COMMUNICATION

Are titanium implants actually safe for magnetic resonance imaging examinations?

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Introduction

Magnetic resonance imaging (MRI) is widely used for the diagnosis, staging, and follow-up of diseases. MRI is a very useful diagnostic tool for musculoskeletal and cerebrovascular imaging, because it has excellent soft tissue contrast and is considered to be safer than other modalities, as it does not expose the body to radiation [1].

However, MRI is not without risks. The presence of a metal implant in the patient's body during an MRI scan can be dangerous due to excessive magnetic field interactions.

Developments in medicine have led to the use of various implants, such as dental and orthopedic implants, in our bodies [2]. In the field of craniofacial surgery, the use of titanium plates and screws in open reduction and internal fixation procedures has exploded since the late 20th century, and titanium is now considered to be the material of choice for implants. Titanium plates are frequently used for cranioplasty, reconstruction of the facial bones, and reconstruction of the orbital bone, because they yield excellent results without posing any major problems in terms of biosafety [3].

Some physicians, however, have questioned whether titanium implants are actually safe for MRI examinations. The greater the number of elderly patients, the higher the probability of conducting brain MRI due to cerebrovascular disease. This has led to the question of whether widespread use of titanium implants in the craniofacial region is acceptable given the likelihood that patients will undergo brain MRI in the future.

In this paper, we present the mechanism of MRI and its relationship to metals, especially titanium, and review the concerns that have been raised about titanium materials in MRI.

Physical principles of MRI

During MRI, a person is placed in a cylindrical machine and a wire is wound around the cylinder. When electricity courses through this wire, a magnetic field flows through the cylinder. In MRI, a magnetic field is applied to our body, and the imaging apparatus senses the signal produced in response to the magnetic field and images it [4].

The physical principles of MRI can be divided into three stages: magnetization, resonance, and relaxation. Magnetization refers to an electromagnetic property with the same directionality as the magnetic moment in an atomic nucleus. In other words, the nucleus can be regarded as an extremely small magnet. MRI uses hydrogen atoms, which are abundant in the human body. Since hydrogen has only one proton in its nucleus, its net magnetic field points in one direction, without being canceled. Since the magnetic moment direction of hydrogen atoms is random when a magnetic field is not applied in a normal human body, the body has no overall magnetic properties when these moments are summed. However, when an external magnetic field is applied, resonance occurs. The magnetic moments of the hydrogen atoms, which previously had different directions, align in the same direction. This phenomenon is known as resonance. In MRI, the intensity of the magnetic field is varied to avoid providing a constant force. When the external magnetic field disappears, the atom returns to its original state. The release of energy when an atom returns to its original state is known as relaxation. The intensity of the magnetic field changes during MRI, and relaxation is repeatedly induced by sequences of these changes. Imaging the energy signals generated from relaxation of the hydrogen atoms through the sensor results in an MRI image that we can see [4].

Relationship between MRI and metals

Common sense indicates that we should not bring metal close to an MRI machine. Although term "magnetism" is often used to refer to the magnetic properties of metals, in fact, all materials have magnetism, which can be classified into ferromagnetism, diamagnetism, and paramagnetism [5].

Ferromagnetic substances are materials that are magnetized even when there is no external magnetic field. When a ferromagnetic substance comes close to an MRI machine, it becomes attached to the MRI machine due to its strong magnetic field or is moved to another location. Representative ferromagnetic materials include iron, cobalt, and nickel. Diamagnetic substances are magnetized in the opposite direction to the magnetic field when placed in a magnetic field, although diamagnetism disappears when the magnetic field disappears. Representative materials include copper, glass, and plastic. Paramagnetic substances are weakly magnetized by an external magnetic field and lose their magnetism when the external magnetic field is removed. Most substances belong to this category, including titanium.

Concerns about MRI in patients with titanium implants

Over the last 3 decades, surgical titanium implants have been tested in numerous studies for safety, compatibility, and imaging diagnostic artifacts. Nearly all studies concluded that most nonferromagnetic implants are safe for patients in MRI [6-9].

The U.S. Food and Drug Administration receives approximately 300 reports annually of adverse events on MRI scans [10]. Contact burns due to skin-to-skin contact or external metallic objects such as electrocardiogram leads, pulse oximeters, and medical patches are most commonly reported. The next most commonly reported events include damage caused by projectile accidents by objects moving due to the magnetic field, digit injuries caused by the patient table, patient falls, hearing loss, and tinnitus, all of which are unrelated to the presence of a surgical implants.

Because MRI devices use strong magnets, metal implants pose the specific risk of potential migration of implants and radiofrequency (RF)-induced heating of the implants, which may cause damage to the surrounding tissue [11].

Studies have shown that implants firmly fixed to the bone are not affected by MRI-induced displacement [1,12]. Given the paucity of recent studies, MRI is not recommended in the immediate postoperative period in patients with passive implants such as coils, filters, and stents [6]. RF heating is theoretically possible because the eddy currents in implants are parallel to the static magnetic field of the scanner. However, all cohort studies have revealed that this temperature change is negligible, indicating that concerns about tissue damage from RF heating are unfounded.

Metal implants can result in image artifacts that cause misinterpretation of results. Advances in technology can minimize image distortion by modifying magnetic resonance pulse sequences and optimizing scanning parameters. When deciding whether patients should undergo MRI, physicians must consider both the advantages of imaging and the possibility of image distortion due to implants.

Titanium is a paramagnetic material that is not affected by the magnetic field of MRI. The risk of implant-based complications is very low, and MRI can be safely used in patients with implants. The titanium plates used in the craniofacial area, however, are made of alloys. More precise research is needed because the effects of MRI depend on the proportion of the constituents of the alloy.

Notes

Conflict of interest

YHK, an editor-in-chief of *Archives of Plastic Surgery*, is the corresponding author of this article. However, he played no role whatsoever in the editorial evaluation of this article or the decision to publish it. Except for that, no potential conflict of interest relevant to this article was reported.

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References

1. Sullivan PK, Smith JF, Rozzelle AA. Cranio-orbital reconstruction: safety and image quality of metallic implants on CT and MRI scanning. Plast Reconstr Surg 1994;94:589-96.
2. Tymofiyeva O, Vaegler S, Rottner K, et al. Influence of dental materials on dental MRI. Dentomaxillofac Radiol 2013;42:20120271.
3. Mosher ZA, Sawyer JR, Kelly DM. MRI safety with orthopedic implants. Orthop Clin North Am 2018;49:455-63.
4. The Korean Society of Magnetic Resonance Imaging. Textbook of magnetic resonance image. Seoul: Chung-Ku Publishing co.; 2011.
5. Magnetism [Internet]. Wikipedia; c2018 [cited 2018 Dec 12]. Available from https://en.wikipedia.org/wiki/Magnetism.
6. Shellock FG. Magnetic resonance safety update 2002: implants and devices. J Magn Reson Imaging 2002;16:485-96.
7. Shellock FG. 3-Tesla MR safety information for implants and devices [Internet]. MRISafety.com; c2018 [cited 2018 Dec 12]. Available from http://www.mrisafety.com.
8. Shellock FG. Biomedical implants and devices: assessment of magnetic field interactions with a 3.0-Tesla MR system. J Magn Reson Imaging 2002;16:721-32.
9. Tsai LL, Grant AK, Mortele KJ, et al. A practical guide to MR imaging safety: what radiologists need to know. Radiographics 2015;35:1722-37.
10. U.S. Food and Drug Administration. MRI (magnetic resonance imaging): benefits and risks [Internet]. Silver Spring, MD: U.S. Food and Drug Administration; c2017 [cited 2017 Dec 12]. Available from https://www.fda.gov/Radiation-EmittingProducts/RadiationEmittingProductsandProcedures/MedicalImaging/MRI/ucm482765.htm.
11. Davis PL, Crooks L, Arakawa M, et al. Potential hazards in NMR imaging: heating effects of changing magnetic fields and RF fields on small metallic implants. AJR Am J Roentgenol 1981;137:857-60.
12. Rupp R, Ebraheim NA, Savolaine ER, et al. Magnetic resonance imaging evaluation of the spine with metal implants: general safety and superior imaging with titanium. Spine (Phila Pa 1976) 1993;18:379-85.