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● *Technical Note*

VASCULAR ACCESS PORTS AND CATHETERS: EX VIVO TESTING OF FERROMAGNETISM, HEATING, AND ARTIFACTS ASSOCIATED WITH MR IMAGING

FRANK G. SHELLOCK*†‡ AND VINCENT J. SHELLOCK

*Future Diagnostics, Inc., Los Angeles, CA, USA
†American Health Services Corporation, Newport Beach, CA, USA
‡Department of Radiology, University of Southern California, School of Medicine, Los Angeles, CA, USA

The purpose of this study was to evaluate ferromagnetic qualities, heating, and artifacts associated with MR imaging of implantable vascular access ports (IVAPs, $N = 9$) and catheters ($N = 8$). Ferromagnetism was determined using previously described techniques. Heating was assessed for the IVAPs by measuring temperature immediately before and after performing a 3D GRASS, MTC pulse sequence for 60 min at an SAR of 2.8 W/kg. Artifacts were evaluated in association with the use of a fast GRASS pulse sequence and graded according to the severity of image distortion. None of the IVAPs or catheters were attracted by the magnetic field of the MR system. The largest temperature change measured was +0.3°C. Artifacts varied, depending on the component materials used for the construction of the IVAPs and catheters. The lack of ferromagnetic qualities and negligible heating indicates that MR imaging performed at 1.5 T or less may be conducted safely in patients with each of the IVAPs and catheters tested. None of the artifacts produced by the presence of the IVAPs or catheters is considered to impair the diagnostic aspects of MR imaging, especially if the device is not positioned directly in the imaging area of interest.

Keywords: **Magnetic resonance imaging (MRI); Safety.**

INTRODUCTION

The presence of certain bioimplants and devices may be hazardous for patients undergoing magnetic resonance (MR) imaging.[1–6] The primary safety concerns of performing MR imaging in patients with bioimplants and devices are related to movement and dislodgement of the objects, excessive heating of the objects, and the production of artifacts that may impair the diagnostic aspects of this imaging modality.[1–6] Therefore, ex vivo testing of biomedical implants and devices is required to determine whether or not these objects are compatible with MR procedures.[1–6]

Implantable vascular access ports (IVAPs) and specialized catheters are used for the long-term vascular administration of antibiotics, chemotherapeutic agents, and analgesics.[7] These devices may be constructed from various forms of metallic materials such as stainless steel, titanium, or tungsten as well as other materials that are nonmetallic (i.e., silicone, plastic, etc.).[3,7]

Because patients with IVAPs are likely to be evaluated by MR imaging, it is imperative that a thorough ex vivo assessment of these bioimplants be conducted to ensure the safety of the patients. Therefore, in the present study, nine IVAPs and their catheters (a type of device that may contain metal that has not been previously tested for MR compatibility) were evaluated for ferromagnetic qualities, heating, and artifacts associated with MR imaging.

MATERIALS AND METHODS

Table 1 lists the nine IVAPs and eight catheters evaluated in this study for MR compatibility. Product information pertaining to the materials used for construction of these devices was obtained from the prod-

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Address correspondence to Frank G. Shellock, Ph.D., Future Diagnostics, Inc., 6380 Wilshire Blvd, Suite 900, Los Angeles, CA 90048.

Table 1. Vascular access ports and catheters tested for ferromagnetism, heating, and artifacts associated with MR imaging

Device & company	Material(s)	Ferromagnetic	Artifact MRI	Heating
1. MRI Dual Port Bard Access Systems Salt Lake City, UT	Delrin, titanium	No	++	+0.1
2. Low profile MRI Port Bard Access Systems Salt Lake City, UT	Delrin	No	++	0
3. Low Profile MRI Port Bard Access Systems Salt Lake City, UT	titanium	No	+++	+0.2
4. CathLink LP Bard Access Systems Salt Lake City, UT	titanium	No	+++	+0.3
5. CathLink SP Bard Access Systems Salt Lake City, UT	titanium	No	+++	+0.2
6. Vital-Port Cook Pacemaker Corp. Leechburg, PA	Polysulfone, titanium	No	++	0
7. Vital-Port, Dual Cook Pacemaker Corp. Leechburg, PA	Polysulfone, titanium	No	++	0
8. Plastic Port Cardial Saint-Etienne, France	Polysulfone, titanium	No	++	0
9. Macroport Infusaid Norwood, MA	Polysulfone, titanium	No	++	0
10. 6.0 Fr. Open-ended Catheter, single lumen Bard Access Systems Salt Lake City, UT	ChronoFlex	No	++	—
11. 8.0 Fr. Groshong Catheter, single lumen Bard Access Systems Salt Lake City, UT	silicone barium sulfate tungsten	No	++	—
12. 8.0 Fr. Open-ended Catheter, single lumen Bard Access Systems Salt Lake City, UT	ChronoFlex	No	++	—
13. 9.5 Fr. Groshong Catheter, dual lumen Bard Access Systems Salt Lake City, UT	silicone barium sulfate tungsten	No	++	—
14. 10.0 Fr. Hickman Catheter, dual lumen Bard Access Systems Salt Lake City, UT	silicone barium sulfate	No	++	—
15. 3.0 Fr. Hickman Catheter, single lumen Bard Access Systems Salt Lake City, UT	silicone barium sulfate	No	++	—
16. OptiPort Catheter, single lumen Simms-Deltec St. Paul, MN	silicone	No	++	—
17. 6.6 Broviac Catheter, single lumen Bard Access Systems Salt Lake City, UT	silicone barium sulfate	No	++	—

Artifacts were characterized relative to the size of the device: 0, no artifact; +, artifact less than size of the device; ++, artifact same size as the device; +++, artifact slightly larger than size of the device; ++++, artifact larger than twice the size of the device.

uct insert and/or from the manufacturers. Eight of the IVAPs and two of the catheters had metallic components. These IVAPs and catheters were selected for ex vivo testing because they are commonly used in the United States.

Assessment of Ferromagnetism

Two different methods were used to assess ferromagnetic qualities of the IVAPs and catheters.[2,5,6] First, each device was suspended by a 30 cm length of silk suture (4.0 silk), attached at the estimated

center of mass from a specially constructed device (a plastic protractor mounted on a wooden stand), so that the angle of deflection from the vertical could be measured, as previously described.[5,6] The accuracy of this measuring apparatus is ±0.5 degrees (based on the ability to read the protractor and the actual alignment of the protractor as it was positioned in a 1.5 T MR system (Signa MR System, General Electric Co., Milwaukee, WI) with the aid of axial, coronal, and sagittal positioning lights).[5] The deflection force was determined at the position of maximum force in the 1.5 T MR system, according to Kagetsu and Litt.[7] The deflection angle for each of the devices was measured twice and averaged.

The deflection force, F (the unit of force in the centimeter-gram-second system is dyne, defined as the force necessary to give a 1 g mass acceleration of 1 cm/s^2) was calculated by the following formula: $F = mg \times \sin \theta(\text{theta})/\cos \theta(\text{theta})$, where m is the mass of the material, g the gravitational acceleration (980 cm/s^2), and θ(theta), the deflection angle from the vertical.[5,6]

Attraction to the static magnetic field was also evaluated by placing each of the IVAPs and catheters in a specific position on a glass sheet with a millimeter scale etched on the underside.[2] The glass sheet was placed on the MR system table a distance of 2 meters from the bore of the magnet. The glass was then introduced slowly into the center of the 1.5 T MR system. Observations were made to determine any displacement of the IVAPs and catheters relative to the millimeter scale. Each device was turned 90° and the procedure was repeated to encompass a 360° movement. The entire testing process was repeated three times for each IVAP and catheter.

Assessment of Heating

Heating associated with MR imaging of the IVAPs was determined by performing an experiment with the use of a three dimensional, gradient recalled echo in the steady state (GRASS), magnetization transfer contrast (MTC) pulse sequence (TR/TE, 100/7 ms; flip angle, 60°; field of view, 12 cm; NEX, 10; section thickness, 1.0 mm) that was conducted for 60 min of imaging with the IVAPs attached to a fluid-filled Plexiglas phantom. This pulse sequence uses an off-resonance RF pulse and deposited an estimated whole body averaged specific absorption rate (SAR) of 2.8 W/kg during MR imaging (note that the U.S. Food and Drug Administration recommends that exposure to RF energy during an MR procedure should not exceed a whole body averaged SAR of greater than 0.4 W/kg). The estimated whole body averaged SAR was determined based on the software information displayed by the GE Signa MR system and using a weight indication of 100 lbs. Surface temperature was measured for each IVAP immediately (within 10 s) before and after MR imaging using a noncontact infrared thermometer (Medi-Therm, Fullerton, CA).[5] This device has an accuracy and resolution of 0.1°C.

Heating was not assessed for catheters because of the relatively small mass of metal (i.e., tungsten) used for the construction of these devices and the fact that the metal was essentially insulated by the silicone component of these devices.

Assessment of Artifacts

Artifacts, defined as an alteration or distortion in the MR image due to the presence of the IVAPs or catheters, were determined by performing MR imaging of the IVAPs and catheters with each one embedded individually in a 5 lb piece of beef to approximate tissue interaction. MR imaging was performed on the IVAPs using a send/receive head coil (for improved signal-to-noise) and the following parameters: axial plane (note that the imaging plane was oriented through the largest cross-sectional area of the each IVAP); fast, multiplanar, GRASS pulse sequence; TR/TE, 100/3.6 ms; flip angle, 30°; field of view, 24 cm; number of excitations, 2; imaging matrix, 256 × 256; section thickness, 3 mm.

Because of the relatively small diameter of the catheters, a vitamin E capsule was placed adjacent to the catheter to facilitate identification of the catheter on the MR image. MR imaging was performed using a send/receive head coil and the following parameters: axial plane (note that the imaging plane was oriented through transverse area of the catheter); fast, multiplanar, GRASS pulse sequence; TR/TE, 34/6.3 ms; flip angle, 30°; field of view, 12 cm; number of excitations, 4; imaging matrix, 256 × 128; section thickness, 3 mm.

The partial flip angle, gradient echo pulse sequence was selected for assessment of imaging artifacts because it is the most likely to result in artifacts, especially whenever there is metal present in a bioimplant.[5,9] This protocol has been used in previous evaluations of artifacts associated with bioimplants.[5]

Artifacts were characterized relative to the size of the device as previously described:[5] 0, no artifact; +, artifact less than size of the device; ++, artifact same size as the device; +++, artifact slightly larger

than size of the device; ++++, artifact larger than twice the size of the device.

RESULTS

A summary of the test results for attraction to the magnetic field, heating, and artifacts associated with MR imaging of the IVAPs and catheters is displayed in Table 1. Both tests conducted to determine the ferromagnetic qualities of the of the IVAPs and catheters indicated that the metals used in the construction of these devices displayed no apparent attraction to the 1.5 T static magnetic field of the MR system.

For the assessment of heating, the temperature changes ranged from no change (0°C) to +0.3°C after the 60-min exposure to the three-dimensional, GRASS, MTC pulse sequence. The evaluation of artifacts indicated that each IVAP and catheter displayed some degree of distortion of the MR image depending on the component materials used for the construction of the device.

DISCUSSION

The IVAPs and catheters did not exhibit attraction to the magnetic field of the 1.5 Tesla MR system. Therefore, there are no safety concerns associated with the movement or dislodgement of the IVAPs or catheters tested in this study. In regards to the interaction with the magnetic field, patients who have these devices may safely undergo MR procedures using MR systems with static magnetic field strengths of 1.5 T or less.

The relatively minor temperature increase (i.e., +0.3°C) associated with MR imaging of the IVAPs is not considered to be a potential hazard for patients. The variability in the amount of heating that occurred during MR imaging of the IVAPs is likely associated witht the shape of the device, the amount of metal present, and the position of the metal in relation to the construction of the device.[1,3]

Every IVAP and catheter studied in this investigation produced an artifact. The relative severity of the artifact was dependent on the type and shape of the material(s) used for the construction of the device. The IVAPs and catheters that produced the largest artifacts were constructed from metallic materials, while the ones that produced the smallest artifacts were composed from nonmetals.

A surprising finding was that, even the IVAPs indicated as "MRI ports" that made entirely from nonmetallic materials were, in fact, seen on MR images in this study because they contain silicone. Silicone is used for the construction of the septum portion of most IVAPs and, in some cases, other portions of IVAPs. Using MR imaging, the MR signal associated with fat is similar to that of silicone.[10] Therefore, silicone used in the construction of IVAPs may be observed on MR images with varying degrees of signal intensity depending on the pulse sequence selected for the procedure.

If a radiologist is not aware that an IVAP is present in a patient undergoing MR imaging, the MR signal produced by the silicone component of the device could be considered an abnormality, or at the very least, present a confusing image. For example, this may present a diagnostic problem in a patient being evaluated for a rupture of a silicone breast implant because silicone from the IVAP may be misread as an "extracapsular silicone implant rupture."

In more general terms, it is improbable that an artifact produced by the presence of any of the IVADs or catheters tested will detract from the diagnostic capabilities of MR imaging because the extent of the artifact is relatively minor and, as such, is unlikely to obscure any important anatomical structures by their presence. Of note is that, MR imaging examinations of the chest, where most IVAPs are typically implanted in a subcutaneous pocket,[7] account for less than 5% of diagnostic studies performed using this imaging modality.

REFERENCES

1. Shellock, F.G.; Kanal, E. Magnetic Resonance: Bioeffects, Safety, and Patient Management. New York: Raven Press; 1994.
2. Shellock, F.G.; Schatz, C.J. Metallic otologic implants: In vitro assessment of ferromagnetism at 1.5 T. AJNR 12:279–281; 1991.
3. Shellock, F.G. Pocket Guide to MR Procedures and Metallic Objects. New York: Lippincott-Raven Press; 1996.
4. Buchli Boesiger, P.; Meier, D. Heating effects of metallic implants by MRI examinations. Magn. Reson. Med. 7:255–261; 1988.
5. Shellock, F.G.; Morisoli, S.M. Ex vivo evaluation of ferromagnetism, heating, and artifacts for heart valve prostheses exposed to a 1.5 Tesla MR system. J. Magn. Reson. Imaging 4:756–758; 1994.
6. New, P.F.J.; Rosen, B.R.; Brady, T.J.; et al. Potential hazards and artifacts of ferromagnetic and nonferromagnetic surgical and dental materials and devices in nuclear magnetic resonance imaging. Radiology 147:139–148; 1983.
7. Denny, D.F. Placement and management of long-term

central venous access catheters and ports. AJR 161:385–393; 1993.
8. Kagetsu, N.J.; Litt, A.W. Important considerations in measurement of attraction force on metallic implants in MR imagers. Radiology 179:505–508; 1991.
9. Bellon, E.M.; Haacke, E.M.; Coleman, P.E.; Sacco, D.C.; Steiger, D.A.; Gangarosa, R.E. MR artifacts: A review. AJR 147:1271–1281; 1986.
10. Gorczyca, D.P.; Sinha, S.; Ahn, C.Y.; DeBruhl, N.D.; Hayes, M.K.; Gausche, V.R.; Shaw, W.W.; Bassett, L.W. Silicone breast implants in vivo: MR imaging. Radiology 1992;185:407–410.