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Placement of a Ferromagnetic Intracerebral Aneurysm Clip in a Magnetic Field with a Fatal Outcome[1]

Magnetic resonance (MR) imaging may be contraindicated in patients with biomedical devices, among the most dangerous of which are intracranial aneurysm clips, owing to the possibility of torque and dislodgment. A case is presented in which a patient with a reportedly nonferromagnetic clip was placed in a magnetic field. The patient developed an acute intracerebral hemorrhage in the MR unit, with a fatal outcome. Imaging studies strongly suggested a torqued clip as the cause. Autopsy revealed a torn middle cerebral artery from clip movement, and the clip was identified as a ferromagnetic type. This is the first reported case, to the authors' knowledge, of a fatal outcome due to an intracranial aneurysm clip placed in a magnetic field.

Index terms: Aneurysm, cerebral, 17.73 • Head, MR, 10.1214 • Magnetic resonance (MR), safety • Radiology and radiologists, iatrogenic injury

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All patients presenting to a magnetic resonance (MR) imaging facility must be adequately screened for implanted biomedical devices and, if these are present, must provide a precise pedigree for the device. Until now, the risk of a catastrophic hemorrhagic event has been a theoretical one in humans, with experimental work demonstrating the potential of generating sufficient torque to cause dislodgment or movement (1). Adequate screening identifies patients with ferromagnetic intracranial aneurysm clips. If an MR study is necessary, knowledge of the type of clip and its material may prevent possible catastrophic complications. Four patients with known intracranial aneurysm clips—one of which was ferromagnetic—have been imaged, without neurologic complications (2). MR imaging centers may image patients with biomedical devices safely by using published data on such implants (3–5). The data concerning intracranial aneurysm clips have been considered complete and are used at MR imaging centers as a reference for those patients who may benefit from an MR study but in whom there is a question of the safety of an aneurysm clip. We present a case in which death was caused by movement of an intracranial aneurysm clip that was misidentified and was believed to be nonferromagnetic. According to the U.S. Food and Drug Administration (FDA), this is the first reported death in an MR unit related to an intracranial aneurysm clip.

CASE REPORT

A 74-year-old woman with multiple medical problems presented to the MR center for a routine examination. The initial screening questionnaire revealed the presence of an intracranial aneurysm clip, which was placed at another institution in 1978. The examination was not performed, and the patient was referred back to her primary physician for possible computed tomographic (CT) scanning, with the reason for rejection given. Several days later, both the primary physician and the patient's family again requested the MR imaging examination and volunteered to investigate the pedigree of the clip. After contacting the office of the operating neurosurgeon at the other institution, the family returned to the MR scheduling office with the information that a Yasargil clip (Aesculap, South San Francisco, Calif) was placed on a middle cerebral artery aneurysm. Published lists of biomedical devices were then consulted (3,4), which showed that Yasargil-type clips (Aesculap 316LVM and Phynox) had no deflection in a magnetic field up to 1.89 T. The patient was then scheduled for the study.

At the time of the examination, the patient was escorted into the magnetic field of a Signa 1.5-T superconducting magnet (GE Medical Systems, Milwaukee, Wis). On reaching the edge of the table within the magnetic field, she complained of a headache at a distance of 4 ft (1.2 m) from the magnet bore. The technologist immediately escorted the patient from the MR room and placed her on a stretcher. Her condition deteriorated quickly, with aphasia and obtundation developing. A specialized emergency team performed intubation and transferred her to the CT scanner. The CT scan revealed a large right sylvian fissure hematoma and subarachnoid hemorrhage beginning at the site of the middle cerebral artery aneurysm clip. There was massive subfalcial herniation and midline shift (Fig 1). Following the CT examination, the patient exhibited decerebrate posturing, with fixed and dilated pupils. The family did not desire surgical intervention to be undertaken.

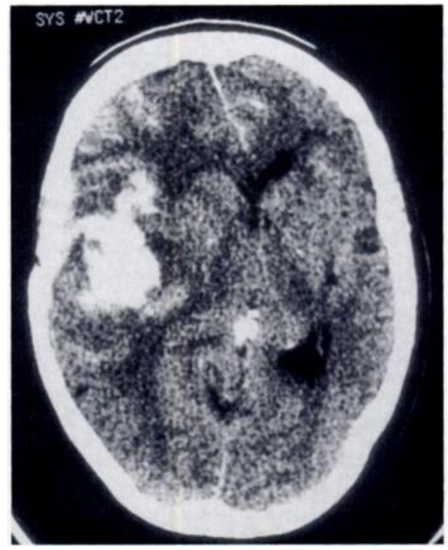

Figure 1. CT scan shows hemorrhage surrounding the site of the middle cerebral artery clip. A large sylvian fissure hematoma caused massive midline shift and subfalcial herniation. There is effacement of the lateral ventricle and displacement of the frontal horn across the midline. The hematoma takes up a large portion of the cerebral hemisphere.

The patient was pronounced dead 1 day after the MR examination. At a brain-only autopsy, the arterial system and clip were dissected from the brain parenchyma. Fresh thrombus surrounded the clip, and cross-sectional analyses revealed a tear in the arterial wall at the site of clip placement. The clip was removed from the autopsy room and was brought into the magnetic field of the same 1.5-T magnet, according to the technique described by New et al (1). There was strong deflection at a distance of 6 ft (1.8 m), with extreme deflection and torque at the bore of the magnet. An intense investigation ensued to identify the clip and the possible source of error. The FDA and GE Medical Systems were notified immediately. Photo-

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See also the editorial by Kanal and Shellock (pp 612–614) in this issue.

graphs of the clip were distributed to the FDA and Aesculap (Fig 2). Aesculap denied that this clip was a Yasargil type. The clip proved to be a type manufactured by Codman & Shurtleff (Randolph, Mass). The "A" on the clip is an internal designation by the manufacturer (Fig 2). Further discussion with the referring neurosurgeon from the other institution took place as well. The original operative note was obtained from microfilm, revealing the clip to be a Vari-angle clip. This clip is listed as ferromagnetic, with deflection in a magnetic field tested up to 1.89 T (3,4).

DISCUSSION

To our knowledge, this is the first reported case of a catastrophic event in a patient studied with MR who had an intracranial aneurysm clip. Previous reports of patients with aneurysm clips studied with MR demonstrated no complications caused by clips that were nonferromagnetic. Indeed, one patient with a ferromagnetic clip survived an MR study without complications, presumably secondary to scarring around the clip (2). Until now, catastrophic hemorrhage due to torquing of the clip was only a theoretical consideration.

Three types of magnetic fields are used in MR imaging: static magnetic fields, time-varying magnetic fields, and radio-frequency electromagnetic fields (6). The static magnetic field is used to align protons and establish a nonzero bulk magnetization. Ferromagnetic objects placed in a uniform static magnetic field may experience torque by the field. The magnitude of the force causing the torque is directly proportional to the strength of the magnetic field and to the length and angulation of the object. It has been shown experimentally that ferromagnetic cerebral aneurysm clips can be dislodged from an artery while in a magnetic field (1). Time-varying magnetic fields are encountered when the patient is moved into or out of the main magnetic field or during data acquisition for spatial encoding. The deleterious effects of placement of ferromagnetic objects such as intracranial aneurysm clips into static magnetic fields have been the greatest concern of MR users. Nineteen intracranial aneurysm clips have been found to be ferromagnetic and to exhibit torque in a magnetic field (4,5). Patients with such clips should not be placed in an MR imager. Nonferromagnetic clips are made of alloys that contain 10%–14% nickel to reduce the magnetic susceptibility of stainless steel (2,7). The most desirable form of stainless steel is the austenitic type, containing 10% nickel along with chromium for corrosion resistance. The Yasargil-type clip typifies the austenitic type, containing 13.5% nickel. A sampling of Yasargil clips produced since the inception of this clip have been tested at up to 1.89 T without deflection (7). In our case, it was initially thought that a Yasargil clip was the causative agent, and a great deal of investigation concerned the safety of this clip. The composition of the Yasargil clip has changed four times since its inception. The patent is for the design of the clip and does not necessarily include the composition. Subcontractors produce the Yasargil clip and follow the patent for design, but it must be assumed that the composition is the same. According to the data available, the Yasargil clip is assumed to be safe. Indeed, Aesculap has issued product safety bulletins that state emphatically that all Yasargil clips are safe in a magnetic field (written communication, J. L. Burridge, Aesculap). Unfortunately, the harmful clip was later found to be a Vari-angle clip. The constitution of the Vari-angle clip is martensitic 17-7 PH stainless steel. Martensitic alloys have a body-centered cubic crystalline structure and are ferromagnetic (7). The published data concerning the Vari-angle clip show that it has ferromagnetic properties and an extent of deflection in a magnetic field of approximately 70% (7).

All MR units have a screening procedure to detect intracranial aneurysm clips and avoid catastrophic events. Most permanent aneurysm clips produced now are safe for MR imaging, and older clips may be safe if the pedigree is positively known. The key point is that there must be written documentation—either in the medical record or operative note—before imaging can be considered.

In the past, the presence of an intracranial aneurysm clip has been considered a contraindication to MR imaging. Recently, the *Sun Signa Users Newsletter* (8) stated that all aneurysm clips are contraindicated in a GE Medical Systems magnet. However, most currently produced permanent clips are nonferromagnetic and may be considered safe, so MR imaging can now be offered to a population that may have been previously excluded. Each institution must evaluate the clips that are in its stock as to the possibility of deflection in a magnetic field. Our case demonstrates the risk at tertiary medical centers with a wide referral base and consequently no intimate knowledge of each clip placed in every particular patient. A diligent effort should be made to document the pedigree of each clip. Our imaging center trusted the verbal information provided by the office of a neurosurgeon at another institution concerning a vital piece of patient information. Only after a tragic occurrence did we learn of the misinformation provided to our institution. Had we only demanded the written operative note to prove the clip's identity, the patient would never have been imaged. Verbal information from either the patient, the family, or a physician's office should never be relied on in making the decision whether to perform MR imaging of a patient with an aneurysm clip. ■

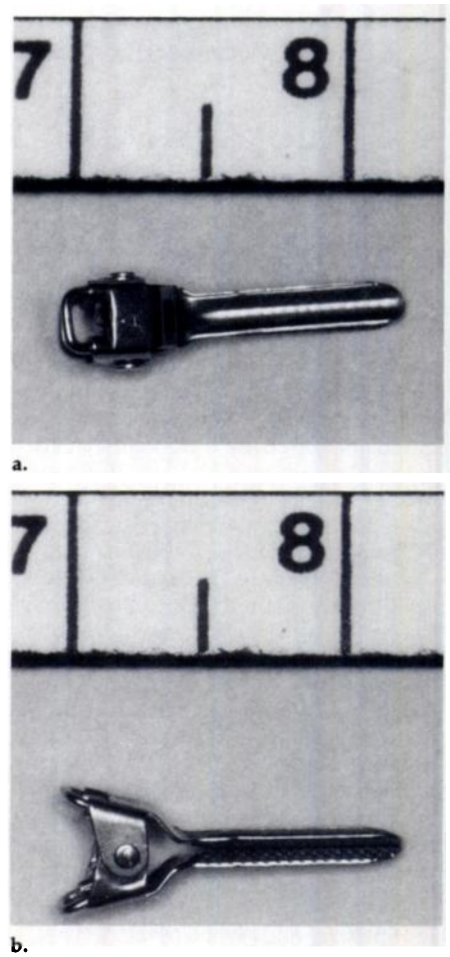

Figure 2. Superior **(a)** and lateral **(b)** views of the clip that was dissected from the middle cerebral artery of our patient. It was identified as a Vari-angle clip. Note the flat jaws seen on the lateral projection. Scale = centimeters.

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