to verify the presumed existence of metal in the jogging pants.[10]

Burn from undershirt with metallic microfibers

An 11-year-old female patient presented for an MRI evaluation of scoliosis[8]. Before the MRI, she was screened for hazardous items verbally, using a handheld metal detector, and with visual checks. During the procedure, the patient wore an undershirt containing Lycra and Coolmax, according to the label. Coolmax is a polyester fabric known for wicking sweat from the body and speeding evaporation.[17] The patient was sedated during the procedure with her arms at her sides. When the patient was aroused from sedation, she noted a right-sided burning sensation. Upon examination, linear erythematous blisters were present on her right flank and wrist where they had been in contact with her undershirt, which was diagnosed as a second-degree burn. Radiography was used to image the shirt after the incident and successfully discerned a pattern of radiopaque silver microfiber within the shirt seams that corresponded with her burns.

Smoldering blanket in MR suite

A 62-year-old female patient was wrapped in a hospital blanket to isolate her from RF coils while undergoing MRI.[11] At the end of imaging, the technician noticed a strong burning odor and soot inside of the MRI bore. The blanket was found to be smoldering without flames. The patient didn't notice the scent because she was afflicted with permanent anosmia. Luckily, she did not suffer from any burns. Site personnel reached out to the blanket manufacturer and were informed that the blanket contained copper fibers. These fibers were used during automatic fabric cutting and could remain within the fabric afterward. 881 examinations had been previously performed using the blankets without similar adverse incidents, so MR personnel had assumed that the blankets were safe for MR use. The team involved concluded that folding the blanket in a specific orientation created a closed loop that augmented heating. After the incident, it was ultimately decided that disposable linens should be used in procedures unless the absence of metallic fibers can be confirmed, a decision presumably in response to the purported lack of metallic components in and the elimination of bacterial growth concerns for disposable items. Further, the manufacturer altered their production process to deter metallic components from being deposited in the blankets going forward.

Burn from athletic pants

In a 2019 incident at a local institution, a male patient with a prosthetic leg wore athletic stretch leggings during an elbow MRI examination. The patient's lower back was in proximity to the bore, separated by a sheet. Towards the end of the last sequence, the patient mentioned a warm sensation, but the technologist didn't hear him, and the patient did not mention it again. Upon imaging completion, the patient mentioned a burning sensation around the upper margin of the leggings at the lower back. It was assessed that a burn was caused by the leggings that likely contained silver thread, and by the close proximity to the bore.

Burns from protective facemasks

A report was submitted to the FDA's Manufacturer and User Facility Device Experience Database (MAUDE) of a patient sustaining third-degree burns across the nose, eyes, mouth, jaw, chin, and neck while wearing a face mask during a 3T MR of the cervical spine.[14] The patient reported that the MRI technologist did not offer the chance to change into institution-approved garments or change their face mask. Due to the distribution of the burn, it was deduced that metallic nanoparticles and/or fibers in the fabric itself may have caused the burns. Further information on this case was not made publicly available and therefore the severity of the burn and materials of the facemask was not confirmed, however, due to the severity of the event, the FDA warned health care providers to not allow MRI patients to wear masks with any metallic components.[15]

Thermal Events due to heat trapping

Thermal discomfort from heat-retardant undershirt

In Japan in 2018, an 80-year-old female patient presented for MR imaging.[9] Five minutes after scanning began, the patient experienced a continuous, severe sensation of heat on the skin of the upper dorsal trunk that was in contact with the magnet bore. The team did not notice any visual dermatological abnormalities and continued imaging. Two days later the patient returned to the facility because the burning sensation had not ceased. It was later revealed that she wore four undershirts for the procedure, one of which was labelled as heat retardant. It was made of 38% polyester, 34% acrylic, 18% rayon, and 10% polyurethane, and did not list any metallic components. However, this material is known to have excellent water and heat retention without evaporation. Therefore, the team was suspicious that the fabric had trapped heat and sweat to the patient's body, leading to the burning sensation. She made a full recovery shortly after. The team reached out to the heat-retardant undershirt manufacturer and were informed that other hospitals had also reported similar heating in patients.

Unpublished Reports and Warnings

Several warning articles have been issued following unpublished reports of textile-induced burns during MR imaging. In 2014 a woman reported a burning sensation during MRI while wearing elastic leggings, typically known as yoga pants.[18] The sensation intensified at 15 minutes, so she alerted the radiologist, and the procedure was halted. She was not seriously harmed. In another report involving yoga pants, the patient reported a burning sensation during the MR exam.[13] She used the emergency stop button to end the procedure, exited the scan room to remove her pants and don a gown, and then imaging was restarted. There were no further complications. Afterward, a resident told her that the pants may contain silver. Another instance occurred where a patient suffered a third-degree burn after wearing a sports bra during an MRI scan.[12] The burn took a day to fully develop. However, the bra material was not inspected so it is unknown if the fabric contained metallic fibers, or if it had a metallic underwire. These adverse event warnings highlight that there may be more thermal injuries occurring during MR that are not discussed in case reports.

Discussion

Thermal burns during MRI represent a significant risk. The temporally variable RF magnetic field can induce electric currents in conducting substances. Foreign metallic objects pose the greatest concern. These include medical equipment such as MR coils, cardiac and other active implants and leads, pulse oximeters, head frames, orthopedic and other passive implants, and dermal patches; body adornments such as jewelry, piercings, tattoos, and permanent makeup; fabric adornments such as clasps, fasteners, hooks, zippers, and mask nose clips; and clothing, masks, and blankets that contain metallic fibers. Electrical induction occurs more readily if a conductive loop is formed, such as by skin-to-object, skin-to-skin, and skin-to-bore contact.[2] Heating occurs when high-resistance materials such as tissue are near the induced electrical current. Clothing

accounted for 5% and blankets 4% of foreign-object-related burns in the United States between January 2008 and the end of December 2017, totaling 48 textile-related thermal injuries.[2]

Most institutions strictly monitor external objects that enter the MR suite to decrease the risk of thermal injuries. Recently, metals such as silver are becoming more common within clothing and masks,[8,12,14,19,20] especially in exercise, spandex, elastic, anti-microbial, and antibacterial clothing due to their ability to keep odour and bacteria from building up.[10,13,18,19,20] Further, newer materials can be cut using automated processes that may leave traces of metal fibers within them.[11] Therefore, staff should be cautious of all fabrics entering the MR suite, especially material claiming to be anti-microbial, anti-bacterial, or activewear.

In each discussed instance in which clothes contained metallic fibers, it was not indicated on the corresponding label.[8,10,11] In the United States, 5% undisclosed material impurity is permitted in clothing item labels.[21] Therefore, clothing labels cannot be used to determine if an item is free of metals and subsequently MR safe. This predicament is mirrored by the possibility of processed foods being contaminated with trace amounts of nuts due to food processing equipment. The food industry responded to this by labeling all foods that may contain nuts, even though the base ingredients did not include them, since the consequences of even a trace amount can have disastrous consequences for those with allergies. Similarly, even an undetectable number of metallic fibers can burn a patient. Until fabrics explicitly mention whether trace metals are involved in manufacturing, MRI safety personnel should be aware that there is always a possibility of metallic content.

Even if a textile is proven to be free of metallic fibers, it can still cause a burn by trapping heat and moisture to the patient's body. This depends on the material's configuration and heat/water retention capabilities. However, to the author's knowledge, this has only been reported in the one case mentioned, where the patient was wearing four layers of clothing.[9] Therefore, the risks associated with textiles containing metallic fibers would seem to be the primary textile related MRI heating concern.

There are multiple screening tools and techniques available to detect metal such as handheld or gate metal detectors, scar inspection, prior imaging examination, and high-resolution digital radiography. Unfortunately, many metallic substances may not be detected using these screening methods.[8,10] High-resolution digital radiography was used in some of the discussed case reports to investigate the presence of metal after burns occurred. This technique was inconsistent at verifying metallic content in the studies reviewed, but it may be useful after a burn occurs if metal is suspected to corroborate burn patterns.[8,10]

Often, the extent injuries depended on whether or not the patient was able to detect and communicate a thermal sensation so staff could halt imaging.[8,9,10,15] This leads to one of the biggest challenges in burn prevention: patients often do not feel a burn while it is happening. Despite sustaining a thermal injury, patients may not alert staff, especially if they are sedated, have nerve damage preventing nociception or other relevant sensations, sustain burns in tissues lacking sufficient sensory innervation for detection, or otherwise cannot communicate.[8,11] These patients are especially vulnerable to thermal injuries during MR imaging.

A valuable resource for combatting fabric-related MR thermal injury is direct communication with fabric and textile manufacturers.[8,10,11] Manufacturers will likely have extensive lists of all fiber contents within a given fabric, keep track of all adverse events reported to them, and provide insight on the manufacturing process. Manufacturers have a wealth of knowledge about their products and will often answer questions relating to them; they may even alter production if concerns are raised.

Imaging artifacts may be a symptom of metallic substances within the MRI scanner. When unknown metal artifacts appear, imaging should be halted, and the patient should be screened again to identify the cause. In general, all cases of unexpected MRI artifacts and thermal injuries should be carefully recorded and tracked. Any incidents involving fabric should be investigated to determine why a preventable injury occurred.

In several of the reviewed cases, staff continued imaging despite patient concerns, and occasionally the patients themselves took the initiative to change their clothing. Staff and patient education and awareness is crucial to prevent injuries. For instance, hospital employees can be warned about incidents and made aware which fabrics caused adverse events. This common-sense approach to MRI safety may be realized via a top-down design that begins with sound MRI safety guidance from hospital MRI safety personnel and administration. Patients should be informed about the danger of fabric-MR interactions, changed into approved gowns and MR-safe masks before procedures, and encouraged to alert staff if any burning sensations arise.

Future Investigations

Investigations determining how to quickly, easily, and accurately identify MR-safe clothing could be beneficial. The amount of time that passed prior to palpable burning sensations varied in every case; patients could feel a burning sensation from five minutes to days after the procedure. Studies into the metallic content and location within fabrics in relation to burning sensation timing and degree could be useful for the further understanding of fabric-related burns. Further, some fabrics may be used extensively during MRI before an adverse event occurs, and folding fabric in a specific orientation could create closed loops that lead to heating.[11] A more thorough understanding of burn patterns and the metals responsible for them would be helpful in both preventing and treating fabric-related burns.

It would also be useful to be able to regionally measure the electrical resistance of items involved in burn incidents to determine threshold resistance levels for safety standards. A fabric's electrical resistance determines its ability to conduct electrical currents that can in turn lead to tissue heating as discussed above. One study hypothesized that electromagnetic eddy currents generated in fibers concentrated either at the fabric seam or between the seam and the patient's skin, and measured fabric resistance to be 10 ohms.[8] This low resistance indicated high electrical conductivity and potential for burns, compared with cotton for example, which is mostly comprised of cellulose[22,23] with virtually infinite resistance. Fabric electrical conductivity information could allow for a more educated determination of safe fabrics to be used in MRI.

Conclusion

Although MRI is a relatively safe imaging modality, in each case report reviewed, a fabric that entered the MR suite led to heating levels sufficient to cause thermal injuries. MR personnel should consider all fabric MR unsafe unless proven otherwise. This entails not relying on labels or screening methods to identify metallic components, and directly communicating with manufacturers when necessary. Extra precautions should be taken to protect vulnerable patients, promptly address patient complaints of thermal sensations during imaging, and investigate imaging artifacts as they arise. Further, radiography and artifact evaluation may be useful in the event a burn occurs, to investigate the presence of metals and compare them to the burn pattern. The most useful recommendation to decrease the incidence of these injuries is for all institutions to require all patients to change into approved gowns and face masks if necessary, and only allow the approved fabric to enter the MR suite.

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