

## Patient Screening Prior to MR Imaging: A Practical Approach Synthesized from Protocols at 15 U. S. Medical Centers

Allen D. Elster,<sup>1</sup> Kerry M. Link,<sup>1</sup> and J. Jeffrey Carr<sup>1,2</sup>

The article by Boutin et al. [1] in this issue of the *AJR* documents a surprisingly great variation in the MR screening procedures used at different academic centers throughout the United States. Although considerable literature now exists concerning the MR imaging of patients with ferromagnetic implants, devices, and foreign bodies [2–4], no uniform screening protocol to identify such patients has yet been adopted. The Safety Committee of the Society for Magnetic Resonance Imaging (SMRI) has recommended that “each imaging site should develop a standardized policy for screening patients with suspected metallic foreign bodies” [5]. To date, however, the SMRI has neither proposed nor endorsed a specific screening protocol for general use.

We agree with the SMRI Safety Committee that each center should develop a standardized MR screening policy specifically tailored to local needs and standards of care. However, we also recognize that new centers and less experienced radiologists may need some guidance in constructing these protocols. Moreover, even established centers must constantly update their existing protocols as new types of biomedical implants are manufactured and marketed.

To aid radiologists in developing or revising their MR screening protocols, we thought that publishing a prototype or model screening protocol might be useful. To generate such a document, we contacted colleagues at 15 institutions (Bowman Gray School of Medicine, Winston-Salem, NC; Cedars-Sinai Medical Center, Los Angeles; Cleveland Clinic, Cleveland; Columbia-Presbyterian Hospital, New York City,

Duke University Hospital, Durham, NC; Johns Hopkins Hospital, Baltimore; Massachusetts General Hospital, Boston; New England Deaconess Hospital, Boston; Stanford University Hospital, Stanford, CA; St. Joseph’s Hospital–Barrow Neurologic Institute; Phoenix, AZ; University of California, Los Angeles; University of California, San Francisco; University of Iowa, Iowa City, IA; University of Pennsylvania, Philadelphia; and University of Wisconsin, Madison) with long-established and widely recognized MR programs. We asked each institution to send us copies of their MR screening protocols (including written policies, guidelines, and patient questionnaires), and they all responded. Notwithstanding the wide geographic diversity of these 15 centers, we found the MR screening forms used at each to be remarkably similar. Combining these data, we developed a “model” MR screening procedure synthesizing what we thought were the best features from each of the 15 centers. Bowman Gray has adopted this model protocol. Other centers may find our model applicable in its present form or as a starting point for the construction of individualized protocols.

Our philosophy concerning effective MR screening is based on two principles: redundant questioning (both oral and written) and the use of simple English (or appropriate native language). We fully admit that such a strategy cannot guarantee to identify with certainty every patient with an MR-incompatible device, implant, or foreign body. Nevertheless, we believe that the compulsive use of such a screening procedure constitutes a high standard of care and is the best

Received September 14, 1993; accepted September 15, 1993.

<sup>1</sup>Department of Radiology, Bowman Gray School of Medicine, Wake Forest University, Winston-Salem, NC 27157-1022. Address correspondence to A. D. Elster.

<sup>2</sup>Present address: Department of Radiology, Hospital of the University of Pennsylvania, 3400 Spruce St., Philadelphia, PA 19104.

single method available to reduce the chances of inadvertently exposing such a patient to a potentially harmful magnetic environment.

### Level 1 Screening: Scheduling Interview

Screening of patients for MR imaging should begin at the time the examination is first scheduled. The MR employee responsible for scheduling patients should be trained in the basics of MR safety and have ready a brief set of screening questions for the referring physician or health care worker ordering the examination. At a minimum, these questions should include: (1) Does the patient have a cardiac pacemaker, pacer wires, or internal defibrillator? (2) Does the patient have any other implanted electronic devices such as a cochlear implant, neurostimulator, or infusion pump? (3) Does the patient have a cerebral aneurysm clip? (4) Does the patient have any known metal fragments in a critical location, such as the eye, brain, lung, or spine? The MR examination should not be scheduled until a satisfactory answer to each of these questions is obtained.

If the patient has a cardiac pacemaker or other implanted electronic device, MR imaging generally is contraindicated, and the examination should not be scheduled. An appropriate substitute imaging test, usually a CT scan, is then suggested. If needed, the referring physician may discuss the matter with the radiologist to determine the most effective alternative imaging strategy.

If the patient has a cerebral aneurysm clip, MR imaging may still be possible, provided the clip has been tested for ferromagnetism and the identity of the clip is certain [6]. The identity of the clip should be established by direct inspection of the operative note in the patient's chart by the radiologist supervising the MR examination. The memory of a surgeon or the words of a patient should not suffice for direct inspection of the medical records; a recent fatality occurred when such a protocol was not rigorously followed [7]. In patients with cerebral aneurysm clips, therefore, we tentatively schedule the MR examination, but far enough into the future to allow the patient or physician time to obtain this necessary documentation.

If the patient responds affirmatively to having metal fragments or shrapnel in a critical location (such as the eye or brain), more detailed questioning generally will be necessary. Because many of these patients can be safely imaged, we usually schedule the examination but inform the patient that further screening or tests (including the use of conventional radiography) may be necessary before exposure to the magnetic field is permitted. Furthermore, the patient should be warned that the examination might be canceled if the radiologist deems that the risk of magnetic field exposure is unacceptably high.

For hospitalized patients, several additional safety questions should be directed to the responsible nurse or physician ordering the examination (Table 1). Additionally, the person scheduling the examination should take this opportunity to find out about the general condition of the patient, including requirements for sedation, oxygen, suctioning, or other special needs.

**TABLE 1: Supplemental Screening Check List for Inpatients**

Implant or Device	Recommended Action
External infusion pump for IV medications (e.g., IVAC, IMED)	All IV catheters should be converted to free flowing or Hep-Locked
Arterial catheter	Remove associated monitoring/recording equipment
Intracranial pressure monitor (bolt)	Remove associated monitoring/recording equipment
Skin staples	Remove if possible; otherwise cover with bandage
Orthopedic appliances (including Halo, tongs, skeletal traction apparatus, external skeletal fixation)	MR may be contraindicated: direct consultation with radiologist
Ventricular and surgical drains	Remove all metal clamps and containers from circuit
Thoracostomy tubes	Many reservoir devices (e.g., Pleur-evacs) are not MR compatible; tube must generally be clamped with nonferromagnetic instrument
Metal tracheostomy tube	Exchange for plastic model
Indwelling catheters, especially Swan-Ganz type with thermal dilution tip	MR may be contraindicated; direct consultation with radiologist
ECG or electroencephalographic electrodes, pads, or leads	Remove
Holter/telemetry monitor	Remove
Pulse oximeter	Remove
Temporary pacer wires	Remove
Transcutaneous electrical stimulator unit/patches	Remove

### Level 2 Screening: Appointment Reminder

At most busy centers the patient is contacted by telephone the day before the MR examination as an appointment reminder. This is a prime opportunity to review the brief checklist of contraindications to MR asked about at the initial scheduling interview. This step is important because it is often the first time the MR staff has talked directly with the patient about safety issues. (Examinations are often scheduled by a nurse or secretary from the office of the referring physician.) Even if previous communications have been with the patient directly, this extra redundancy for safety's sake still seems worthwhile.

### Level 3 Screening: Arrival for Appointment

After arriving at the MR center on the appointed day, the patient should read, review, and sign a safety screening checklist that queries the patient in written form about the presence of specific implanted devices and other contraindications to MR imaging. If the patient is unable to read or understand this form, then a parent, guardian, or other authorized person is asked to complete and sign it. The patient should have ample opportunity to ask questions about the items on the form before signing.

In the event the patient does not speak English, an interpreter must be available to translate the form. Some MR

centers in the southwestern United States have screening forms routinely printed in both Spanish and English. Centers in large metropolitan areas may find it useful to have these forms translated into Vietnamese, Chinese, or other relevant languages.

In the design of a such a safety checklist, one of three general strategies may be used: (1) an exhaustive listing of all possible implanted devices, including their brand names and technical descriptions; (2) a complete list, but using generic descriptions in plain English, grouping similar items whenever possible; or (3) an abbreviated form, listing only the major contraindicated devices. All three strategies were represented in our sample of 15 centers, although the second type (generic listing) was the most popular by far.

Although a case can be made for each of these three principal questionnaire strategies, we think the use of simple English and a generic listing makes the form more understandable to the largest number of patients. Further oral questioning of marked items can then be used to refine one's knowledge about the precise type of implanted device so that a proper safety decision can be made. Our prototype MR screening form (see Appendix) uses this generic listing approach, as well as combining several other excellent features (e.g., the drawing of the human figure) gleaned from the 15 protocols we reviewed.

After the patient completes and signs the MR screening form, a nurse, technologist, or physician should carefully review it. The patient should be quizzed at length about any positive responses on the form. Additionally, the patient should be asked one last time about the several major contraindicated implants and foreign bodies (e.g., pacemakers, aneurysm clips, electronic devices, shrapnel). Only when the patient passes this final spoken screening review is entry into the MR imaging suite permitted.

If a parent, relative, or guardian wishes to accompany the patient into the MR imaging suite, then it is imperative that that person also be screened for metallic foreign bodies. (Family members standing near the magnet could be injured just as easily by their own metallic implants as could a patient.) We recommend that friends and family members be required to fill out the same screening form and be subjected to the same oral screening procedures as the patient. Additionally, accompanying family members should either be dressed in hospital gowns or be thoroughly screened for ferromagnetic foreign bodies on their clothes or person (such as earrings and hairpins) prior to entry into the imaging room. We have found the use of an airport-style walk-through metal detector most useful in this setting, to detect metal objects that might be inadvertently carried into the imaging suite in the hair or pockets of accompanying family members and become dangerous missiles in the powerful magnetic field.

What should be done when a patient raises the possibility, either orally or on the checklist, that a metallic implant, foreign body, or other biomedical device may be present? At this point, more detailed questioning and analysis, preferably by a physician, is usually required.

As a general rule, many patients with metallic implants listed on the MR safety screening form can be imaged safely. The items in this checklist have been listed in an

order that roughly parallels their risk: the further down the list, the less danger to the patient. For example, pacemakers, cochlear implants, and other electronic devices are generally considered absolute contraindications to MR imaging and head the list. Conversely, most orthopedic appliances (including joint prostheses, plates, screws, nails, and rods) are generally safe for MR imaging and are found near the bottom of the list.

In addition to listing implanted devices, the MR screening form also contains a checklist of carry-on items (such as hairpins and earrings) that should be removed prior to imaging. The drawing of the human figure provides yet another level of redundancy for safety's sake; here the patient has another chance to mark the location of any metal within his or her body.

We also use the screening form as a place to gain information about the patient's surgical and occupational history. Alternatively, this information can be asked on a separate medical history form. Likewise, we use the screening form to provide the patient with information about gadolinium contrast material and assess the risk of potential reaction. (Known risk factors include prior allergic reaction to gadolinium contrast material and a history of asthma or emphysema.) In some states, a separate signed consent form for contrast administration may be required; in others, the form presented may be sufficient.

A complete discussion concerning which patients can and cannot be safely exposed to MR imaging lies beyond the scope of this article. The reader is referred to several recent excellent articles and books that address these MR safety issues in more detail [2, 4, 8].

#### **Level 4 Screening: Continuous Surveillance During the Examination**

Any metallic device, even one rigidly affixed to the skeleton and otherwise considered safe for MR imaging, can cause local tissue heating by an eddy current mechanism, resulting in discomfort or internal burns. Therefore, all patients with any type of implanted metallic device should be made aware of such possible local heating effects and told to notify the MR technologist immediately if any discomfort arises during the examination. For this reason (and others to be described), the final stage of MR safety assurance should entail continuous surveillance of the patient during the examination.

Many MR scanners are equipped with emergency call buttons, small devices patients hold in their hands during the examination to signal the MR technologist about a problem. If such a device is not available, vigilant periodic voice checks with the patient between sequences should be done.

Careful surveillance of the patient is especially required after administration of gadolinium contrast material. Although most of the reported severe or life-threatening reactions to gadolinium contrast material have occurred within seconds after IV administration, some cases of bronchospasm and laryngeal swelling have taken several minutes to develop [9]. Therefore, continuous monitoring of patients who have received contrast material is warranted during and for a short period after the examination.

**Conclusions**

No questionnaire, consent form, metal detector, or other screening procedure can guarantee to identify with 100% confidence every patient at risk for injury by magnetic field exposure. Fortunately, significant injuries are extremely rare, especially in light of the fact that several million patients undergo MR imaging in the United States each year.

The safety screening form we have constructed contains what we think are the best features from protocols used at 15 established MR imaging centers nationwide. We invite others to improve on our prototype, and for all centers to develop policies and protocols suitable to their local needs and standards.

**ACKNOWLEDGMENTS**

We thank our colleagues for sharing their MR screening protocols with us for use in this article: Larry Boxt (Columbia-Presbyterian), John Crues (Cedars-Sinai), Dirk Sostman (Duke University), Burton Drayer (Barrow Neurologic Institute—St. Joseph's Hospital), Robert Herfkens (Stanford University Medical Center), Vincent Mathews (Johns Hopkins, now at Bowman Gray), Jeff Carr (University of Pennsylvania), Tom Brady (Massachusetts General Hospital), Richard White (Cleveland Clinic), Bill Buff (New England Deaconess), Robert Lufkin (University of California, Los Angeles), Charles Higgins (University of California, San Francisco), Bill Yuh (University of Iowa), and Patrick Turski (University of Wisconsin, Madison).

**Appendix: MR Safety Screening Form Used at Bowman Gray School of Medicine**

**ATTENTION: MR PATIENTS AND ACCOMPANYING FAMILY MEMBERS**

The MR room contains a very strong magnet. Before you are allowed to enter, we must know if you have any metal in your body. Some metal objects can interfere with your scan or even be dangerous, so please answer the following questions carefully.

Yes  No Have you ever had an operation or surgical procedure of any kind? Please list all with dates:  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

Yes  No Have you ever been a machinist, welder, or metal-worker?

Yes  No Have you ever been hit in the face or eye with a piece of metal (including metal shavings, slivers, bullets, or BBs)?

Yes  No Have you ever had a piece of metal removed from your eye?

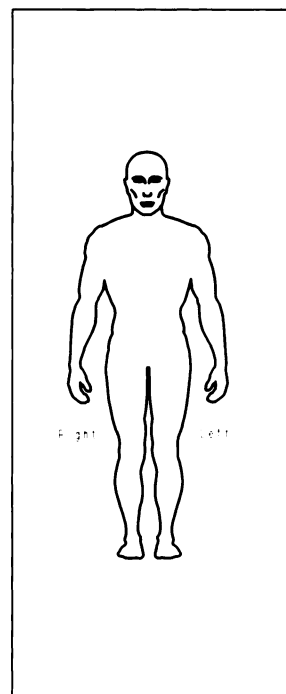
Yes  No Are you pregnant, possibly pregnant, or breast-feeding?

**DO YOU HAVE ANY OF THESE ITEMS IN YOUR BODY?**

- Yes  No Pacemaker, wires, or defibrillator
- Yes  No Brain/aneurysm clip
- Yes  No Ear implant
- Yes  No Eye implant
- Yes  No Electrical stimulator for nerves or bone
- Yes  No Bullets, BBs, or pellets
- Yes  No Metal shrapnel or fragments

- Yes  No Magnetic implant anywhere
- Yes  No Infusion pump
- Yes  No Coil, filter, or wire in blood vessel
- Yes  No Artificial limb or joint
- Yes  No Eyelid tattoo
- Yes  No Implanted catheter or tube
- Yes  No Artificial heart valve
- Yes  No Penile prosthesis
- Yes  No Shunt
- Yes  No False teeth, retainers, or magnetic braces
- Yes  No Surgical clips, staples, wires, mesh, or sutures
- Yes  No Diaphragm or intrauterine device
- Yes  No Orthopedic hardware (plates, screws, pins, rods, wires)

Please mark on this drawing the location of any metal inside your body.



The following items may become damaged or cause injury to others in a strong magnetic field. **THEY MUST NOT BE TAKEN INTO THE MR SCAN ROOM.** Place an "x" by any item you have with you on the list below.

- Hearing aid
- Glasses
- Watch
- Safety pins
- Hairpins/barrettes
- Wigs/hair pieces
- Jewelry (rings, earrings, etc.)
- Wallet/money clip
- Purse/pocketbook
- Pens/pencils
- Keys
- Coins
- Pocketknife
- Credit or bank cards
- Artificial limb/prosthesis
- Dentures/partial plates/retainers
- Belt buckle
- Bra/girdle/sanitary belt
- Metal zippers/buttons

**INFORMATION CONCERNING GADOLINIUM CONTRAST MATERIAL**

As part of your examination, the MR radiologist may deem it advisable to give you an I.V. injection of a contrast agent containing gadolinium. This injection may help the physician more accurately diagnose your condition. Although gadolinium contrast agents have been used safely in millions of cases, minor reactions (principally headache or nausea) occur in about 2% of patients, whereas serious or life-threatening reactions have been reported in about one in 400,000 patients.

Have you ever had a previous allergic reaction to gadolinium contrast material?  Yes  No  
 Do you have a history of asthma or emphysema?  Yes  No

I attest that the answers I have provided to questions on this form are correct to the best of my knowledge. I have read and understand the entire contents of this form and have had the opportunity to ask questions regarding the information on this form.

Signature (Patient or Guardian): \_\_\_\_\_ Date: \_\_\_\_\_

Witnessed by \_\_\_\_\_

## REFERENCES

1. Boutin RD, Briggs JE, Williamson MR. Injuries associated with MR imaging: survey of safety records and methods used to screen patients for metallic foreign bodies before imaging. *AJR* 1994;162:189-194
2. Kanal E, Shellock FG, Talagala L. Safety considerations in MR imaging. *Radiology* 1990;176:593-606
3. Teitelbaum GP, Yee CA, Van-Hom DD, Kim HS, Colletti PM. Metallic ballistic fragments: MR imaging safety and artifacts. *Radiology* 1990;175: 855-859
4. Shellock FG, Curtis JS. MR imaging and biomedical implants, materials, and devices: an updated review. *Radiology* 1991;180:541-550
5. Shellock FG, Kanal E. SMRI report: policies, guidelines, and recommendations for MR imaging safety and patient management. *J Magn Reson Imaging* 1991;1:97-101
6. United States Food and Drug Administration. Caution needed when performing MRI scans on patients with aneurysm clips. *FDA Med Bull* 1993; 23(2):1
7. Klucznik RP, Carrier DA, Pyka R, Haid RW. Placement of a ferromagnetic intracerebral aneurysm clip in a magnetic field with a fatal outcome. *Radiology* 1993;187:855-856
8. Elster AD. *Questions and answers in magnetic resonance imaging*. St. Louis: Mosby, 1993:240-260
9. *Safety and efficacy of Magnevist (gadopentetate dimeglumine) injection: four years of experience*. Wayne, NJ: Berlex Laboratories, 1992



American  
Roentgen Ray Society  
**94<sup>th</sup>**  
Annual Meeting  
New Orleans, LA  
April 24 - 29, 1994