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CASE REPORT

Acute vertigo in an anesthesia provider during exposure to a 3T MRI scanner

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Abstract: Vertigo induced by exposure to the magnetic field of a magnetic resonance imaging (MRI) scanner is a well-known phenomenon within the radiology community but is not widely appreciated by other clinical specialists. Here, we describe a case of an anesthetist experiencing acute vertigo while providing sedation to a patient undergoing a 3 Tesla MRI scan. After discussing previous reports, and the evidence surrounding MRI-induced vertigo, we review potential etiologies that include the effects of both static and time-varying magnetic fields on the vestibular apparatus. We conclude our review by discussing the occupational standards that exist for MRI exposure and methods to minimize the risks of MRI-induced vertigo for clinicians working in the MRI environment.

Keywords: occupational medicine, MRI worker safety, vestibular dysfunction, magnetic field, 3T MRI scanner

Introduction

Anesthesia providers routinely care for patients undergoing magnetic resonance imaging (MRI), and the implications for patient care are well known. However, there is scant literature on the occupational hazards of MRI for health care workers. It is well known in the radiology community that exposure to a magnetic field of sufficient strength from an MRI scanner can cause vertigo, though the practical considerations for health care workers involved in direct patient care are not well established.[1] In the 3 months following introduction of a 3T MRI scanner (replacing a 1.5T scanner) at our institution, there were three incidents of vertigo reported by our anesthesia providers, unseen during years of standard MRI anesthesia practice. Herein, we describe one such case of an anesthetist experiencing acute vertigo while caring for a patient undergoing a scan in a 3T MRI machine. We then discuss the incidence, mechanism, risk factors, and practical implications of this phenomenon.

Case report

A 52-year-old male nurse anesthetist with no significant past medical history was caring for a patient undergoing an MRI in a 3T scanner (MAGNETOM Skyra; Siemens Healthcare, Erlangen, Germany) under sedation with a propofol infusion. On two occasions, he had to approach and lean toward the MRI bore to assess the patient's airway patency. During these events, the anesthetist experienced acute onset of a sensation that the room was spinning. He did not have lightheadedness or feel that he was going to pass out. There was no chest pain, shortness of breath, or palpitation. There was no headache, ocular complaint, tinnitus, or other subjective neurologic deficit. He did

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not lose his balance or become nauseated though the vertigo was so intense that he felt he needed to sit down. The sensation lasted for 15–20 seconds and resolved when he stopped moving and sat down in a chair. He was relieved by another anesthetist and was evaluated in occupational medicine.

The anesthetist had no history of vertigo, inner or middle ear dysfunction, or recent respiratory infection. He had no risk factors for stroke. He was not on medications. His physical examination was unremarkable, with a normal neurologic examination and no nystagmus. The vertigo was attributed to exposure to the MRI, and no further evaluation or treatment was required. The anesthetist felt that the intensity of the vertigo was such that it impaired his ability to provide safe care and he requested that he not be assigned to the MRI in the future. Consent was obtained from the anesthetist to describe the scenario for publication.

Discussion

Multiple authors have reported transient sensory effects, including vertigo, nausea, dizziness, metallic taste, and visual phosphenes, in subjects exposed to static magnetic fields.[1] Despite being a well-known phenomenon, there are only limited data about the incidence and contributing factors of MRI-induced vertigo. In a survey of workers in an MRI scanners manufacturing department, 22% reported experiencing vertigo while at work.[2] Wilen and de Vocht[3] published the results of a questionnaire, about health complaints, given to nurses working with MRI scanners. In that study, 47% of the nurses surveyed reported at least one health complaint, but only 15% attributed the symptoms to MRI exposure. Seven percent reported vertigo or dizziness specifically, 12% reported an illusion of movement, and 14% reported a ringing sensation in the head. In a recent observational study of 361 clinical and research employees working in MRI facilities, 5.6% of study subjects exposed to a static magnetic field reported vertigo.[4]

The vestibular system in the inner ear is the peripheral organ that is primarily responsible for the sensation of balance as well as movement in one's environment. It is composed of the six (three on each side) semicircular canals that detect angular acceleration, in addition to the connected structures known as the utricle and the saccule that detect linear acceleration (Figure 1). These structures are filled with fluid known as endolymph that moves or flows when the head moves in space. This fluid movement causes deflections of tiny stereocilia attached to specialized neural structures within the vestibular apparatus, known as hair cells, which respond to these movements by firing neural impulses to the brain that in turn are ultimately interpreted as the perception of movement (Figure 2). As a result, the vestibular system can become activated through hydrodynamic pressure changes in the endolymph, direct deflection of stereocilia, or neurostimulation via electrical currents. However, the precise mechanism through which magnetic vestibular stimulation occurs is unclear, with some proposed mechanisms including electromagnetic induction (ie, voltage induced by a changing magnetic field) and magnetic susceptibility differences between vestibular organs and surrounding fluid.[5] In 2011, Roberts et al[6] published compelling evidence that the static magnetic field produced by the MRI scanner is the primary cause of vertigo caused by interaction with the vestibular system in the inner ear. The authors contend that the magnetic field induces an electrical perturbation in the potassium-rich endolymph within the semicircular canals, which stimulates the hair cells in the vestibular system, thereby causing an abnormal sensation of movement. This work was later refined by providing more-detailed calculations of the Lorentz forces and resulting pressures within the vestibular system in strong static magnetic fields (Figure 3).[7] More recently, stationary exposures to a static 7T MRI field were found to be associated with the presence of vertigo and nystagmus, and the reversal of symptoms following withdrawal from the field was taken as evidence for adaptation to continuous vestibular input caused by the static magnetic field.[8] A separate body of work further confirms that these effects should be more pronounced with stronger magnetic fields that are encountered with higher-field-strength MRI scanners and in closer proximity to the epicenter of the MRI scanner bore (ie, on the patient undergoing the MRI). De Vocht et al[2] reported an increase in the incidence of symptoms with higher-strength magnets (1.0T and higher) and increased exposure time (>20 minutes). Wilen and de Vocht[3] reported that the majority of symptoms in the study subjects were observed after exposure to higher-strength magnets (1.5T and 3.0T).[3] There is evidence that the measured velocity of nystagmus in MRI-exposed volunteers increases in proportion to the strength of the magnetic field,[9] and Schaap et al[4] have found a positive correlation between scanner strength and reported symptoms in health care and research workers using 1.5T, 3T, and 7T systems. Given that the fringe magnetic field declines exponentially with distance from the MRI scanner, the anesthetist in the current case would have experienced the largest static magnetic field when peering into the end of the bore to evaluate the sedated patient, which corresponded to symptom onset (Figure 4). Although variable depending on the exact position of the anesthetist's head relative to the

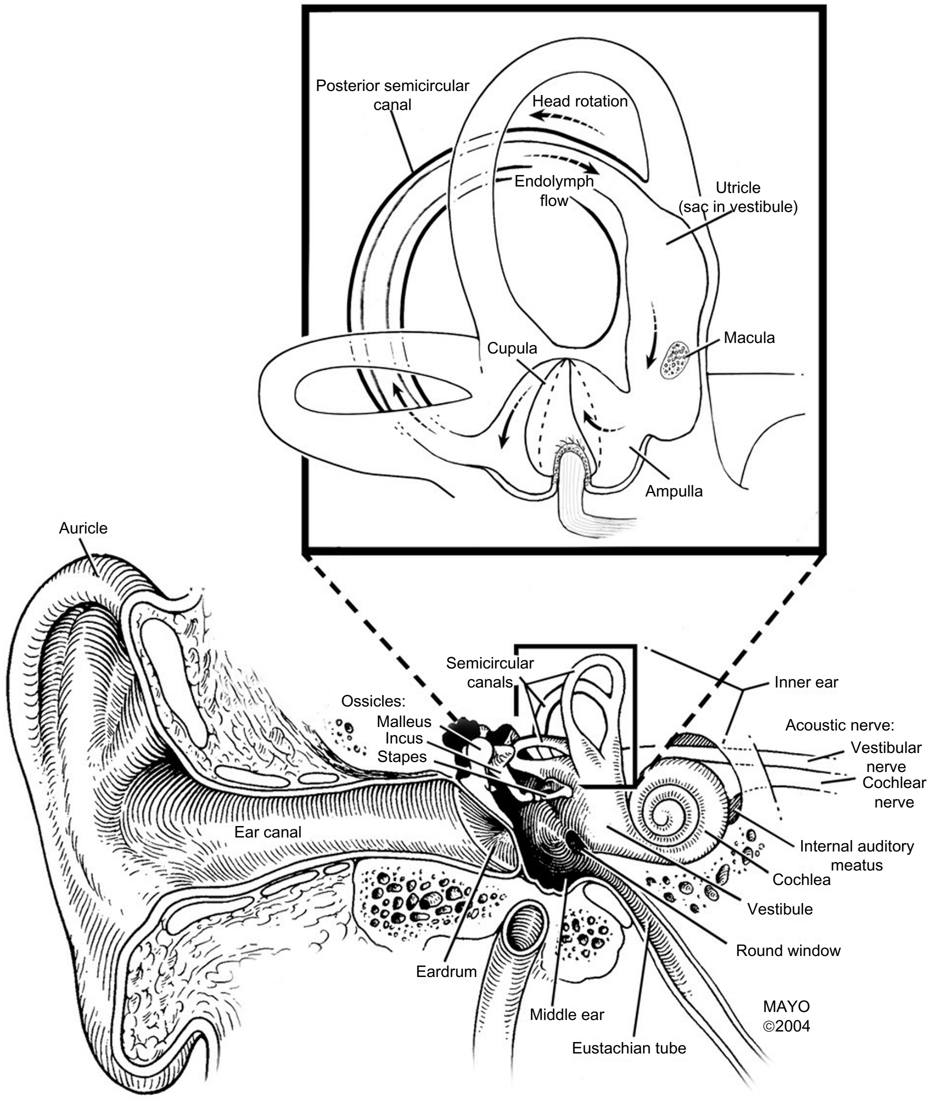

Figure 1 The vestibular system.

Notes: Used with permission of Mayo Foundation for Medical Education and Research. All rights reserved. The vestibular system is composed of the three semicircular canals, the utricle, and the saccule (not labeled but adjacent to the utricle), which are filled with endolymph fluid. Hair cells located in the cupula have stereocilia that detect endolymph flow in response to angular or linear acceleration.

magnetic flux isolines of the 3T scanner, it is likely that the anesthetist's head was experiencing a magnetic field on the order of 2T.

Although the static magnetic field appears to play the strongest role in magnetic vestibular stimulation, the induction of electrical current within a time-varying magnetic field may still be contributory. This routinely occurs as patients are repeatedly exposed to switching gradient fields during MRI. However, these are much smaller in magnitude than the static magnetic field, so the net changes in the fringe magnetic field felt by anesthesia staff outside of the bore are rather small. The second form of time-varying magnetic field occurs when moving through a magnetic field, such as when the patient is advanced into and out of the MRI scanner bore. This becomes applicable to health care workers as they move through the magnetic field in the MRI scanner room, which includes both linear (walking) and angular (head rotation) movement. Laakso et al[10] modeled head movement in the vicinity of a 3T MRI scanner and found that induced eddy currents are within the same order of magnitude as currents used to electrically stimulate the vestibular apparatus. Furthermore, faster motion through the magnetic field will produce stronger electrical currents and thus, in theory, more frequent or intense vertigo. In fact, De Vocht et al[11] reported a much higher incidence of vertigo in subjects who were defined as "fast movers" as opposed to slower-moving subjects.

In addition, head position in relation to the MRI bore is an important factor, mainly because the strength of the static

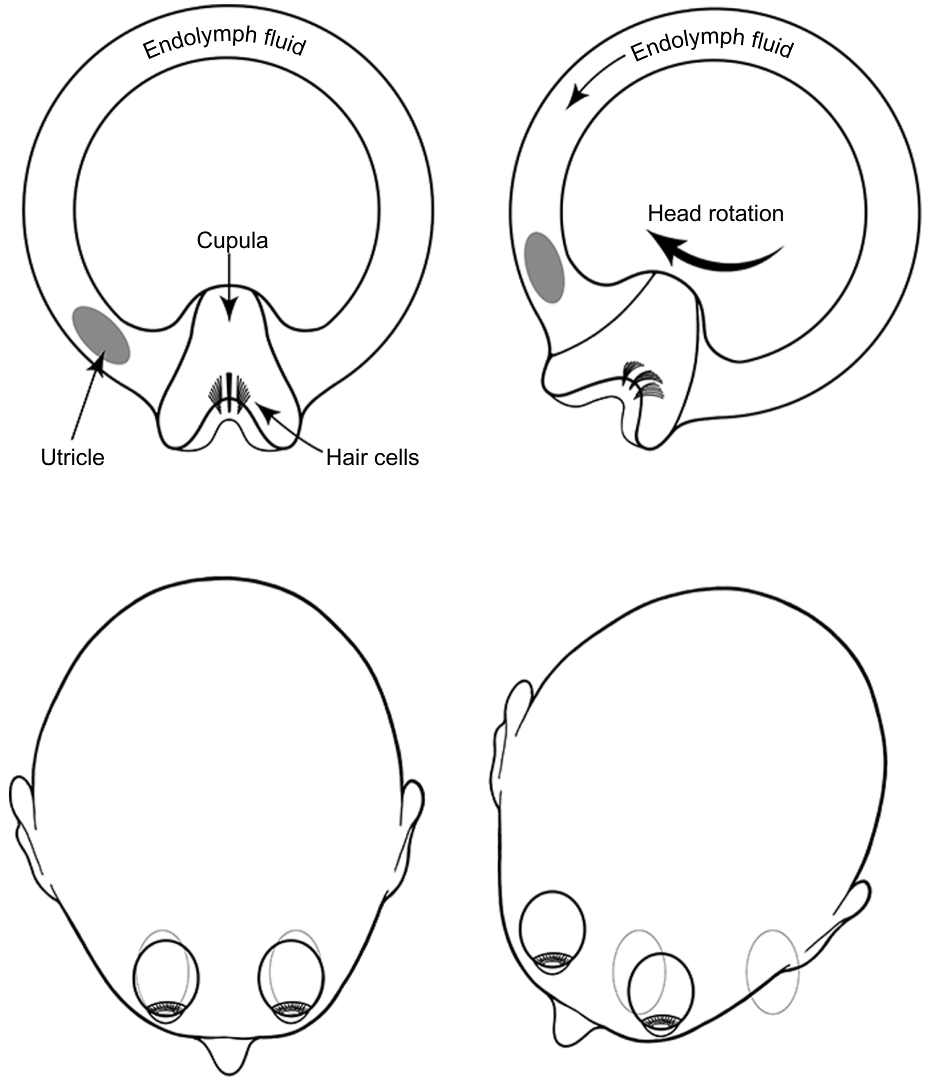

Figure 2 Motion detection in the vestibular system.
Notes: Adapted from Current Biology; 21(19); Straumann D, Bockisch C; Neurophysiology: vertigo in MRI machines; R806–R807; Copyright © 2011, with permission from Elsevier.[9] As the head moves in space, the endolymph flows in an opposite direction within the semicircular canal. This flow creates hydrodynamic pressure, which is detected by hair cells in the cupula.

magnetic field is stronger within the MRI bore. Furthermore, if a person's head is within the bore, he or she may be exposed to the gradient and radiofrequency magnetic fields that are usually confined to the patient, and this may in theory increase the likelihood of vertigo.[12] It is unknown whether there are any subject-specific factors, such as age, gender, body weight, or other medical conditions (in particular preexisting vertigo disorders), that predispose a person to experiencing vertigo when exposed to an MRI scanner.

Currently, there are no known long-term sequelae from MRI-induced vertigo or, for that matter, from MRI exposure in general. Clinical experience suggests that the symptoms of vertigo are mild and transient, disappearing when exposure to the magnetic field ceases. Preliminary data also suggest that low-dose diphenhydramine may help lessen symptoms,[13] which may be useful for awake and symptomatic patients undergoing MRI but is not practical for workers because of the drug's sedating effects. Interestingly, there is substantial evidence that exposure to MRI can adversely affect measurable neurobehavioral functions such as hand–eye coordination, presumably via its effects on the vestibular system and the vestibular–ocular reflex. In two studies of healthy volunteers, De Vocht et al[14] report a decrease in performance of hand–eye coordination and visual tracking tasks when subjects move their heads within a static magnetic field of 1.5–3.0T. There is some theoretical concern that higher-strength magnets, in particular, could pose some safety and performance issues for health care providers by

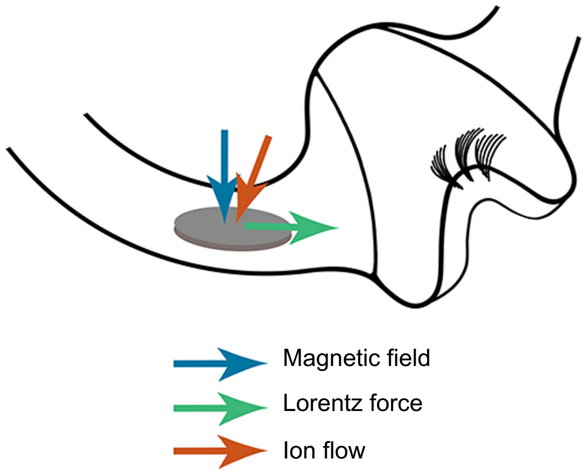

Figure 3 The Lorentz force.

Notes: Adapted from Current Biology; 21(19); Straumann D, Bockisch C; Neurophysiology: vertigo in MRI machines; R806–R807; Copyright © 2011, with permission from Elsevier.[9] The Lorentz force arises in response to current flow that is induced by the magnetic field. Depending on the orientation of the subject's head, the Lorentz force can cause deflection of the hair cells in the cupula, which can cause a sense of movement, when in fact the subject is stationary. This is experienced as vertigo (illustration adapted from Straumann and Bockisch,[9] with permission of the author and publisher).

causing disequilibrium, poor hand–eye coordination, nausea, or falls.[1]

Regulations regarding occupational exposure to high-field-strength MRI scanners have been deficient in some countries and misleading in others. The European Union issued the Physical Agents (EMF) Directive in 2004, which was primarily intended to limit the exposure of electrical power and telecommunications workers to electromagnetic fields, or EMFs as they are known. However, this legislation had the unintended consequence of potentially constraining the clinical use of MRI, particularly at 3T field strengths, which have become part of standard-of-care imaging.[15]

Figure 4 An anesthesia provider leans into the MRI bore while attending to a patient, exposing him to a much stronger magnetic field and increasing his risk of vertigo (photo by Peter Pallagi).

According to the guidelines on the limits of exposure to static magnetic fields, published in 2009 by the International Commission on Non-Ionizing Radiation Protection (ICNIRP), head and neck exposure to static magnetic fields should not exceed 2T due in large part to concerns about symptoms of vertigo and nausea.[1] The most recent ICNIRP guidelines published in 2014 further distinguish between controlled and uncontrolled exposures.[16] In general, health care workers operating in the vicinity of an MRI scanner would be considered to be in a controlled environment because they have training on the biologic effects of high-field-strength MRI and they typically can control their movements when exposed to the magnetic field. As such, the workers can decrease the likelihood of experiencing vertigo by maximizing the distance between themselves and the MRI scanner (to reduce the effect of the static magnetic field) and limiting their motion to maintain the magnetic flux density below 2T for any 3-second period (ie, to decrease the potential for motion-induced electrical currents). In Directive 2013/35/EU, the European Union established new standards for exposure to static and time-varying magnetic fields but largely exempted the use of MRI equipment in the health sector. This begs the question of what are the occupational exposure limits for health care workers in the US? The simple answer is that there are no standard limits. Anesthesiologists are exposed to MRI more than most other clinicians, but the major anesthesiology organizations have not declared an official stance on MRI exposure. The American Society of Anesthesiologists' Practice Advisory on Anesthetic Care for Magnetic Resonance Imaging, published in 2009, does not address vertigo or other potential health effects of MRI exposure.[17] In fact, occupational exposure is not addressed at all in those guidelines. In a letter to the editor of *Anesthesiology* in 2010, Bryan et al[18] expressed concerns about the lack of both adequate tracking and standard exposure limits to electromagnetic fields among health care personnel. Clearly, as scanners become stronger, anesthesia providers and other health care personnel may be exposed to much stronger magnetic fields. In the absence of clear guidelines for exposure limits and safe practices, we suggest that local institutions educate anesthesia providers about the risks of vertigo induced by MRI exposure and formulate standard practices to prevent and manage those symptoms. Recent data from Schaap et al[19] confirm that workers with the same job demonstrate significant variability in exposure levels to both static magnetic fields and motion-induced time-varying magnetic fields. This inconsistency suggests that education and behavioral modification have the potential to reduce exposure and potentially decrease the incidence and severity of vertiginous symptoms. In our institution, we have instituted a number of practice and safety recommendations. Obviously, limiting exposure altogether is the ideal practice, so if it is feasible, the anesthesia provider should simply remain outside of the MRI room and remain inside the MRI room for as little time as possible. In cases where the anesthesia provider must be close for monitoring or needs to actively attend to a patient, the practitioner should be advised to avoid rapid head movements and to avoid leaning directly into the scanner bore. Furthermore, if the symptoms become too intense or begin to interfere with safe work practice, the anesthetist should notify the MRI technician and call for immediate assistance. Finally, our anesthetists have been encouraged to obtain an evaluation by occupational medicine and can opt out of practicing in the MRI environment if health concerns are significant. Since the initiation of an educational program and these practice recommendations, we have had no problems with vertigo among our anesthesia providers.

Disclosure

The authors report no conflicts of interest in this work.

References

1. International Commission on Non-ionizing Radiation Protection. Guidelines on limits of exposure to static magnetic fields. *Health Phys*. 2009;96(4):504–514.
2. De Vocht F, Stevens T, van Wendel-de-Joode B, Engels H, Kromhout H. Acute neurobehavioral effects of exposure to static magnetic fields: analysis of exposure-response relations. *J Magn Reson Imaging*. 2006;23:291–297.
3. Wilen J, de Vocht F. Health complaints among nurses working near MRI scanners – A descriptive pilot study. *Eur J Radiol*. 2011;80:510–513.
4. Schaap K, Christopher-de Vries Y, Mason C, de Vocht F, Portengen L, Kromhout H. Occupational exposure of healthcare and research staff to static magnetic stray fields from 1.5–7 Tesla MRI scanners is associated with reporting of transient symptoms. *Occup Environ Med*. 2014;71:423–429.
5. Glover PM, Cavin I, Bowtell R, Gowland PA. Magnetic-field-induced vertigo: a theoretical and experimental investigation. *Bioelectromagnetics*. 2007;28:349–361.
6. Roberts D, Marcelli V, Gillen J, Carey J, Santina C, Zee D. MRI magnetic field stimulates rotational sensors of the brain. *Curr Biol*. 2011;21:1635–1640.
7. Antunes A, Glover PM, Li Y, Mian OS, Day BL. Magnetic field effects on the vestibular system: calculation of the pressure on the cupula due to ionic current-induced Lorentz force. *Phys Med Biol*. 2012;57:4477–4487.
8. Mian O, Li Y, Antunes A, Glover P, Day B. On the vertigo due to static magnetic fields. *PLoS One*. 2014;8(10):e78748.
9. Straumann D, Bockisch C. Neurophysiology: vertigo in MRI machines. *Curr Biol*. 2011;21(19):R806–R807.
10. Laakso I, Kännälä S, Jokela K. Computational dosimetry of induced electric fields during realistic movements in the vicinity of a 3T MRI Scanner. *Phys Med Biol*. 2014;58:2625–2640.
11. De Vocht F, van Drooge H, Engels H, Kromhout H. Exposure, health complaints and cognitive performance among employees of an MRI scanners manufacturing department. *J Magn Reson Imaging*. 2006;23:197–204.
12. Wang H, Trakic A, Liu F, Crozier S. Numerical field evaluation of healthcare workers when bending towards high-field MRI magnets. *Magn Reson Med*. 2008;59:410–422.
13. Thormann M, Amthauer H, Adolf D, Wollrab A, Rcike J, Speck O. Efficacy of diphenhydramine in the prevention of vertigo and nausea at 7T MRI. *Eur J Radiol*. 2013;82:768–772.
14. De Vocht F, van-Wendel-de-Joode B, Engels H, Kromhout H. Neurobehavioral effects among subjects exposed to high static and gradient magnetic fields from a 1.5T magnetic resonance imaging system – A case-crossover pilot study. *Mag Reson Med*. 2003;50:670–674.
15. Abbot A. MRI set to win reprieve from EU ban. *Nature*. 2010;465:854–855.
16. ICNIRP. ICNIRP guidelines for limiting exposure to electric fields induced by movement of the human body in a static magnetic field and by time-varying magnetic fields below 1 Hz. *Health Phys*. 2014;106(3):418–425.
17. The American Society of Anesthesiologists. Practice advisory on anesthetic care for magnetic resonance imaging. *Anesthesiology*. 2009;110:459–479.
18. Bryan Y, Hoke L, Templeton L, Taghon T. Exposure limits to magnetic resonance imaging fields: invisible land mines or fields to mine (letter). *Anesthesiology*. 2010;112(3):763–764.
19. Schaap K, Christopher-De Vries Y, Crozier S, De Vocht F, Kromhout H. Exposure to static and time-varying magnetic fields from working in the static magnetic stray fields of MRI scanners: a comprehensive survey in the Netherlands. *Ann Occ Hyg*. 2014;58(9):1094–1110.