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Response to Dr. Kanal:

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MR of the Spine in the Presence of Metallic Bullet Fragments: Is the Benefit Worth the Risk?

In general, radiologists are reluctant to perform MR imaging for patients with retained metallic bullet fragments (1–3). This reluctance is heightened for those patients with retained fragments near vital and susceptible anatomic structures such as the spinal cord. This issue led us to review the medical records of 19 patients (December 1991 to May 1996) at our institution who had retained metallic fragments (presumed lead) in the region of the spine, and who were studied with MR imaging. This study was done to assess whether the information obtained from the images could justify the potential hazards related to the procedure.

There were retained metallic fragments in the cervical spine in six patients, the thoracic spine in eight patients, and the thoracolumbar and lumbar spine in two and three patients, respectively. Fifteen patients had retained bullet fragments larger than 1 cm (mean, 1.5 cm), four were inside the spinal canal, six were embedded in the spinal bony structures, and five were in the paraspinal region. Three smaller metallic fragments (0.4–0.9 cm) were located in the paraspinal soft tissues. Metallic fragments smaller than 0.4 cm were located inside the spinal canal in six patients, in the bony spinal structures in six patients, and in the paraspinal region in six patients. Six patients were quadriplegic and 12 were paraplegic; these conditions were unrelated to the history of gunshot wound injury. MR examinations were performed within 3 weeks after the time of injury in six patients while in the remaining 13, a time period of 1 month to 6 years had elapsed.

MR imaging was performed at either a 1.0 or 1.5 T with T1-weighted spin-echo and gradient echo images in the sagittal and axial plane. Additional sagittal or axial T2-weighted spin-echo and T2-weighted fast spin-echo sequences were performed in six and four patients, respectively. None of the patients imaged had retained metallic fragments. Fragments, such as the ball-bearing or Prometheus type of air gun pellets, have been shown to be strongly ferromagnetic (4).

All procedures were performed without the patients experiencing any untoward effect. All metallic foreign bodies showed mild artifact (1) approximately the same size as the metallic object imaged. In two cases, however, metallic fragments smaller than 0.4 cm were confirmed by plain radiography or CT, but were not visible on the MR images. This led to the conclusion that these bullet fragments were not ferromagnetic (1).

MR studies established diagnoses in 27 patients (five acute/subacute and 12 chronic). In those two cases in which the MR image was deemed suboptimal, artifact precluded exclusion of a spinal lesion in the region of interest. Imaging artifacts in these two patients were the result of multiple small metallic fragments associated with a dominant (>1 cm) metallic fragment. In the six recently injured patients, two had a cord contusion and two had an epidural hematoma with cord compression that was subsequently treated surgically. One patient had no identifiable lesion and one had a nondiagnostic study owing to extensive artifacts induced by the metallic fragments. In the 13 chronically injured patients, four studies yielded negative results for cyst, scarring, atrophy, or a compressive lesion. Atrophy and myelomalacia were identified in six patients, one of whom had a small nonsurgical extramedullary cyst. One patient had a bullet embedded in a cord with a cyst above and below it, and one patient was diagnosed with an epidural abscess that was subsequently treated surgically. One study was nondiagnostic because of extensive metallic artifact.

On the basis of our experience, we support the use of MR imaging for patients with retained metallic ballistic fragments in the region of the spine; the information we gained would have been difficult to obtain with other imaging techniques. Certainly, as with any patient with a metallic implant or any potentially hazardous medical device, serious consideration should be given to determine which (if any) of these patients should enter the MR environment. Results obtained from MR led to surgical intervention in three of 19 patients. No untoward effects were seen.

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References

1. Teitelbaum GP, Yee CA, VanHorn DD, et al. **Metallic ballistic fragments: imaging safety and artifacts.** *Radiology* 1990;175: 855–859
2. Pohost GM, Black GG, Shellock FG. **Safety of patients with medical devices during application of magnetic resonance methods: biological effects and safety aspects of nuclear magnetic resonance imaging and spectroscopy.** *Acad Sci*; 1992;302–312
3. Shellock FG, Kanal E. **SMRI Safety Committee: policies, guidelines, and recommendations for MR imaging safety and patient management.** *J Magn Reson Imaging* 1991;1:97–101
4. Oliver C, Kabala J. **Air gun pellet injuries: the safety of MR imaging.** *Clin Radiol* 1997;52:299–300

Response:

In their letter, Drs Finitsis, Falcone, and Green summarize their retrospective review of medical records of 19 patients with ''retained metallic fragments in the regions of the spine'' who underwent MR examinations without adverse outcomes. MR studies provided diagnostic information in almost all cases that led to surgical intervention in three.

Although the objective of this work is quite laudable, the methods performed by Finitis, Falcone, and Green unfortunately do not permit one to reach the conclusions and recommendations made. A purely retrospective study was performed with no controls whatsoever. No explanation is provided of how the correspondents documented the lack of injury from MR exposure. Was any follow-up performed of these patients? Was there any investigation for possible subclinical internal injury to tissues adjacent to the metallic foreign bodies? Because the majority of patients seem to have had some prior injury, often in the area of the metallic fragment, it is quite possible that additional injury to these previously damaged tissues might go unnoticed, especially if no formal follow-up examination was performed. Further, is the correspondents' safety recommendation of metallic bullet fragments applicable to all field strengths? Is 2 T acceptable? How about a 4.7-T research system? Where do they draw the line—and why specifically there? It has been well documented (1–4) that there are innumerable types of ''bullet fragments'' from various sources—some (<20%) powerfully ferromagnetic (2), others weakly ferromagnetic, and others nonferromagnetic. On what basis are these data apparently ignored? How was the degree of ferromagnetism of the metallic bullet fragments in these 19 patients assessed to see if their conclusions would be applicable to other potential projectiles?

Perhaps one of the most important take-home lessons of MR safety is that a safe MR examination does not mean repeat MR will be safe for the patient. There are dozens of variables that can affect the outcome and safety of exposing a patient with metallic foreign bodies to MR. The degree of ferromagnetism of the metallic object impacts significantly on the safety of MR exposure. The dimensions and mass must be examined; whether an object is massive or linear, has a long-axis or spherical shape, raises concern for translational or rotational forces. The precise location of the object in or near the spine must be determined; is the object free within the thecal sac, anchored within the cortical bone, or embedded in the cord itself? The strength of the static magnetic field and static magnetic field gradient (spatial distribution of the static B_o magnetic field) should be identified. The field and field gradient traverse during scanning; the stronger the field and its associated gradient, the greater the translation (projectile) and rational (torque) forces, and presumably the risk to the patient. The rate the patient and metallic object move through the static field and field gradient increases risk. To state that ''19 patients with bullet fragments in or near the spine were permitted to undergo an MR study, and no one got hurt,'' and to conclude that it is safe to expose such patients to MR environments is fraught with peril and not scientifically sound. I would like to remind our readers of one patient who suffered an intraocular hemorrhage and unilateral blindness after inadvertent exposure to MR imaging at 0.35 T (5), and who was subsequently found to have had a 2- by 3-mm fragment of metal on his retina. What is not well known is that this adverse event occurred at the *end* of the study after three imaging sequences were successfully acquired (5). It is entirely possible that this patient might have exited the MR scanner without difficulty, just as he had entered it, and remained there for almost an hour without difficulty. Imagine the consequences if one would erroneously conclude that, because nothing untoward had occurred during the prior exposure, it would be safe to expose this patient to MR scanning once again in the future.

I am also personally aware of a patient who was placed in the bore of a high-field MR scanner. Site practitioners were not aware that the patient had a ferromagnetic Codman variangle aneurysm clip implant—the same type that was implicated in the death of another patient of intracranial hemorrhage during positioning in a high-field MR scanner (6). The former patient was removed from the scanner when the clip was identified on the initial scan of the brain, with fortunately no untoward outcome. Certainly one would assume that, because no injury had occurred in that case, it would be safe to prospectively place this patient again into another high-field MR scanner!

Clearly, deciding whether one should permit a patient into the bore or environment of an MR scanner should always be considered as a risk-benefit ratio to be assessed on a patient-to-patient basis. The potential risks, however, should be determined by carefully and prospectively performing studies based on scientifically sound methods. I would like to respectfully submit that the conclusions reached and broad recommendations suggested in this letter do not meet such criteria, and may inadvertently lead the uninitiated to draw inappropriately optimistic conclusions about the safety of a very unforgiving environment.

We, at the University of Pittsburgh Medical Center, weigh the potential benefits of an MR study for a particular patient in light of the potential risks this imaging technique poses. There is the possibility of substantial translation or rotation forces or motion of a metallic foreign body depending on where in the body it is located, and

how and if it is anchored to cortical bone, as noted above. The decision to expose a patient to an MR environment should hinge on these variables.

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References

1. Teitelbaum GP. **Metallic ballistic fragment: MR imaging safety and artifacts (letter).** *Radiology* 1990;177:883
2. Teitelbaum GP, Yee CA, van Horn DD, Kim HS, Colletti PM. **Metallic ballistic fragments: MR imaging safety and artifacts.** *Radiology* 1990;175:855
3. Lufkin RB. **MR imaging of firearm projectiles (letter).** *Radiology* 1991;179:285
4. Smith AS, Hurst GC, Duerk JL, Diaz PJ. **MR of ballistic materials: imaging artifacts and potential hazards.** *AJNR Am J Neuroradiol* 1991;12:567–572
5. Kelly WM, Paglen PG, Pearson JA, San Diego AG, Soloman MA. **Ferromagnetism of intraocular foreign body causes unilateral blindness after MR study.** *AJNR Am J Neuroradiol* 1986;7: 243–245
6. Klucznik R, Carrier D, Pyka R, Haid R. **Placement of a ferromagnetic intracerebral aneurysm clip in a magnetic field with a fatal outcome.** *Radiology* 1993;187:855–856

Response to Dr. Kanal:

We appreciate Dr. Kanal's comments concerning our letter. The premise that ''deciding if one should permit a patient into the bore of an MR scanner should always be considered as a risk-benefit ratio to be assessed on a patient-to-patient basis'' is one that all of us should abide by and is emphasized in our letter.

We also agree with Dr. Kanal that we did not employ scientifically sound methods in our report. We lacked controls, follow-up, and the detection of subclinical injury. This is precisely why we chose to submit a Letter to the Editor rather than an original research article. We could not, however, ignore our experience and the experience of our neurosurgical colleagues (verbal communications) who deal with hundreds of gunshot-wound victims with spinal cord injury and paralysis each year. We have never seen any evidence of bullet movement, and more important, neurologic deterioration associated with MR scanning at 1.5 T or below. Even after patients were informed about a potential warm feeling about their spine while in the magnet, we never received any reports of discomfort. Our observations, along with the observations of our colleagues who have scanned similar patients, are consistent in that there was no evidence of neurologic deterioration or pain during or after scanning. Although we cannot attest to the presence or absence of subclinical internal injury, even if we could detect a subclinical adverse event, we are not sure how this would affect our decision to put a particular patient in the MR environment. Certainly, subclinical internal injury can occur within many areas of medical practice from various surgical/interventional procedures to pharmaceutical applications.

Notwithstanding the overwhelming circumstantial evidence that the presence of lead bullets or bullet fragments in or near the spinal canal presents minimal risk to the spinal cord–injured or paralyzed patient, Dr. Kanal's comments are valid. We have, in fact, embarked on a plan in the laboratory to pursue the issues of safety in a laboratory model. In addition, we will establish a prospective protocol with pre- and post-MR evaluation of plain radiographs for detection of bullet movement and a detailed neurologic assessment of the patient before and after MR imaging. Before such studies can be completed, we continue to support the use of MR imaging of patients with retained metallic (lead) ballistic fragments in the region of the spine because we believe that the knowledge we gain outweighs potential risks.

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