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EVALUATION OF MAGNETIC RESONANCE IMAGING UNDER THE INFLUENCE OF HAIR POWDER PRODUCTS

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ABSTRACT

Background: Commercial hair powder products are being increasingly used for purposes such as covering thin hair. As these products are often unnoticeable, magnetic resonance imaging (MRI) while using them may occur. As hair powder products may contain strong magnetic substances, they may scatter in MRI devices, possibly damaging the device. Purpose/Hypothesis: We conducted a physical evaluation about displacement force of magnetic fields induced by hair powder products from various manufacturers and related image artifacts aiming to evaluate their effects on MRI. Study Type (retrospective/prospectiveWhen hair powder contains a strong magnetic substance and MRI is performed under its influence, image artifacts occur, indicating possible damage to the MRI device due to powder scattering in the device caused by magnetic forces. The physical evaluation provided safety insights for MRI that may help prevent accidents and poor imaging when the device interacts with hair powder.

KEYWORDS: Hair powder, MRI, imaging safety, ASTM

1. INTRODUCTION

Over the last years, the use of commercial hair powder products has increased for purposes such as covering thin hair. As the use of these products may go unnoticed, the cases of magnetic resonance imaging (MRI) in patients using them may increase. However, when hair powder has a strong magnetic substance, it may be scattered in the MRI device by the generated magnetic forces and may cause damage to the device. In this study, we aimed to examine the safety of MRI for patients using hair powder products.

2. MATERIALS AND METHODS

A physical evaluation was conducted to determine the displacement force and image artifacts caused by the magnetism of hair powder products from different manufacturers and to establish the safety of hair powder use during MRI. The safety of hair powder products was considered by examining the displacement force and image artifacts due to the magnetic influence of 13 hair powder products from 5 manufacturers (Table 1, Figure 1).

2-1. MRI devices

The MRI devices used in this study were an Ingenia 1.5T (Philips Healthcare, Amsterdam, Netherlands) and a Skyra 3.0T (Siemens Healthcare, Erlangen, Germany).

2-2. Displacement force

A safe measurement experiment for the displacement force was performed according to the American Society for Testing and Materials (ASTM) standard F2052.[1]

Hair powder was fixed to the cling film by 1 g inward and hung with a thread of 0.1 g. The displacement measurement of the force container under magnetic induction along the horizontal plane ($y = 0$) in the neighborhood of a signal bridge opening in the horizontally static magnetic field and maximal inclination corner rank are shown in Figure 1. Under static magnetic field intensities of the 1.5T and 3.0T MRI devices, we waved the weight at the maximal intensity magnetic field position of the MRI device according to the ASTM standard and measured inclination angle θ.

The measurements were repeated three times, and the measurements were averaged to obtain the experimental result.

2-3. Image artifacts

Based on the ASTM standard F2052, the hair powder restorer of 1 g used for the displacement force experiment was enclosed in the contrast measurement section of a spherical phantom (90-401; Nikko-fines, Kyoto, Japan) with water enclosure on both sides (Figure 4). Then, imaging was performed using the spin echo, gradient echo, and echo planar imaging methods. The imaging parameters for each method are listed in Table 2.

2-4. Analysis of image artifacts

To evaluate image artifacts, the maximal distance from the measurement object to the border where the image signal intensity changed by 30% was obtained using the 1.5T and 3.0T MRI device according to the ASTM standard (Figure 5). MATLAB 2020a (MathWorks, Natick, MA, USA) and Image J (http://imagej.nih.gov/ij) were used for image analysis.

The image of water at the center of the phantom was considered as the reference, and the signal level change of the image was calculated by inserting a hair powder preparation to calculate the following relation per pixel:

$$\Delta S(x, y)[\%] = \frac{|S_0(x, y) - S_R(x, y)|}{S_R(x, y)} \times 100 \quad \cdots\cdots\cdots (1)$$

Where $\Delta S(x, y)$ is the signal intensity change in the pixel at position (x, y), $S_0(x, y)$ is the signal level, and $S_R(x, y)$ is the intensity when there is hair powder preparation in the pixel with a signal level similar to the water preparation.

We defined pixel intensity $\Delta S \geq 30$ as an artifact region according to ASTM F2119. In addition, the image ratio considering the artifact region was calculated as

$$Area\ ratio\ [\%] = \frac{Area_{\Delta S \geq 30}}{Area_{\mathrm{phantom}}} \times 100 \quad \cdots\cdots\cdots\cdots (2)$$

Where *Area ratio* is the ratio of the region where an artifact occurs in the phantom, $Area_{\Delta S \geqq 30}$ is the area of the artifact region, and *Area*phantom is the area of the whole phantom. The calculation range was limited to the region where the phantom appeared in the image and contained water preparation, whereas the air region was excluded.

In addition, the maximum distance from an artifact to the border of the preparation was measured. We defined the signal part of the water preparation in the reference image as the preparation border and the region with $\Delta S \geq 30$ in the phantom image containing hair powder as an artifact.

Again, the air region was excluded from the calculation.

An image mask of the water preparation and an image for the region with $\Delta S \geq 30$ were manually added as shown in Figure 4, and the maximum distance (in pixels) from the artifact to the preparation border was measured using Image J.

In addition, the region with $\Delta S \geq 30$ resulting from a position gap in the phantom marginal region was excluded and measured. The same experimenter conducted the measurement for all the images. The calculation range in the phantom was limited to the region with water preparation, excluding the air region.

3. RESULTS

3-2. Displacement force

The results of the displacement force due to the magnetic substance in the 13 hair powder products within the static magnetic field of the 1.5T and 3.0T MRI devices are listed in Table 3.

Most hair powder products produced an inclination angle of 0° for a swing, but four types of foundation products produced an angle of 90°.

3-3. Image artifacts

The T1 weighted images and T2* weighted images acquired using the 1.5T and 3.0 T MRI devices are shown in Figure 6. Artifacts did not occur with any preparation of hair thickener in both the T1 and T2* weighted images. However, the five foundation products generated artifacts in both types of images and both MRI devices, being consistent with the results of the displacement force.

The evaluation results of ΔS based on ASTM F2119 are shown in Figures 7–10. The images acquired using the 3.0T and 1.5T MRI devices showed average maximum artifact distances of 6.2 ± 1.0 pixels (5.0–8.0 pixels) and 5.9 ± 0.8 pixels (5.0–7.0 pixels) for the hair thickener products, respectively. The average maximum artifact distance of the five foundation products was 126.1 ± 9.5 pixels (104.0–135.0 pixels) and 90.8 ± 4.7 pixels (87.0–103.0 pixels) in the images acquired using the 1.5T and 3.0T MRI devices, respectively.

4. DISCUSSION

The inclination angle at 1.5 T and 3.0 T for the foundation products was 90°, whereas the hair thickener products produced 0° inclination. An angle of 45° induced by the displacement force indicates overcoming gravity according to the evaluation criterion of ASTM

F2052.[1] Consequently, the foundation hair powder products may adhere to the MRI device.

In addition, MRI may produce distorted images owing to the heterogeneity of the magnetic field induced by such products. Furthermore, the quantity of hair powder scattered in the MRI device may require considerable time and cost for restoration. Nevertheless, hair thickener products are less likely to be scattered in the MRI devices during operation compared with foundation products.

The five foundation hair powder products showed an inclination angle of 90° and produced artifacts regardless of the static magnetic field and imaging sequence. Severe artifacts occurred with a distance of 4–6 times and a preparation diameter of approximately 20 pixels.

Generally, the more adverse effects occur at 3.0 T than at 1.5 T and when the gradient echo is greater than the spin echo. However, these relations were reversed in this study.

Overall, considering the characteristics of the evaluated hair powder products, we suggest discouraging the use of the foundation hair powder products as they may produce serious image artifacts and damage MRI devices.

4. CONCLUSIONS

Products containing iron oxide and two iron oxides and cosmetics including titanium oxide may produce artifacts during MRI.[2] MRI artifacts caused by hair powder products that include strong magnetic substances may adversely influence diagnosis.

Magnetic substances such as iron oxide were contained in some hair powder products evaluated in this study, and these products caused image artifacts.

We determined that hair powder products with magnetic materials cause displacement forces and artifacts during MRI. However, some products did not cause an artifact and are unlikely to scatter within the MRI device. Nevertheless, MRI should be preferably conducted without the patient using hair powder, as many products contain undisclosed ingredients.

The hair thickener products produced neither a displacement force nor artifacts. Therefore, hair thickeners may be acceptable for MRI, but this cannot be concluded with certainty because this study did not consider circulating hair powder. Therefore, no hair powder product with magnetic substances can be considered safe and suitable for MRI until further studies are conducted.

We suggest asking patients about the use of hair powder before MRI to ensure safety of the subjects and devices as well as the quality of imaging in clinical practice. If the patient is using any type of hair powder product, we recommend its removal before MRI given its possible consequences.

6. REFERENCES

1. ASTM F2052-06, Standard Test Method for Measurement of Magnetically Induced Displacement Force on Medical Devices in the Magnetic Resonance Environment, ASTM International, West Conshohocken, PA, 2006; 935–940.
2. Escher K, Shellock FG Evaluation of MRI artifacts at 3 Tesla for 38 commonly used cosmetics, Magnetic Resonance Imaging, 2013; 31(5): 778–782.

Figure legends

Figure 1: Hair powder products evaluated in this study.
Figure 2: Weight containing hair powder used to determine displacement force based inclination angle induced by magnetic field.
Figure 3: Displacement force goniometry using MRI device. The example shows inclination angle θ of 90°.
Figure 4: Image of phantom used to determine image artifacts. Hair powder was placed the center and surrounded by water.
Figure 5: Measurement of maximum distance from artifact.
Figure 6: Gradient echo images obtained using the evaluated hair powder products.
Figure 7: Area ratio of spin echo and gradient images obtained from 1.5T and 3.0T MRI devices for evaluated hair powder products.
Figure 8: Artifact distance of spin echo and gradient images obtained from 1.5T MRI device for evaluated hair powder products.
Figure 9: Artifact distance of spin echo and gradient images obtained from 1.5T MRI device for evaluated hair powder products.
Figure 10: Artifact distance of spin echo and gradient images obtained from 3.0T MRI device for evaluated hair powder products.

Table titles

Table 1: Characteristics of hair powder products evaluated in this study.
Table 2: MRI parameters used in this study.
Table 3: Inclination angle produced by magnetic substance in hair powder products at 1.5 T and 3 T.