Clinical Note

MR Imaging and Metallic Implants for Anterior Cruciate Ligament Reconstruction: Assessment of Ferromagnetism and Artifact[1]

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Magnetic resonance (MR) imaging is contraindicated for patients with certain ferromagnetic implants, primarily because of potential risks related to movement or dislodgment of the devices. An additional problem with metallic implants is the potential image distortion that may affect the interpretation of the MR study. Since MR imaging is frequently useful for the evaluation of postoperative anterior cruciate ligament (ACL) reconstruction, the ferromagnetic qualities and artifacts associated with MR imaging were determined for five metallic orthopedic implants commonly used for this surgery. Only the Perfix interference screw displayed a substantial deflection force and caused extensive signal loss. Images of the knee of one patient with two Perfix screws in place were not interpretable because of the image distortion caused by these implants. Therefore, alternative nonferromagnetic implants should be considered for reconstruction of the ACL.

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MAGNETIC RESONANCE (MR) imaging is potentially contraindicated for patients with certain ferromagnetic implants, primarily because of risks related to movement or dislodgment of these devices (1–14). Previous studies have indicated that patients with some metallic implants, materials, or devices may safely undergo MR imaging if the objects are nonferromagnetic or display relatively negligible ferromagnetism and, therefore, have no possibility of being displaced by the strong magnetic fields used in this imaging modality (2–16). An additional problem with the presence of metallic implants is the potential image distortion that may affect the interpretation of the MR study (17). Metallic objects are typically tested with ex vivo methods to determine their interaction with the MR imager, by assessment of ferromagnetism and identification of artifacts (1–16).

Because MR imaging is useful for the evaluation of anterior cruciate ligament (ACL) reconstruction (18,19), the ferromagnetic qualities and artifacts associated with MR imaging at 1.5 T were determined for five metallic orthopedic implants commonly used in this surgery.

• MATERIALS AND METHODS

Five metallic orthopedic implants were evaluated for the presence of deflection forces and/or artifacts associated with MR imaging at 1.5 T: two cortical bone screws of different sizes, one large staple plate, one fixation staple, and two different interference screws (Table). These implants were selected for assessment because they are commonly used for ACL reconstruction.

Assessment of Deflection Forces

The metallic biomedical implants were suspended by a 30-cm silk suture (4.0), attached at the estimated center of mass, from a specially constructed device (a plastic protractor mounted on a wooden stand), so that the angle of deflection from the vertical could be measured (2–4,9,10). The accuracy of this device is ±0.5° (based on the ability to read the protractor and the actual alignment of the protractor as it was positioned in the MR imager with the aid of axial, coronal, and sagittal laser lights) (2–4,9).

The deflection force was determined at the center of the z axis, at the position of maximum force in a 1.5-T superconducting magnet (Signa; GE Medical Systems, Milwaukee), according to Kagetsu and Litt (15). If the angle of deflection was greater than 90°, an aluminum weight was used to reduce the angle of deflection so that a more accurate deflection force could be determined (2–4,9). This was necessary for the Perfix interference screws. The deflection angle for each of the metallic implants was measured twice.

The deflection force F (the unit of force in the centimeter-gram-second system is the dyne, defined as the force necessary to give a 1-g mass an acceleration of 1 cm/sec^2) was calculated by the following formula: $F = mg \cdot \sin\theta/\cos\theta$, where m is the mass of the material, g the gravitational acceleration (980 cm/sec^2), and θ the deflection angle from the vertical (2–4,9).

Torque was not quantitatively evaluated because, like Soulen et al (10), we believe that torque is difficult to calculate with any degree of accuracy, owing to the rotational forces associated with the complicated geometric distribution of the ferromagnetic components of the objects examined in the present study. It should be noted that objects with high deflection forces will also have large torques.

Assessment of Artifacts

Artifacts were assessed by attaching the metallic orthopedic implant to the periphery of a 20-cm-diameter, fluid-filled quality-assurance Plexiglas phantom (GE Medical Systems). MR images were obtained with a T1-weighted spin-echo pulse sequence through the center of the greatest area of the implant (TR msec/TE msec, 500/20; field of view, 32 cm; matrix, 256 × 128; two signals averaged; section thickness, 3 mm; and no intersection gap). Additionally, a routine MR study of the knee was performed in one patient with a previous ACL reconstruction who had two Perfix interference screws in place. There was no knowledge of the presence of these implants before MR imaging.

The following scale was used to quantify the relative amount of artifact produced by the presence of each metallic implant: 0, no artifact; +, artifact smaller than size of implant; ++, artifact approximately same size as implant; +++, artifact twice the size of the implant or greater (8).

Metallic Orthopedic Implants Used for ACL Reconstruction

Implant	Deflection Force (dynes)	Artifact*
Cortical bone screw, small		
Titanium, Ti-6AL-4V alloy (Zimmer, Warsaw, Ind)	0	0
Cortical bone screw, medium		
Titanium, Ti-6AL-4V alloy (Zimmer)	0	0
Large staple plate		
Zimaloy (Zimmer)	0	++
Fixation staple		
Cobalt chromium alloy, ASTM F 75 (Richards Medical, Memphis)	0	+
Endoscopic noncannulated interference screw		
Titanium (Acufex Microsurgical, Norwood, Mass)	0	0
Perfix interference screw		
17-4 stainless steel, AL 630-17Cr (Instrument Makar, Okemos, Mich)	78,692	+++

*See text for artifact scale.

• RESULTS

The Table summarizes the study results. Of the metallic orthopedic implants tested, only the Perfix interference screw exhibited ferromagnetism. No apparent imaging artifacts were caused by the presence of the cortical bone screws or the Acufex interference screw. The large staple plate and the fixation staple produced relatively minor artifacts that were confined to the immediate vicinity of the implant.

The Perfix interference screw produced a substantial artifact, such that signal void affected approximately 60% of the quality-assurance phantom (Fig 1). MR images obtained in the knee were not interpretable because of the presence of the two Perfix interference screws, which essentially obliterated the entire anatomic area of interest (Fig 2).

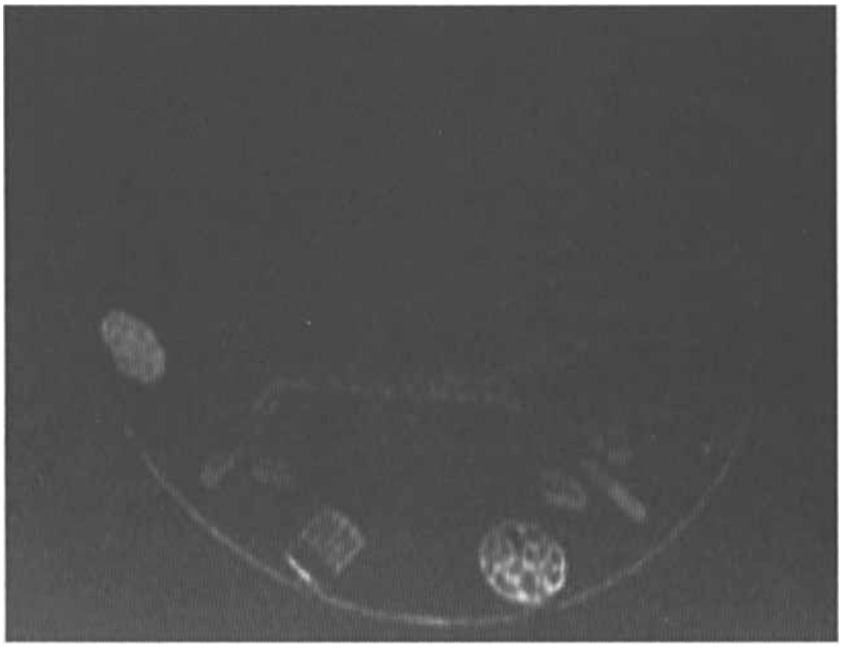


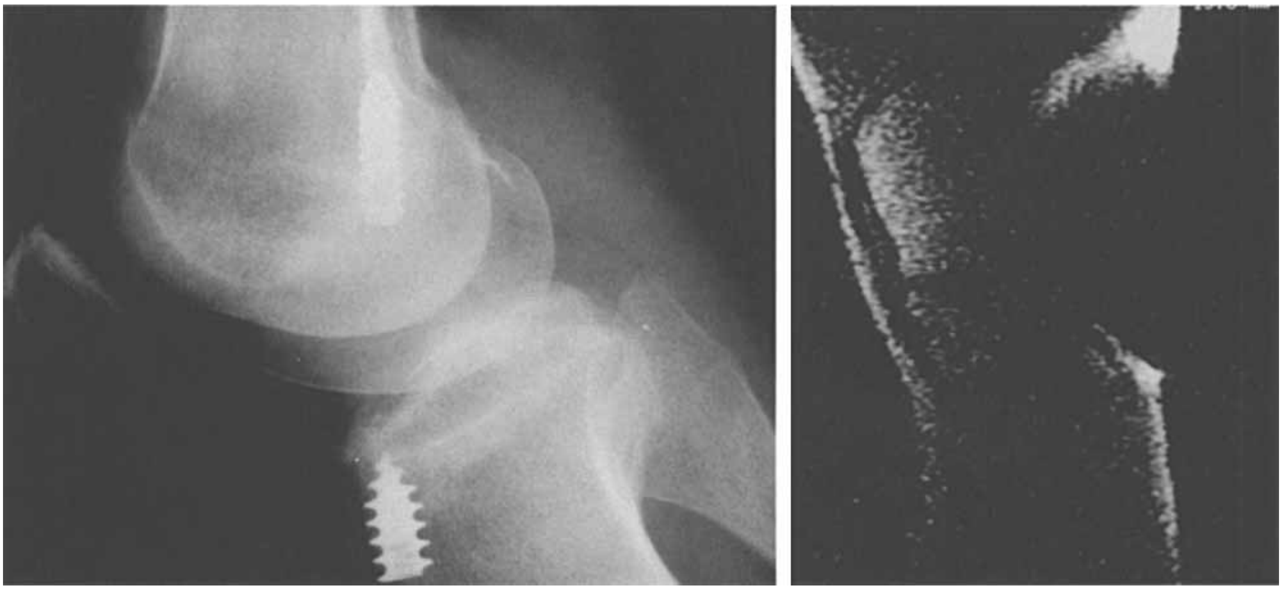
Figure 1. T1-weighted spin-echo image of a 20-cm-diameter, fluid-filled quality-assurance phantom that has a Perfix interference screw attached at the 12 o'clock position. Signal void affects approximately 60% of the phantom.

• DISCUSSION

The presence of a ferromagnetic object in a patient represents a potential contraindication for MR imaging (1,6). The principal danger associated with performing MR imaging in a patient who has a ferromagnetic metallic implant, device, or material is displacement or movement of the object (1–14). Several factors determine the absolute risk of imaging a patient who has an implanted ferromagnetic object. They include the strength of the static and gradient magnetic fields, the mass of the object, the degree of ferromagnetism of the object, the geometry of the object, the orientation and location of the object in situ, the length of time the object has been implanted (ie, the presence of fibrosis or granulation serves to stabilize the object), and the means by which the object is maintained in place (1,6,9,10). Each of these factors must be carefully assessed and considered before a patient with a metallic implant may be safely subjected to MR imaging.

The metallic orthopedic implants tested for ferromagnetism and artifacts in the present study were made of various types of metals: titanium, Zimaloy, cobalt chromium alloy, or 17-4 stainless steel. Titanium, Zimaloy, and cobalt chromium alloy were found to be nonferromagnetic, whereas the 17-4 stainless steel was highly ferromagnetic. Previous studies evaluating the ferromagnetism of various metallic orthopedic implants reported that these devices were made either of nonferromagnetic materials or of materials that were only slightly ferromagnetic (2–4,6,12–14,16). Therefore, the metallic orthopedic implants tested to date displayed little or no deflection in the magnetic fields used for MR imaging and caused artifacts that were limited to a localized signal void. By comparison, the ferromagnetic Perfix interference screw evaluated in the present study is the first orthopedic implant that showed substantial deflection when placed in the static magnetic field of the MR imager and produced substantial imaging artifact. Although it is unlikely that this implant would be moved or dislodged in situ, because of the manner in which it is used, the substantial extent of the associated artifact prevents evaluation of the knee with MR imaging (Fig 2).

During MR imaging, distortion of the image by metallic implants is caused by



a. b.

Figure 2. **(a)** Plain radiograph of a patient with an ACL reconstruction. Note the presence of the two Perfix interference screws. **(b)** T1-weighted, coronal spin-echo image (800/20, 16-cm field of view, 128 × 256 matrix; 5-mm section thickness) of same patient. The presence of the two Perfix interference screws prevents an evaluation of this knee with MR imaging.

a disruption of the local magnetic field that alters the relationship between position and frequency, two factors crucial for image reconstruction (17). The extent of image distortion related to the presence of a ferromagnetic object depends on a variety of factors, including the relative magnetism of the implant, the size and shape of the implant, the orientation of the implant in the body, and the MR techniques used for image acquisition and processing (1,9,17).

Nonferromagnetic implants may also cause image artifacts because eddy currents can be generated in these objects by the gradient magnetic fields used for MR imaging, which, in turn, disrupt the local magnetic field (1,9,17). MR imaging artifacts due to nonferromagnetic implants are characteristically smaller than those produced by ferromagnetic objects. For example, with respect to MR imaging of ACL reconstruction, the presence of titanium interference screws causes only a local signal void that may prevent adequate visualization of the bone tunnel but does not affect the assessment of the ACL autograft in the intraarticular space (18), nor would it affect examination of other soft-tissue components of the knee (unpublished observations, 1991).

MR imaging has been demonstrated to be a useful imaging modality for evaluating ACL reconstruction and provides supplemental information about the postoperative knee (18–20). Therefore, nonferromagnetic orthopedic implants should be considered for use at knee surgery, to permit, if necessary, examination of the knee with MR imaging. Patients referred for evaluation of the knee with Perfix screws in place should not undergo MR imaging because the images will not be diagnostically useful. ●

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