Evaluation of magnetic susceptibility artefact induced by personal care product with gold nanoparticles on brain magnetic resonance (MRI) images

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Abstract. MRI is an important diagnostic imaging tool as it provides excellent soft tissue contrast resolution. Artefact in MRI is an undesirable appearance in the image that affect the image quality and may hinder true diagnosis of the pathological events. Gold in bulk form does not cause any artefact in MRI as it is diamagnetic whereas in its nanoscale version, it was proven to pose magnetic properties. Previous studies also shown that some personal care products (PCPs) produce artefact in MR images due to the presence of metallic compounds in the PCP. Hence, this study was conducted to investigate the effect of PCP with gold nanoparticles (AuNPs) on brain MRI images. The study was conducted using 1.5 Tesla MRI system where moisturiser and compact powder with AuNPs were tested. The products were applied onto the micropore tape attached to the MRI water phantom. The phantom was placed in an RF coil at the isocentre of the MRI bore and scanned using T1-weighted fast-spin-echo (FSE), T2-weighted FSE and fluid attenuated inversion recovery (FLAIR) sequences. The images were evaluated using Visual Grading Analysis (VGA) checklist by two radiologists. Based on the VGA score, brain MRI images in moisturiser group were all scored ‘1’ which indicate minimal artefact with only loss of fine details seen. Whereas, brain MRI images of compact powder group were all scored ‘0’ which indicate no artefact seen. Therefore, it can be concluded that PCP with AuNPs produce little to no artefact on brain MRI images, thus, there will be no need for the patient who wears PCP with AuNPs to clean their face prior to brain MRI examination.
1. Introduction

Magnetic Resonance Imaging (MRI) now has become one of the most important diagnostic imaging tools as it provides images with outstanding soft tissue contrast resolution. Therefore, MRI is the modality of choice when it comes to neurological cases and other pathologies related to brain such as brain tumors, multiple sclerosis, aging-related changes and cerebrovascular diseases [1], [2]. In diagnostic imaging, the quality of the images produced is very crucial as they aid in disease detection. Thus, if the quality of MRI images is reduced, the accuracy of the investigation also will be reduced.

MRI is known as the high-end technology that operates using strong magnetic field [3]. In MRI, image artefact is defined as an undesirable appearance in the image that may appear in the form of distortion, hyper- or hypointensities [4]. Whereas, magnetic susceptibility is defined as the degree of magnetization of an object in an external magnetic field [5]. Magnetic susceptibility artefact affect the quality of MRI images by causing large signal void. The main cause of this artefact is the large magnetic susceptibility difference between metal and soft tissues. Metal substance will cause large variations of field inhomogeneity and this can only be compensated partially by shimming of the field. Part that is not compensated appear as artefact in MR images [6]. Magnetic susceptibility artefacts in MRI not only caused by metallic implants [7] but also been reported in some cases that cosmetics induce this kind of MRI artefact due to the metallic compounds incorporated in the products [4], [7–9].

Nanotechnology now has been widely used in the production of cosmetics [11]. According to American Society for Testing and Materials (ASTM), nanoparticles are particles that have two or more than two dimensions and are in size range of one to one hundred nanometre (nm). Nanoparticles are used in cosmetics because of its ability to enhance the effectiveness and it also can improve the cellular responses [12]. Gold nanoparticles (AuNPs), also called as gold colloids are known to be the most stable metal nanoparticles [13]. AuNPs have distinct properties from the gold in bulk form as the bulk gold is yellow solid, inert [14] and is diamagnetic which means non-magnetic [15]. Interestingly, it was recently reported that gold nanoparticles poses magnetic behaviour [16], [15].

In every MRI examination, patient often asked to remove any metals from their body to ensure patient’s safety as well as to optimize image quality. However, some metallic objects cannot be easily removed for example surgical clips, orthopaedic implants, dentures and cosmetic tattoos. Makeup applied to the face by patient also will cause artefact formation if one does not remove it before brain MRI examination due to the presence of metallic substances in the cosmetic. Therefore, the purpose of our study was to investigate magnetic susceptibility artefact induced by personal care product with gold nanoparticles on brain MRI images. Since nowadays there is more and more PCP product incorporated with AuNPs, which is a type of metal, thus it is expected that AuNPs will cause artefact in MR images. To our best knowledge, this is the first study that evaluate the effect of PCP with gold nanoparticles on MR images.
2. Materials and methods

2.1 Personal care product (PCP) samples
Two commonly used PCP were selected for evaluation in this study which were moisturiser and compact powder. Both products were incorporated with gold nanoparticles (AuNPs) as stated on their packaging. Table 1 shows the list of ingredients of the PCP that underwent assessment for artefacts.

### Table 1. Ingredients list

| Personal skin care product                     | Ingredients |
|-----------------------------------------------|-------------|
| Day Moisturizer Cream with Nano Gold 24K Brand X | Water, isohexadecane, glycerine, niacinamide, ethylhexyl methoxycinnamate, cyclopentasiloxane, ethyl triazone, butylene glycol, cyclohexasiloxane, triethylenoxanin, betaine, titanium dioxide, methylene bis-benzotriazolyl tertramethylbutylphenol, PPG-3 myristyl ether, octocrylene, bis-ethylhexyloxyphenol methoxyphenyl triazine, hydroxyethyl acrylate/sodium acryloyldimethyl taurate copolymer, methyl metacrylate crosspolymer, arachidyl glucoside, alumina, carnosine, bisabolol, carbomer, glyceryl stearate, PEG-100 stearate, stearic acid, aminomethyl propanol, dimethicone crosspolymer, disodium EDTA, citric acid, dimethicone/vinyl dimethicone crosspolymer, sodium hyaluronate, lithothamnioncalcareum extratct, mannitol, tin oxide, diatomaceous earth, zingier officinale (ginger) root extract, propolis extract, zinc sulfate, acetyl heptapeptide-9, colloidal gold, fragrance, phenoxyethanol, methylparaben, CI 19140, CI 15985, CI 77891. |
| 24K Compact Powder Brand Y                  | Talc, Mica, titanium dioxide, magnesium stearate, silica, colloidal gold, collagen. |

2.2 Sample preparation
The evaluation of the magnetic susceptibility artefacts involved applying each of the PCP to the surface of an MRI water phantom. A 7.62 cm x 7.62 cm square of micropore tape was attached on the surface of the water phantom. Then, each PCP with AuNPs was applied onto the micropore tape for the evaluation of artefacts. Next, to assist in the selection of slices of MRI images, an MRI oil marker was placed on the left side of the micropore tape.

2.3 Determination of artefacts
In order to avoid motion artefact due to the motion of the liquid inside the water phantom, it was let to rest for five minutes inside the isocentre of the MRI bore. MRI system of 1.5 Tesla was used and the artefacts were assessed using T1-weighted fast-spin-echo (FSE), T2-weighted FSE and fluid attenuated inversion recovery (FLAIR) sequences. The parameters used were the same as the parameters for brain MRI in Clinical Training Centre (CTC), UiTM Sungai Buloh. The parameters used for: (1)T1-weighted FSE; repetition time (TR), 520ms; echo time (TE), 12ms; flip angle, 150°; matrix size, 256 x 256; field of view (FOV), 190 x 190mm; thickness, 3mm; number of excitations (NEX), 4 (2)T2-weighted FSE; TR, 3400ms; TE, 91ms; flip angle, 150°; matrix size, 256 x 256; FOV,
Images obtained were analysed by two experienced radiologists in Clinical Training Centre, UiTM Sungai Buloh. The radiologists evaluated the acquired images using Visual Grading Analysis (VGA) adapted from Sacco, Bellon, Coleman, and Hacke (1987). Table 2 shows the list of VGA criteria.

**Table 2.** Visual Grading Analysis (VGA) Checklist (Adapted from Sacco et al. (1987)).

| Score | Susceptibility artefact grading                                      |
|-------|---------------------------------------------------------------------|
| 0     | No artefact is seen                                                 |
| 1     | A minimal artefact with only loss of fine details                   |
| 2     | A moderate artefact with some image distortion                      |
| 3     | A severe artefact with extensive image distortion involving a large area |

3. Results

Score one (1) were given by both raters for all moisturiser with AuNPs images. This indicates that there was minimal artefact present in the images but with only loss of fine details. Whereas, score zero (0) were given by the raters for all compact powder with AuNPs images which indicates no presence of artefact in the images. Figure 1 and Figure 2 display the resulting images. Noted that the small circle outside the structure is an oil marker and the artefacts produced were as pointed by the yellow arrow.

![Figure 1](image1.png)  
**Figure 1.** (a) T1-weighted FSE, (b) T2-weighted FSE and (c) FLAIR image of moisturiser with AuNPs.
Figure 2. (a) T1-weighted FSE, (b) T2-weighted FSE and (c) FLAIR image of compact powder with AuNPs.

4. Discussion

Two personal care products with gold nanoparticles were used in the study but only moisturiser exhibited minimal artefacts on brain MRI images. The artefact appeared as a thin hyperintense line that does not interfere with the structure in the image. This may be because of the micropore tape used in conducting this study as it is very different from human skin topography. Human skin consist of the combination of furrows, follicular orifices and sweat pores, and corneocytes which makes it unique [17]. Besides that, the skin dermis has rich supply of blood and tissue macrophages, lymph vessels, dendritic cells and five different types of sensory nerve endings aid in increasing the absorption of personal care products applied to the skin [18].

Apart from that, time provided for the personal skin care products to absorb into the micropore tape also plays a vital role in the appearance of the artefact in this study. After the application of the products on the MRI water phantom, they were left to rest for only five minutes before start scanning. The main purpose was to avoid motion of the liquid in the phantom. Therefore, the products only have five minutes to penetrate the micropore tape, which was not enough. Thus, the artefact appear as a hyperintense line outside the brain, not interrupting with the structure.

Furthermore, the content of the gold nanoparticles greatly affects the presence of the artefact in the MRI images. The appearance of minimal artefact might be because of the small amount of gold nanoparticles incorporated in the product. Since imaging and characterisation of the nanoparticles were not performed prior to this study, the actual amount of the gold nanoparticles in the personal care products used were unknown. The gold standard of nanoparticles imaging and characterisation is electron microscopy [19]. Two major types of electron microscopy are scanning electron microscopy (SEM) and transmission electron microscopy (TEM). SEM is the most appropriate technique for cosmetic testing as suggested by the authors.

5. Conclusion and recommendations

Assessment of artefacts on two personal care products with gold nanoparticles indicated that the products are MRI safe as there were no severe artefact induced. Even though minimal artefact was produced by the moisturiser, it did not affect the region of interest as the artefact only appear as a hyperintense line outside the structure. Therefore, MRI patient who put on PCP with AuNPs do not need to clean their face before the brain magnetic resonance (MR) examination and this can save some time.

For future work, it is recommended to perform SEM for imaging and characterisation of the nanoparticles prior of this study to confirm and note the amount of AuNPs present in the product.
tested. In addition, for the evaluation by the radiologist, images acquired are recommended to be viewed using DICOM image viewer as it is a standard way of diagnostic medical images. JPG images has lower quality as it is produced through lossy image compression. Thus, there will be some loss of information in the MRI images [20]. Better viewing of the MRI images lead to more accurate VGA scoring of the MR images.

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