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Fiberoptic Intracranial Pressure Monitoring during Magnetic Resonance Imaging

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MAGNETIC resonance imaging (MRI) provides high quality diagnostic information in many central nervous system disorders.[1,2] During MRI, patients are exposed to a large static magnetic field (*e.g.*, 1.5 Tesla) and radiofrequency (RF) pulse sequences.[1–3] It has long been appreciated that the presence of metallic objects within the magnetic field can lead to image distortion or, worse yet, patient injury.[1–7]

Magnetic resonance imaging centers typically keep compatibility registers of commonly used biomedical devices.[5,6] Unfortunately, with the growing number of biomedical devices, it is often difficult to keep such registers up to date.[6]

We report a case in which a commonly used intracranial pressure (ICP) monitor was found to be MRI incompatible. We also discuss a practical two-step method for performing *ex vivo* MRI compatibility screening.

Case Report

A 24-yr-old man with a severe closed head injury requiring intubation and ventilation underwent an emergent computed tomography (CT) scan of his head and neck. There was no evidence of intracranial pathology requiring surgery, although due to his injury, a fiberoptic ICP monitoring catheter (Camino Laboratories, San Diego, CA, Model 110-4B) was placed in the parenchyma of the right frontal lobe *via* a small burr hole. The initial ICP reading was 9 mmHg. The cervical spine CT scan was positive for fractures of C5 and C6, with subluxation of C6 on C7.

To better characterize the extent of the neck injuries, an MRI examination of the cervical spine was scheduled, and the neuroanesthesiology service consulted for patient management during the scan. As part of routine patient screening, the radiology department queried whether the patient had any ferromagnetic devices that would preclude exposure to a magnetic field. This initial screen was negative, and the patient was brought to the MRI suite. Before scanning, the ICP monitor was noted, and imaging was deferred until MR compatibility of the indwelling monitor could be determined. Neither the Mayo Clinic MRI database nor the catheter product insert had information pertaining to its MRI compatibility. Additionally, a search of the current MR safety literature was devoid of compatibility information for this monitor. Lastly, we contacted the manufacturer *via* telephone and were informed that MRI compatibility testing had not been performed on this device.

Because we were unable to determine the safety of this device in a 1.5 Tesla magnetic field, the fiberoptic catheter was electively removed by the neurosurgical service. As part of the ferromagnetic screening process, the fiberoptic catheter was then exposed and strongly attracted to a hand-held ring magnet. Based on this observation, the catheter was not replaced, and the MR examination proceeded without incident. Subsequently, the ICP monitor was sent to our Magnetic Resonance Imaging Research Laboratory for further compatibility testing.

Testing was done using a two-stage process. The first stage was a simple screen for ferromagnetism using a hand-held ring magnet, as had been done previously (fig. 1). Any perceptible deflection was considered positive for ferromagnetic properties. The second stage of testing involved calculating a deflective force at the bore of the imager magnet. This was achieved by suspending the biomedical implant from a fine silk string and exposing it to the 1.5 Tesla magnetic field of the MR imager (GE Medical Systems, Milwaukee, WI). Assuming the mass of the string is zero, the force acting on the object can be calculated using the following standardized[3,4] formula:

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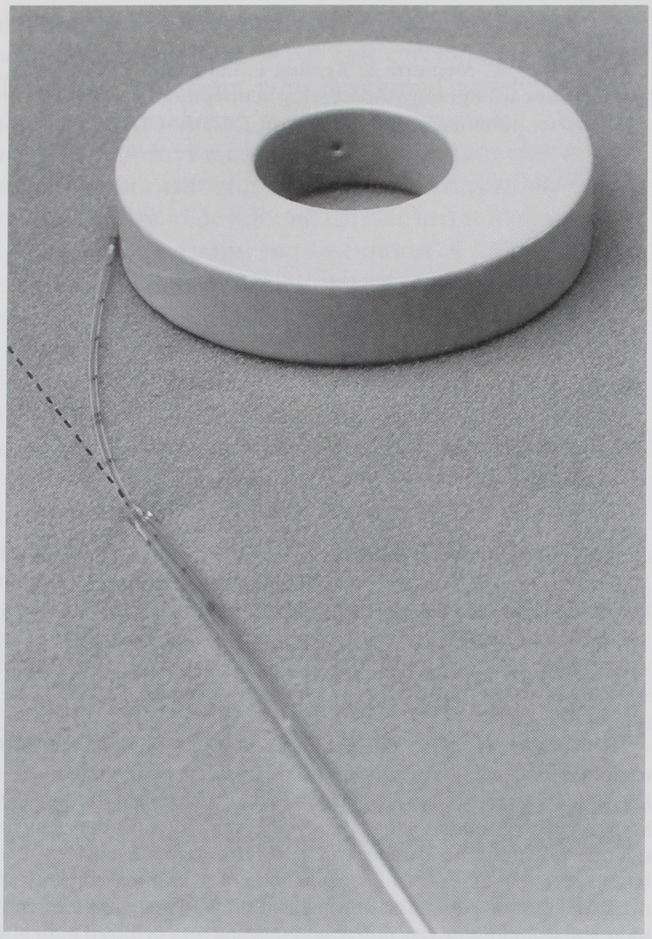

Fig. 1. *Ex vivo* ferromagnetic screening of a fiberoptic intracranial pressure monitor. *Dashed line* represents the location of the fiberoptic monitor before *ex vivo* testing. When exposed to a standard 0.15 Tesla cardiac pacemaker magnet, the catheter tip was observed to be attracted to the hand-held magnet (*i.e.*, yielded a positive ferromagnetic screen).

$$F = m \cdot g \cdot \tan\theta$$

where F = deflective force, m = mass of the object in kg, g = gravitational acceleration (*i.e.*, 9.8 m/s^2), $\tan\theta$ = tangent, and θ = the deflection angle from vertical.[3,4] The SI unit of deflection force is the Newton (N); 1.0 N is approximately equal to 0.2 pound (lb). To determine which component was responsible for deflection, the catheter was disassembled, and the screening process was repeated. The 3.5 mm x 1.0 mm (length x diameter) distal metallic tip was the only component noted to possess ferromagnetic properties warranting formal deflection force testing. Its deflection force was 1.6×10^{-3} N at the bore of the 1.5 Tesla magnet.

Discussion

It is well known that the presence of ferromagnetic biomedical implants or devices are regarded as contradictions for MRI.[4-6] This is due to the potential risk of patient injury resulting from movement, dislodgment, or malfunction of the biomedical device.[1-7] The extent of injury is influenced by the strength of the static magnetic field, the degree of ferromagnetism of the object, the object's geometry and orientation, the location of the object *in situ*, and the length of time the object has been indwelling (the presence of fibrosis or granulation tissue can serve to stabilize the object).[4-6]

Although there is no current standard,[7] ferromagnetic screening is typically performed using any bar, horseshoe, or ring magnet having a field strength of $\geq$ 0.1 Tesla. Because the force exerted on a ferromagnetic object is inversely proportional to the fourth power of its distance from the magnet, it would follow that placing the object in question immediately adjacent to the magnet would yield the best *ex vivo* screening results. In our case, we elected to use a standard cardiac pacemaker ring magnet (0.15 Tesla) simply based on immediate availability in most, if not all, hospitals. The magnetic field strength of a hand-held magnet is small (*i.e.*, in our case, one tenth that of the MR imager), yet deflection of the device in this low magnetic field is a clear sign of ferromagnetic properties (*i.e.*, a positive screen) and should preclude entry into the MRI suite.

In contrast, a negative screen typically indicates that the object is devoid of ferromagnetic properties. However, deflection force testing (as outlined previously) is required before an object can be assured to be safe. The deflection force provides a quantitative measure of potential for movement of ferromagnetic objects when exposed to a strong magnetic field. Although there is no "gold standard" threshold above which a deflective force is known to be injurious to the human brain, we believe it is sufficient to say that the magnitude of deflective force exhibited by this particular fiberoptic catheter tip could have resulted in brain injury.[3,5,6]

It is important to note that ferromagnetic screening does not evaluate the potential for RF-related patient injury. That is, nonferromagnetic metals (*e.g.*, aluminum or copper), which would yield a negative hand-held magnet screen, can absorb RF energy (similar to an antenna) resulting in MR image artifact or thermal injury to the patient.[1-6] However, to keep this in perspective, the principal danger of MRI in patients having metallic implants is typically associ-

ated with movement, dislodgment, or malfunction of the biomedical device.[4-6]

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Lactic Acidosis as a Serious Perioperative Complication of Antidiabetic Biguanide Medication with Metformin

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BIGUANIDES have been established in the therapy of non-insulin-dependent diabetes mellitus for decades. However, after the introduction of sulfonylureas, biguanides were nearly eliminated from the market, largely because of the risk of severe lactic acidosis.[1-4] In the Unites States, use of biguanides was stopped in 1976 for this reason.[3] In 1995, the biguanide metformin was approved for the US market.[2,5] The advantage is that biguanides reduce hyperglycemia with only a very low risk for hypoglycemia.[2,6] In addition, they have a positive effect on blood lipid concentration and lead to a mild weight reduction in obese patients.[5,7] Again, however, the most important risk is the development of severe lactic acidosis.[1,4]

Little information is available in the current anesthesia literature about the perioperative management of patients who receive biguanides. The following report describes the clinical course of a patient receiving metformin therapy who developed severe lactic acidosis after minor surgery.

Case Report

A 66-yr-old man was admitted for surgical repair of an abdominal wall hernia. He had a history of hypertension, non-insulin-dependent diabetes mellitus, peripheral vascular disease, obesity, and a previous pulmonary embolism. On admission, the patient was in good health. His arterial blood pressure, blood glucose, creatinine, and blood urea nitrogen levels were within normal limits. His medications were nifedipine, isosorbitmononitrate, metformin, and phenprocoumon (coumarin). After the coumarin was replaced by intravenous heparin, the patient had an uncomplicated hernia repair, which was performed with the patient during fentanyl/N_2O/isoflurane balanced anesthesia. His immediate postoperative course was uncomplicated, and he was discharged from the postanesthesia care unit to a surgical ward. The patient's regular medications, including a single dose of metformin (500 mg/day), were administered on the day before surgery but were not given on the day of surgery. From postoperative day 1 on, the regular medication was administered again. During his

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