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Metallic artifact in MRI after removal of orthopedic implants

Mohammad Hadi Bagheri [a,*], Mehrdad Mohammad Hosseini [a,1], Mohammad Jafar Emami [b,2], Amin Aiboulhassani Foroughi [a,3]

[a] Department of Radiology, and Medical Imaging Research Center, Namazi Hospital, Namazi Square, Shiraz, Iran
[b] Department of Orthopedic, and Bone and Joint Disease Research Center, Chamran Orthopedic Hospital, Chamran St., Shiraz, Iran

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ABSTRACT

Objective: The aim of the present study was to evaluate the metallic artifacts in MRI of the orthopedic patients after removal of metallic implants.
Subjects and methods: From March to August 2009, 40 orthopedic patients operated for removal of orthopedic metallic implants were studied by post-operative MRI from the site of removal of implants. A grading scale of 0–3 was assigned for artifact in MR images whereby 0 was considered no artifact; and I–III were considered mild, moderate, and severe metallic artifacts, respectively. These grading records were correlated with other variables including the type, size, number, and composition of metallic devices; and the site and duration of orthopedic devices stay in the body.
Results: Metallic susceptibly artifacts were detected in MRI of 18 of 40 cases (45%). Screws and pins in removed hardware were the most important factors for causing artifacts in MRI. The artifacts were found more frequently in the patients who had more screws and pins in the removed implants.

Gender, age, site of implantation of the device, length of the hardware, composition of the metallic implants (stainless steel versus titanium), and duration of implantation of the hardware exerted no effect in producing metallic artifacts after removal of implants. Short TE sequences of MRI (such as T1 weighted) showed fewer artifacts.
Conclusion: Susceptibility of metallic artifacts is a frequent phenomenon in MRI of patients upon removal of metallic orthopedic implants.

1. Introduction

An image artifact is a shadow not truly present but detected due to presence of a problem with the hardware or software of the MRI device. It is important to have advanced knowledge on factors interfering with MRI quality and those cause artifacts. Artifacts might vary from few pixels out of balance to such significant that distort most parts of an image and interfere with true diagnosis of the pathological events [1,2]. A confounding factor is the metallic materials responsible for image distortion by producing non-linearities with the MRI system. These non-linearities result in pixel shifts and intensity variations and cause problems for meaningful assessment of the entire image [3–5].

At magnetic resonance (MR) imaging, artifacts arising from orthopedic implant pose obstacles in optimal imaging; however MR imaging has been used safely in patients with orthopedic metallic implants. This is due to that most of metallic implants do not have ferromagnetic properties and are fixed into position. However, during MR imaging metallic implants may produce geometric distortion known as susceptibility artifact caused by susceptibility differences between the metallic implant and surrounding tissue [6–10].

The susceptibility artifact depends upon the composition of the metallic devices, orientation of devices in relation to direction of the main magnetic field, type of pulse sequence, and other MR imaging parameters that primarily include voxel size as determined by the field of view, image matrix, section thickness, and echo train length [10–15].

Although various techniques for reducing such artifacts have been developed and illustrated by previous researchers [12–19], artifacts remain as significant problems in MR imaging. Several studies have evaluated the effects of metallic orthopedic devices in MRI and various techniques used for reducing these artifacts [10–19]. However, our previous observations showed that upon removal of these metallic implants from their site in the body,

* Corresponding author. Tel.: +98 917 111 2020; fax: +98 711 647 4329.
E-mail addresses: bagherih@sums.ac.ir (M.H. Bagheri), mehrdadmh@yahoo.com (M.M. Hosseini), emamimj92@yahoo.com (M.J. Emami), amin11849@yahoo.com (A.A. Foroughi).
1 Tel.: +98 917 713 9023; fax: +98 711 647 4329.
2 Tel.: +98 917 316 2366; fax: +98 711 623 1409.
3 Tel.: +98 9173001392; fax: +98 711 647 4329.

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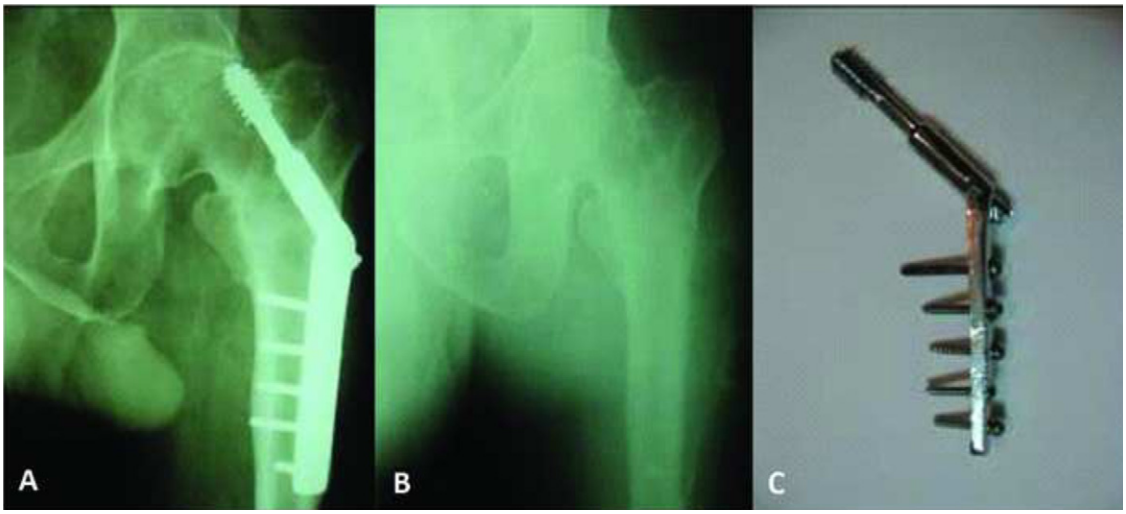

Fig. 1. A 67-year-old male with history of fracture of neck of left femur and implantation of a dynamic hip screw (DHS) with 5 screws 7 years ago, who was operated and the device was removed. (A) Simple anteroposterior X-ray of left hip before removal of implant and, (B) after removal of implant. (C) The removed orthopedic metallic hardware (DHS).

some artifacts were remained in the MR imaging despite no metallic residue were remained in plain X-rays.

To our knowledge and by reviewing the literatures, the present report is the first on evaluating artifacts in MRI after removal of orthopedic implants. Thus, the purpose of the present study was to evaluate artifacts in MR imaging of orthopedic patients after removal of the metallic implants, as well as determining the factors that affect production of the artifacts.

2. Subjects and methods

In a prospective study from March to August 2009 we followed patients referred to an orthopedic referral hospital for removal of orthopedic implants.

Pre-operative conventional X-rays were taken from the site of implantation. Thereafter, patients were operated by an experienced orthopedist and metallic devices were removed completely.

Post-operation, plain X-rays were taken from the sites of implant removal for evaluation of remained metallic shadow in the radiographs. Only cases of completely removed implants were selected. The cases were excluded from the study if any metallic devices or any segment of hardware were remained in the site of implantation. These metallic devices were cleaned and evaluated for corrosion, fracture or other macroscopic damages after removal (Fig. 1). Thereafter, patients were evaluated by MRI (GE 1.5 T Signa HDx, Milwaukee, USA). The MRI was taken from the site of removal of implant. In this period, 40 cases were collected.

An experienced radiologist reviewed the MRI of selected cases and evaluated the presence or absence of the metallic susceptibility artifact and the amount of artifact in T1 weighted (T1W), T2 weighted (T2W), and STIR sequences of MR imaging. A quantitative score of 0–III was applied for degree of artifacts in MR images. Grade 0 was defined as no artifact. Grades I–III were applied when mild, moderate, or severe degradation of images was noted due to metallic artifact in MR sequences, respectively (Fig. 2).

Thereafter, in addition to demographic data including gender and age, the site of orthopedic devices in the body, the type, size, shape and number of devices and composition of metallic devices were recorded. Thereafter, each sequence of MRI (T1W, T2W and STIR) was evaluated for the presence or absence of the artifact and graded. Thereafter, the relationship was evaluated between grading of the artifact and other factors including type of the metallic hardware, presence or absence and number of screw in the removed hardware, gender and age of the cases, place of the implantation in the body, material of the hardware, mean length of the hardware, mean duration of hardware stay inside the body and the grading of the artifact in T1W, T2W and STIR sequences (Fig. 3).

Fischer's exact test was used as the statistical analysis for correlation between presence and number of screws, site of implantation of devices in the body, and composition of hardware with producing artifact in MRI. Mann–Whitney test was used for analysis of the correlation between age of the patient, length of the hardware and duration of implantation of hardware with producing artifacts in MRI.

Informed consent was taken from all patients and the study was approved by institutional review board.

3. Results

A total of 40 patients were evaluated in the present study with age range of 9–70 years (mean = 30.82 years), including 31 males and 9 females.

Overall metallic susceptibility artifacts from each grading were detected in 18 of 40 cases (45%).

3.1. Types of implants

In our cases different types of orthopedic implants were removed from the patients, such as plates, intramedullary nails, and screws and pins (Fig. 4).

We had no cases of plate without screw. We had 2 major groups of metallic implants:

(1) Plate and screw; (2) intamedullary nail. We had only 3 cases of intramedullary nail with screw. This limited number was not enough for statistical analysis, so the major comparison groups in the present study were:

1 Plate with screws or pins.
2 Nails without screws.

From all 40 removed implants, 25 were plates all with screws or pins. 15 remainders were intramedullary nails, 12 had no screws or pins and 3 had screws.

Due to small number of the cases with each subtype of hardware, each case could not be evaluated separately. We noticed that hardwares with additional screw and pins exert higher susceptibility to

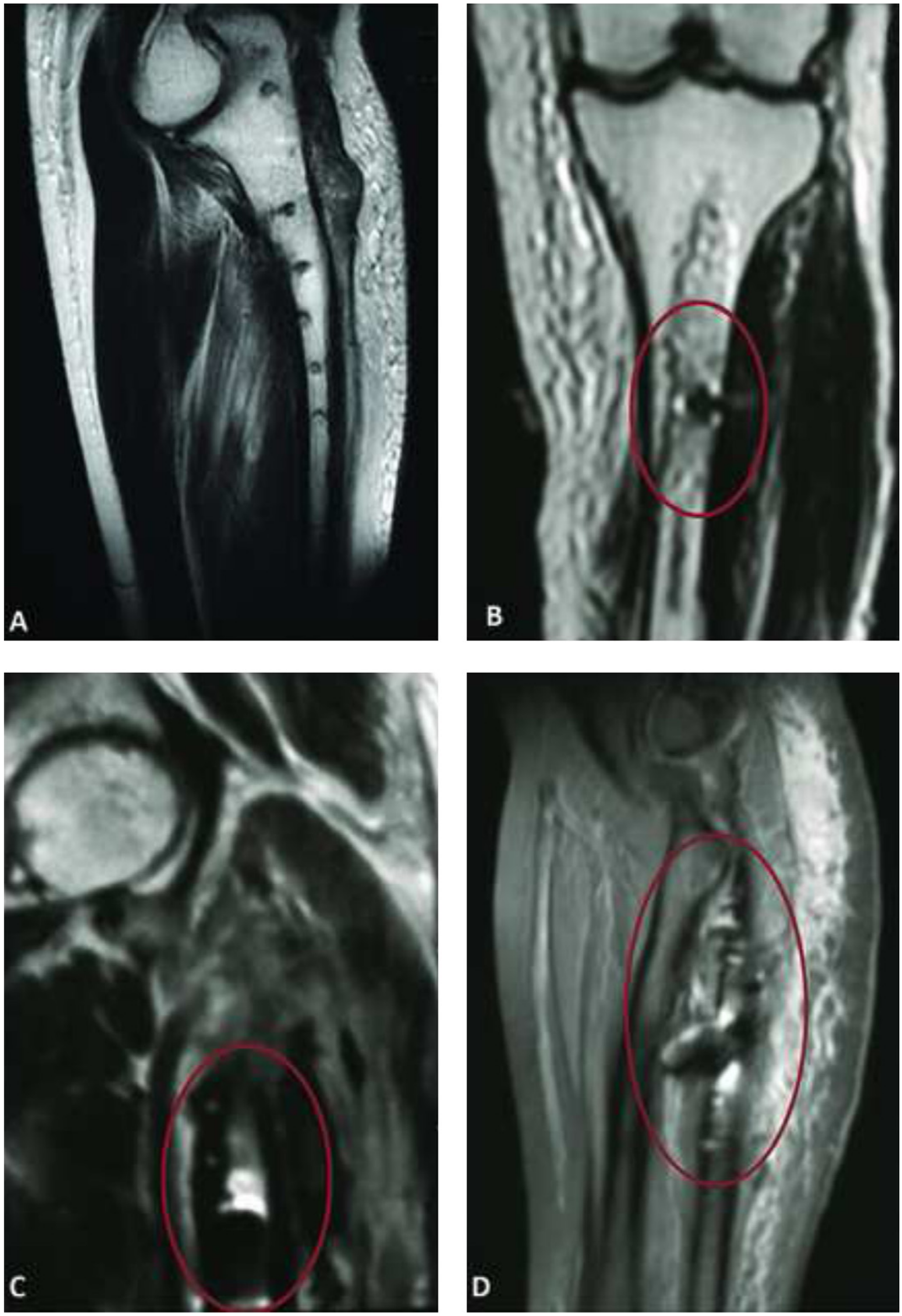

Fig. 2. Examples of different grades of metallic artifact in MRI after removal of metallic implant. (A) Grade 0: a 37-year-old woman after removal of a plate with 7 screws from left ulna, after 1 year of implantation. Fast spin echo (FSE) sagittal T2W MRI (TR/TE, 3000/105) from left ulna shows no metallic artifact (grade 0) after removal of the implant. (B) Grade 1: a 26-year-old man after removal of an intramedullary nail with 3 screws from right tibia, after 3 years of implantation. FSE coronal T2W MRI (TR/TE, 3080/110) from right tibia shows mild (grade 1) metallic artifact at the site of removal of the implant. (C) Grade 2: a 50-year-old man after removal of a DHS with 5 screws from left hip, after 10 years of implantation. FSE coronal T2W MRI (TR/TE, 5367/124) from left hip shows moderate (grade 2) metallic artifact at the site of removal of implant. (D) Grade 3: a 35-year-old woman after removal of a plate with 7 screws from left ulna, after 4 years of implantation. FSE sagittal T2W MRI from left ulna shows severe (grade 3) metallic artifact at the site of removal of implant.

artifact than others. Intramedullary nails with no screw and pins show no artifact after removal. Three cases had dynamic hip screw (DHS), which is the hardware for fixation of the fracture of the neck of femur, and all these cases of removed DHS show susceptibility artifact in MRI.

3.2. Presence of screw

We found that susceptibility artifacts can only be presented in MRI of cases that have screws or pins in the removed devices. There was no artifact in the MRI of cases with no screws or pins in removed

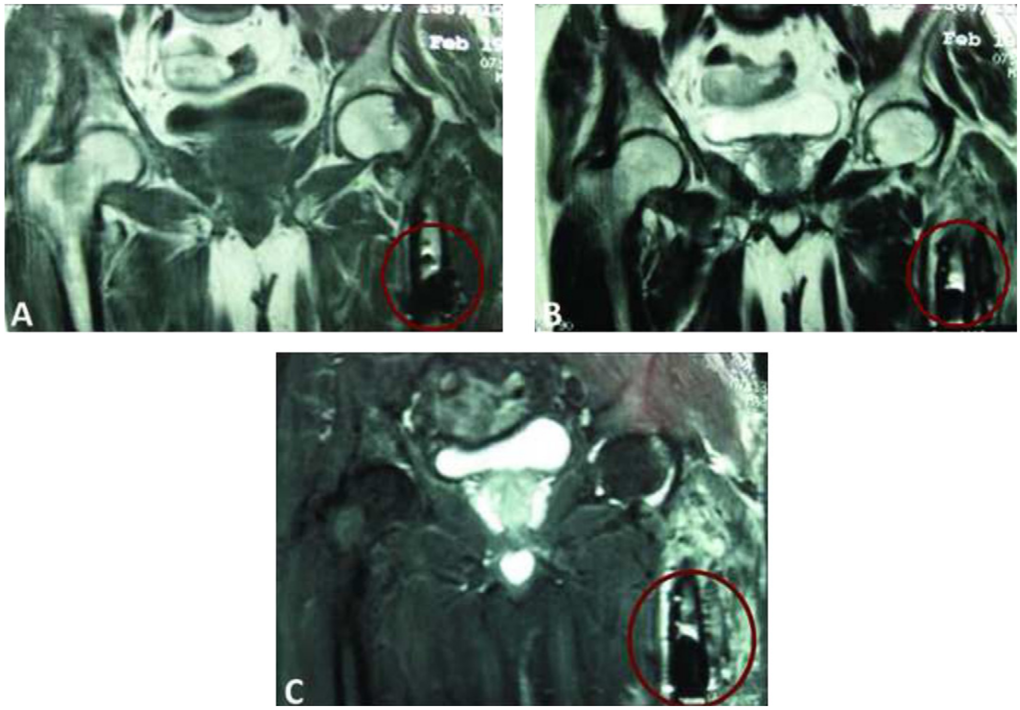

Fig. 3. A 50-year-old man after removal of DHS with 5 screws from left hip, after 10 years of implantation. Grade 2 (moderate) of metallic artifact in (A) FSE coronal T1W MRI (TR/TE, 433/15), (B) FSE coronal T2W MRI (TR/TE, 5376/124) and, (C) FSE coronal STIR MRI (TR/TE, 4867/40; inversion time, 150 ms).

implants. Cases with different types of intramedullary nails without screws or pins show no artifact in the MRI (Table 1).

We evaluated the presence of metallic artifact in MRI of cases in correlation with the presence of screws in implants. The results showed that screws and pins are significantly higher for presence of metal artifacts in MRI of the patients after removal of metallic implants (P-value <0.001).

Although there was no artifact in MRI of cases without screws or pins, it should be mentioned that we demonstrated artifact in 18 of 28 patients with screws and pins (64%), but not all of them.

3.3. Number of screws

In all of the 40 cases, removed hardware of 12 cases had no screw or pin, and 28 had between 1 and 13 screws and pins. We evaluated the correlation between the number of screws and pins with artifact in all of the 40 cases with and without screw. There was a statistically significant correlation between the number of screws and susceptibility to artifact in MRI of all cases after removal of metallic implants. (Mean number of screws was 7.22 in cases with artifact and 3.91 in cases without artifact $P = 0.037$.)

Fig. 4. Different types of removed metallic implants. (A) Plates (stainless steel and titanium), (B) intramedullary nails (stainless steel), (C) screws and pins (stainless steel and titanium) and, (D) an example of a plate with 8 screws (stainless steel) after removal from the site of implantation in the body.

Table 1
Correlation between the presence or absence of screw in metallic implants and producing artifact in MRI after removing the metallic implants.

Screw	Artifact		Total
	–	+	
–	12	0	12
+	10	18	28
Total	22	18	40

Thereafter, the correlation between the number of screws and the artifacts in cases with screw in the hardware (28/40) were evaluated. No correlation was found between the number of screws and the susceptibility to artifact in MRI of cases that have screw in their metallic hardware after removal of implants. (Mean number of screws was 87.22 in cases with artifact and 7.22 in cases without artifact, *P*-value = 0.14.)

3.4. Location of implantation of the device in the body

In all 40 cases, 16 hardwares were implanted in the femur, 21 in the tibia and fibula, 1 in the humorous, and 2 in the radius and ulna.

Due to small number of cases with implanted devices in the upper extremities, statistical analysis could not be performed to compare the effect of site of implantation in upper or lower extremities in producing artifact in MRI. However, we compared artifact between cases with the site of implantation in the femur and tibia or fibula, in cases with implants with screw. There was no statistically significant difference between metallic artifacts in MRI after removal of implants from the thigh or leg.

3.5. Gender and age

Of total 40 cases, 31 were male and 9 female. The distribution of age of selected cases was between 9 and 70 years, with the mean of 30.82 years. Statistical analysis showed no correlation between gender and age of the patients with artifact in the MRI after removal of metallic implants.

3.6. Length of the hardware

Statistically, there was no correlation between the mean lengths of the removed plates or intamedullary nails with producing susceptibility to artifact in MRI after removal of implants.

3.7. Composition of metallic hardware

The metal implants were of 2 types: stainless steel (32 cases) and titanium (8 cases). The correlation between the presence or absence of metallic artifact in MRI and the type of implant was evaluated. Statistically, there was no correlation between the composition of metallic hardware and producing artifact in MRI after removal of implants (*P* = 0.7) (Table 2).

However, analysis of the grading of the artifact revealed that cases with titanium hardware showed artifact after removal (3/8), all produced grade 1 artifact, and there was no sign of moderate or severe artifact in MRI. Therefore, the present study showed that the grade (severity) of susceptibility to artifact in cases that have stainless steel hardware is more than those with titanium hardware. This means that there may be a relationship between the composition of the hardware and severity of metallic artifact.

The same analysis was performed for cases with screw in their hardware. Statistically, no correlation was detected between composition of metallic hardware and producing the artifact in MRI of cases that have screw in their hardware after removal of implants (*P* = 0.091).

Table 2
Number of each composition of metallic implants in correlation with producing artifact in MRI after removing the metallic implants.

Composition	Artifact		Total
	–	+	
Stainless steel	17	15	32
Titanium	5	3	8
Total	22	18	40

Table 3
Correlation between mean duration of period of implantation of metallic implants and producing artifact in MRI after removing the metallic implants.

Artifact	Mean	Number	SD
–	3.82	22	1.701
+	2.92	18	2.251
Total	3.41	40	1.993

3.8. Duration of implantation stay of the hardware

Duration of implantation stay in the body prior to removing the hardware was recorded in all 40 cases and found to be between 1 and 10 years in different cases with a mean duration of 3.41 years. We evaluated the correlation between mean periods of implantation stay of the metallic hardware with the artifact in all cases (Table 3).

The data showed that the susceptibility to artifact was more frequent when the mean duration of implantation stay was shorter. Statistically, there was a correlation between the mean duration of implantation stay before removal and the presence of artifact in MRI after removal of implants (*P* = 0.037). More susceptibility to artifact was seen in cases with shorter stay duration of implantation.

The same test was performed for cases with screw in their hardware. The results showed no correlation between the stay duration of implantation of metallic hardware and producing artifact in MRI of cases that have screw after removal of the implant (*P* = 0.064).

3.9. Sequences of MRI

In our study 3 sequences of MRI was used for each cases after removing the metallic hardware: T1W, T2W and STIR. Thereafter, the grade of artifact for each sequence was evaluated (Table 4).

In the present study, from all 40 cases, 14 showed artifact in T1W (short TE) and 18 showed artifact in T2W and STIR (long TE) sequences. Severe artifact (grade 3) was observed in T2W and STIR more than T1W. Therefore, overall metallic artifacts were less seen in short TE sequences (such as T1W) than in long TE sequences (such as T2 and STIR).

Table 4
Number of each grade of metallic artifacts in MRI in T1, T2 and STIR sequences after removing the metallic implants.

Grading of MRI	T1W	T2W	STIR
0	26	22	22
I	11	14	14
II	2	2	2
III	1	2	2
Total	40	40	40

4. Discussion

Nowadays, metals and metallic devices are widely used in the humans for reconstruction purposes. Evaluation of these foreign materials and their effects in the body is an important aspect in medicine, particularly in imaging modalities.

One of the important types of artifacts in MR imaging is susceptibility to artifact that arise from metallic devices placed in different parts of the body [3–9]. Artifacts from orthopedic implants are significant problems in gaining desirable images in MRI [10]. The presence of susceptibility to artifacts may depend on many factors including the composition of the metallic devices, orientation of the devices in relation to the direction of magnetic field, pulse sequence and other MR imaging parameters (mainly voxel size) [10–15].

Several studies have focused on artifacts arising from orthopedic implants [3–11] in MRI and various techniques have been recognized for reducing these artifacts [12–19].

It was expected that, after removing the orthopedic implants, the source of producing artifact, no sign of artifact should be seen in MRI. For the first time, the present study evaluated the MRI of patients after removing the orthopedic implants. The present study found that susceptibility to artifact from metallic particles is a frequent problem in MRI of cases early after removing the orthopedic implants.

In our cases, although no sign of metallic particles was found in simple X-ray at the site of removal, susceptibility to artifact was found frequently in MRI (in about 45% of cases). To our knowledge and by review of the literature, the present report is the first on metallic artifact in MRI after removing the orthopedic implants.

In the present study, we evaluated the presence and amount of susceptibility to artifact in MRI of the orthopedic patients after removing the metallic hardware. In a period of 6 months, we randomly selected 40 cases that were referred to an orthopedic hospital for removing the metallic implants.

Of 40 cases, 18 showed artifact in MRI. Therefore, frequency of detection of susceptibility to artifact after removing the metallic implants was about 45% that represents a frequent problem in reporting MRI. Therefore, the radiologist should be aware of metal artifact in these cases.

Different types of orthopedic hardware were removed from the site of implantation. They included plates, intramedullary nails, screws and pins. After analysis of the artifact arose from each type, we considered that intramedullary nails alone, with no additional screw or pins, show no artifact after removal. Susceptibility to artifacts was seen in cases whereby the implant was fixed to the bone with screw or pins. Therefore, the present study revealed that screws and pins represent as major factors for susceptibility to artifact in MRI after removing the orthopedic devices.

According to our results, we performed other statistical analysis with focusing on cases that have screw and pins in their hardware.

Evaluating the correlation between the number of screw and pins with artifact in all cases revealed that there was a meaningful and statistically significant correlation between them. However, no statistical correlation was found between the number of screws and pins in producing artifact in MRI after removing the metallic hardware in cases with screws in the hardware. This indicated that only one screw is enough to produce a metallic artifact.

No statistical correlation was found between gender and age of cases and artifact after removing the metallic hardware.

In our study, the sites of implantation of hardware were long bones of upper and lower extremities. In 26 of 28 cases with screws in their implants removed from femur and tibia, statistical analysis showed no correlation between the site of implantation in femur or tibia and the artifact in the MRI after removing the metallic hardware.

There are 2 hypotheses for etiology of these artifacts after removing the metallic implants. The first hypothesis is that small microscopic particles of metals separated from the edge of the hardware at the time of insertion of the devices into the hard cortical bone serves at the source of artifact. The second hypothesis may be that artifacts are caused by the same particles that separated from the main hardware during removing the implants.

For better evaluation and confirmation of these hypotheses, further studies with larger number of cases and further evaluations including microscopic study of the removed hardware and long-term follow up of cases with MRI after removing the hardware is needed.

Sofka [14] described that titanium implants typically result in artifact fewer than stainless steel, when the hardware is inside the body. In our study, 32 removed hardware composed of stainless steel and 8 were titanium. Due to the small number of cases, an appropriate statistical analysis between the two hardware was not plausible and no statistical correlation was observed between the composition of metallic hardware and artifact in MRI after removing the orthopedic implants. However, when the grade of artifact was evaluated, we noted that higher grades of susceptibility to artifacts were found in cases with stainless steel hardware.

Evaluation of the duration of implantation stay of the hardware showed fewer artifacts in cases with longer duration of implantation stay. However, analysis of only cases with screws (28/40) showed no statistical correlation between the duration of implantation stay and artifacts. Therefore, the present study hypothesizes that certain biological process in the body might be responsible for absorption of the remaining small metallic particles separated from the main orthopedic hardware at the time of implantation or removal. Further studies including serial follow up MRI of the patients are needed to confirm this hypothesis.

Removed metallic hardware was precisely evaluated after careful cleaning. No definite macroscopic sign of corrosion at the edge of metallic hardware and screws were found. Therefore, we suggest further studies on the removed metallic implants such as in metallurgy laboratory be conducted.

Port and Pomper [15] described that the greatest reduction in artifact size was due to using a short TE sequence. In our study, for each case T1W, T2W and SIIR sequence was performed. Our results showed susceptibility to artifact in 14 of 18 cases in T1W (short TE) sequence and 18 (all) showed artifact in T2W and STIR (long TE) sequences. Overall high grade of artifact was more in T2W and STIR sequences rather than T1W. Therefore, short TE (such as T1W) sequences can be used for better reduction of metallic susceptibility to artifact after removing the hardware.

In conclusion, our study showed that susceptibility to metallic artifacts are a frequent phenomena in MRI after removing the metallic orthopedic implants; and these artifacts are less common and less intense in T1 weighted images.

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