An In vitro Assessment of MRI Issues at 3-Tesla for Antimicrobial, Silver-Containing Wound Dressings

Kirin B. Escher; and Frank G. Shellock, PhD

Abstract

Although no reports of adverse events have been published to date, the presence of metallic dressing ingredients may present a magnetic resonance imaging (MRI) safety concern for patients using silver-containing wound dressings. The purpose of this in vitro study was to test magnetic field interactions (ie, translational attraction and torque), heating, artifacts, and conductivity (ie, electrical resistance) when using MRI at 3-Tesla for two (nonborder and border) silver-containing wound dressings. The results indicated the dressings displayed no magnetic field interactions (deflection angle 0˚; no torque), and in each case, MRI-related heating effects were at the same levels as the background temperature increases (ie, <1.8˚C). The dressings created extremely subtle artifacts (one-for-one relationship) on the MR images. With regard to the conductivity assessments, the average resistance values were 20 kOhm and 1.1 kOhm, respectively, for the nonborder and border wound dressings, which were acceptable levels. The findings show the two silver-containing wound dressings tested will not pose hazards or risks to patients and, thus, are considered “MR safe” according to the current labeling terminology used for medical products, and each dressing may be left in place when a patient undergoes an MRI examination. To date, only a hydrofiber silver-containing dressing has been tested for MRI safety. Because of potential variances in material characteristics, MRI test results are specific to the dressings tested and cannot be applied to other products. Future studies to define the level of silver concentration in dressings that may pose a hazard for performing an MRI are warranted.

Keywords: in vitro study, safety, magnetic resonance imaging, silver, dressings


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Antimicrobial, silver-containing dressings often are used to manage wounds, particularly wounds that may be susceptible to infection.1,2 These dressings are indicated for a variety of wound types, including superficial and partial-thickness burns, traumatic and surgical wounds, pressure ulcers, and abrasions.1,2 Results of an open, parallel, randomized, comparative, multicenter study3 of patients (N = 101) with partial-thickness burns showed healing outcomes were similar for wounds dressed with a silver-containing soft-silicone foam dressing (Mepilex Ag, Mölnlycke Health Care, Goteborg, Sweden) or silver sulfadiazine cream (control), but the group of patients treated with the soft-silicone foam experienced significantly less pain (P <0.05) and dressing treatment costs were lower in the dressing than in the control group.

Magnetic resonance imaging (MRI) is an important diagnostic procedure that has been used in the clinical setting for approximately 30 years. MRI examinations may be unsafe or problematic for patients with certain biomedical products due to movement or dislodgment of the objects related to the powerful static magnetic field, excessive MRI-related heating generated by radiofrequency (RF) energy, and substantial imaging artifacts associated with the presence of metal.4,5 Therefore, to ensure the safe use of MRI technology, medical products are typically characterized using in vitro testing techniques and worst case-MRI conditions to identify issues that may pose risks to patients.4,5

Patients with wounds treated by silver-containing dress-
ings may require assessment by MRI. However, some manufacturers state in their labeling that silver-containing dressings are contraindicated for patients referred for MRI exams because of possible hazards or simply due to the fact that these particular dressings have not undergone MRI testing. Therefore, controversy exists with regard to performing MRI examinations in patients with antimicrobial dressings that contain silver.

Silver ions are known to be electrically conductive and, as such, according to descriptive reports and/or experimental findings, medical products containing this ingredient may pose hazards during MRI as a result of heating that could cause burns. However, to date, no adverse events have been reported for a medical product that contains silver, such as a wound dressing. Additionally, imaging artifacts associated with silver may impair the diagnostic use of MRI if the area of interest is where the product was applied.

The purpose of this in vitro, experimental investigation was to assess MRI issues (ie, magnetic field interactions, heating, and artifacts) at 3-Tesla (the highest static magnetic field for an MR system used in the clinical setting) for antimicrobial, silver-containing wound dressings. In addition, these dressings were characterized with respect to determining conductivity values because MRI-related heating is related to the electrical conductivity of a given medical product.

**Materials and Methods**

Antimicrobial silver-containing wound dressings. Two different antimicrobial, silver-containing wound dressings were evaluated: 1) a nonborder dressing: Mepilex Ag Antimicrobial Absorbent Foam Dressing with Safetac Technology, 10 cm x 10 cm (see Figure 1a); and 2) a border dressing: Mepilex Border Ag Antimicrobial Bordered Foam Dressing with Safetac Technology, 10 cm x 30 cm (see Figure 1b), both manufactured and distributed by Mölnlycke Health Care AB, Goteborg, Sweden and Norcross, GA. These dressings were selected for evaluation because they are commonly used in the author’s facility to treat patients with wounds who may, in turn, be referred for MRI examinations. Please note: the findings for the MRI tests performed on these products are specific to these particular items and cannot be applied to other similar products because of variances in material characteristics.

Assessment of magnetic field interactions. Magnetic field interactions may pose hazards for medical products due to translational attraction and torque. Therefore, magnetic field interactions were determined for each dressing using a 3-Tesla MR system (Excite, HDx, Software 14X.MS, General Electric Healthcare, Milwaukee, WI; active-shielded, horizontal field scanner).

Translational attraction. Translational attraction was assessed using the deflection angle method, commonly utilized to test metallic medical products, as previously described. Each dressing was rolled together to facilitate proper testing for magnetic field interactions. For translational attraction, each dressing was attached to a test fixture to measure the deflection angle in the 3-Tesla MR system. This test fixture consisted

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**Figure 1.** The silver-containing wound dressings that underwent MRI testing at 3-Tesla: a) nonborder wound dressing (10 cm x 10 cm); b) border wound dressing (10 cm x 30 cm).
of an inverted protractor with 1° graduated markings, mounted to the structure. The test fixture consisted of a sturdy structure capable of holding each dressing in position without movement. The 0° indicator on the protractor was oriented vertically. The test fixture also had a plastic bubble level device attached to the top to ensure proper orientation in the MR system during the test procedure. Each dressing was suspended from a thin, 20-cm length of string (<1% of dressing weight) placed at the 0° indicator. Measurements of deflection angles for each dressing were obtained at the location in the 3-Tesla MR system that produced the greatest magnetically induced angle. This point was determined for the MR system using gauss line plots — ie, measurements using a gauss meter (Extech 480823 Electromagnetic Field and Extremely Low Frequency Meter; Extech, Nashua, NH) and visual inspection to identify the location where the spatial magnetic field gradient was the greatest.\textsuperscript{9,10} The highest patient-accessible spatial gradient magnetic field for the 3-Tesla MR scanner is 720 gauss/cm and occurs at an off-axis position 74 cm from the isocenter of the MR system.\textsuperscript{8-12} Each dressing was held vertically from the test; released, the deflection angle from the vertical position to the nearest 1° measured three times; and the mean value calculated.\textsuperscript{8-11}

Qualitative assessment of torque. Magnetic field-induced torque was assessed qualitatively for each dressing, as previously described.\textsuperscript{9,10} The test apparatus was a flat plastic material with a grid on the bottom. Each dressing was placed in a position in the phantom at a 45° orientation relative to the static magnetic field and/or image distortion — may seriously impact the diagnosis.

Magnetic Resonance Imaging (MRI) system. The gelled, saline-filled phantom was placed in the 3-Tesla MR system and equilibrated for more than 24 hours. Baseline (pre-MRI) temperatures were recorded at 4-second intervals for 5 minutes, and MRI then was performed for 15 minutes, recording temperatures at 4-second intervals. Post-MRI temperatures were recorded for 2 minutes at 4-second intervals. Proper fluoroptic thermometry probe positions were confirmed immediately before and after each heating evaluation. The highest temperature changes recorded for each thermometry probe and for each dressing were reported.

Assessment of MRI-related heating without the dressing. A magnetic field-induced torque was assessed qualitatively for each dressing, as previously described.\textsuperscript{9,10} The test apparatus was a flat plastic material with a grid on the bottom. Each dressing was placed in a position in the phantom at a 45° orientation relative to the static magnetic field and/or image distortion — may seriously impact the diagnosis.

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tic use of MRI. Accordingly, artifacts were assessed for each dressing by performing MRI with the respective dressing attached to a plastic frame and placed inside of a gadolinium-doped, saline-filled plastic phantom, as previously described. MRI was conducted using a 3-Tesla MR system, a send-receive RF coil, and the following pulse sequences: T1-weighted, spin echo pulse sequence; repetition time, 500 milliseconds; echo time, 20 milliseconds; matrix size, 256 x 256; section thickness, 10 mm; number of excitations, two; bandwidth, 16 kHz, and gradient echo pulse sequence; repetition time, 100 milliseconds; echo time, 15 milliseconds; flip angle 30˚; matrix size, 256 x 256; section thickness, 10 mm; number of excitations, two; bandwidth, 16 kHz.

The image locations obtained through each dressing were selected in an attempt to represent the largest or worst-case artifacts based on reviewing multiple section locations in each imaging plane for each dressing. These section locations then were used for the artifact evaluations. Planimetry software was utilized to measure (accuracy and resolution ±10%) the cross-sectional area of the artifact size for each dressing, for each pulse sequence, and for each orientation of the section location. The MR image display parameters (ie, window and level settings, magnification, and other factors) were carefully selected and used in a consistent manner to provide valid measurements of sizes for the artifacts. Notably, this methodology has been used in many previous reports involving the characterization of artifacts for medical products and permits comparison to many other items that have undergone similar evaluations of artifacts.

Assessment of electrical conductivity. Because MRI-related heating of a medical product is dependent on the conductivity of the object, each dressing was assessed to characterize electrical conductivity. Each sample was immersed for 2 minutes in deionized water (conductivity of 0.35 micro Siemens) and then allowed to hang and drain for 2 minutes. Immediately after draining, surface resistance measurements were recorded for each dressing. A function generator was used to induce a current on one side of each dressing (outer electrode; Resistance/Resistivity Probe, ETS Model 803B; Electro-Tech Systems, Inc, Glendale, CA), and the voltage was measured on the other side of the dressing (inner electrode; Resistance/Resistivity Probe, ETS Model 803B; Electro-Tech Systems, Inc, Glendale, CA).

Data collection and analysis. The data were collected by the principal investigator and stored on a laptop computer for later evaluation and analysis, which predominantly involved descriptive techniques standard for MRI testing procedures applied to implants and devices.

Results

The calculated average deflection angle was 0˚ and the qualitatively measured torque was 0 (no torque) for each dressing (ie, nonborder dressing and border dressings) assessed for magnetic field interactions. The MRI-related heating assessments indicated that the highest temperature changes were comparable to the background temperatures (ie, the temperature changes without each dressing present in the phantom).

Table 1. Information for the MRI-related heating tests for the nonborder and border silver-containing wound dressings

<table>
<thead>
<tr>
<th>Thermometry probe</th>
<th>Highest temperature change (°C)</th>
<th>Background</th>
<th>Nonborder wound dressing</th>
<th>Background</th>
<th>Border wound dressing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Probe 1</td>
<td>+1.6</td>
<td>+1.6</td>
<td></td>
<td>+1.6</td>
<td>+1.6</td>
</tr>
<tr>
<td>Probe 2</td>
<td>+1.4</td>
<td>+1.4</td>
<td></td>
<td>+1.4</td>
<td>+1.4</td>
</tr>
<tr>
<td>Probe 3</td>
<td>+1.8</td>
<td>+1.8</td>
<td></td>
<td>+1.8</td>
<td>+1.8</td>
</tr>
</tbody>
</table>

Table 2. MRI artifact information for the silver-containing wound dressings

<table>
<thead>
<tr>
<th>Pulse sequence</th>
<th>T1-SE</th>
<th>T1-SE</th>
<th>GRE</th>
<th>GRE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signal void size (area)</td>
<td>100,012 mm²</td>
<td>620 mm²</td>
<td>100,023 mm²</td>
<td>662 mm²</td>
</tr>
<tr>
<td>Imaging plane</td>
<td>Parallel</td>
<td>Perpendicular</td>
<td>Parallel</td>
<td>Perpendicular</td>
</tr>
<tr>
<td>Oriented to the dressing</td>
<td>Long axis</td>
<td>Short axis</td>
<td>Long axis</td>
<td>Short axis</td>
</tr>
</tbody>
</table>

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<th>GRE</th>
<th>GRE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signal void size (area)</td>
<td>300,227 mm²</td>
<td>318 mm²</td>
<td>300,439 mm²</td>
<td>320 mm²</td>
</tr>
<tr>
<td>Imaging plane</td>
<td>Parallel</td>
<td>Perpendicular</td>
<td>Parallel</td>
<td>Perpendicular</td>
</tr>
<tr>
<td>Oriented to the dressing</td>
<td>Long axis</td>
<td>Short axis</td>
<td>Long axis</td>
<td>Short axis</td>
</tr>
</tbody>
</table>

(T1-SE, T1-weighted spin echo; GRE, gradient echo)
With regard to the conductivity assessments, the average resistance values were 20 kOhm and 1.1 kOhm for the nonborder dressing and border wound dressings, respectively. These are acceptable values with respect to those that will not be associated with hazards relative to the use of MRI.

**Discussion**

Before performing an MRI examination, each patient undergoes a pre-MRI screening procedure during which he/she is carefully questioned and interviewed in order to identify implants, devices, and other medical products, as well as underlying health conditions, that may pose MRI hazards.4,5 The preservation of a safe MRI environment requires constant attention to the care of patients with medical products because the variety and complexity of these items constantly changes.4,5 The evaluation of a medical product for MRI issues is not a trivial matter. The proper assessment entails characterization of magnetic field interactions (translational attraction and torque), MRI-related heating, and artifacts.4,5 Currently, MRI systems used in the clinical setting operate with static magnetic fields that range from 0.2 to 3 Tesla. Accordingly, the 3-Tesla scanner represents a worst-case MR imaging scenario with respect to exposure to the electromagnetic fields used for MRI; as such, this type of MRI system is commonly utilized when assessing medical products for potential risks or other problems.4,5,8-10

Magnetic field interactions. Both dressings (nonborder and border) assessed at 3-Tesla exhibited the absence of magnetic field interactions. This is not surprising, because the metallic material (silver) used in these medical products is known to be diamagnetic, which means it is slightly repelled by a magnetic field and does not retain magnetic properties when the external field is removed; thus, it has a negative susceptibility to magnetic fields. As such, there are no risks for patients related to magnetic field interactions for these particular wound dressings with respect to the MRI environment. The current findings on this matter were similar to the experimental findings of an in vitro study reported by Nyenhuis and Duan8 for another type of silver dressing.

MRI-related heating. MRI procedures may generate substantial temperature rises in medical products and other objects made from conductive materials.4,5 Serious patient injuries, including full-thickness burns, have occurred in patients during MRI exams in association with tattoos (created with metal-based pigments), medication patches containing metallic foils, aluminum warming blankets, and other surface-related items.4,5 Therefore, although not reported in the literature to date, excessive temperature elevation is a realistic concern when performing an MRI examination in a patient with a silver-containing wound dressing.5-8

In this study, worst-case MRI conditions were used to...
assess the two different silver-containing wound dressings. Although temperature changes occurred, these same temperature changes were also recorded for each dressing at each temperature probe position without each product present (ie, the background temperatures), and no MRI-related heating specifically related to the presence of the study dressings occurred. These findings were most likely due to the relatively low concentration of silver ions present in each dressing, which resulted in no heating due to a relative lack of conductivity (see section to follow on conductivity). Again, the results in the current study were comparable to those reported by Nyenhuis and Duan for another silver wound dressing.

Artifacts. Artifacts associated with a metallic object are directly dependent on the magnetic susceptibility of the material, the object’s dimensions, the static magnetic field strength of the MR system, the imaging parameters, and other factors according to experimental studies as well as descriptive reports in the literature.4,5,9,10,11,12 Depending on the pulse sequence used for MRI, artifacts may impair visualization of the anatomy of interest as a result of the associated signal loss and/or distortion of the image. Therefore, artifacts can affect the diagnostic use of the MRI examination if the area of interest is the same as or close to the site of the product.

For the silver-containing wound dressings evaluated, the artifacts that appeared on the MR images were shown as extremely subtle signal changes that represented a one-for-one relationship based on the size and shape of each product. Notably, no signal changes were observed below the surface of each dressing (for example, see Figure 2b). Overall, the artifacts for the study dressings are not likely to present problems if the MR imaging area of interest is in or near the area where each product is located, suggesting these dressings can be left in place when patients go through MRI examinations. These results are similar to those reported in an experimental study of a silver-containing hydrofiber dressing.8

Electrical conductivity. Medical products made from conductive materials may cause burns in patients in association with MRI exams.4,5 The potential for this to occur is dependent on many factors, including the conductivity, size, and shape of the material and the amount of contact the material has with the patient in relation to the position in the transmit RF coil of the MR system.4,5 Because of the presence of silver ions in the wound dressings, electrical conductivity was assessed for these products. The findings revealed the silver ions exist in relatively low concentrations because the conductivity values were within a range of low-frequency conductivity for human tissues.15 Therefore, these dressings will not pose an MRI-related heating hazard for patients.

Study Limitations
Several possible limitations may exist with the current study. The findings for the MRI tests performed on these products are specific to these particular items and cannot be applied to other similar products because of variances in material characteristics. For example, for the evaluation of conductivity, deionized water was used. The effect of actual wound fluid is not known. Furthermore, human subjects were not involved in these MRI test procedures for the wound dressings, although in vitro testing is considered a valid and more acceptable approach for such an evaluation and has been used to assess many products that contain metal.4,5,8,11,13

Conclusion
Managing patients in the MRI setting requires pre-MRI screening procedures that include identifying implants or devices and assessing the relative risks for these items.4,5 According to the findings of this investigation, the two specific antimicrobial, silver-containing wound dressings tested will not pose hazards or risks to patients and, thus, are considered to be “MR safe” according to the current labeling terminology used for medical products (ie, MR safe, MR conditional, and MR unsafe).16 Importantly, these dressings may be left in place when patients undergo MRI exams. Of further note is that the results of the MRI tests for these products are specific to these particular items and cannot be applied to other similar products because of variances in material characteristics. The MRI safety of only one other silver-containing dressing has been tested,8 and although the results of the current study and the study conducted using the silver-containing hydrofiber dressing are similar, research is needed to investigate potential MRI issues for other silver-containing wound dressings. Such research may be directed toward defining the level of silver concentration the conductivity may approach that may pose a hazard for a silver-containing wound dressing.

References
7. ECRI Institute. Antimicrobial dressings containing silver may cause