International Journal of Research in Medical Sciences
Kaur A et al. Int J Res Med Sci. 2017 Mar;5(3):759-763
www.msjonline.org
pISSN 2320-6071 | eISSN 2320-6012

DOI: http://dx.doi.org/10.18203/2320-6012.ijrms20170620

Review Article

MRI: an update and review on bio-effects and safety considerations

Amarinder Kaur[1], Naureen Dhillon[1], Simarpreet Singh[2], Ramandeep Singh Gambhir[3]*

[1]Department of Oral Medicine and Radiology, Gian Sagar Dental College and Hospital, Rajpura, Punjab, India
[2]Department of Public Health Dentistry, Surendera Dental College and Research Institute, Sri Ganganagar, Rajasthan, India
[3]Department of Public Health Dentistry, Rayat and Bahra Dental College and Hospital, Mohali, Punjab, India

Received: 27 December 2016
Revised: 30 December 2016
Accepted: 04 February 2017

***Correspondence:**
Dr. Ramandeep Singh Gambhir,
E-mail: raman2g@yahoo.com

ABSTRACT

Diagnostic imaging technologies such as magnetic resonance (MR) are vital to catching signs of disease early and high quality diagnosis for treatment planning. However, some patients are unable to take advantage of its life saving capabilities. The procedures can be claustrophobic and the contraindications of MRI in patients having implants, pacemakers and also the risks associated with the use of cryogens, contrast agents etc. So this article provides an update on review on the bio effects and safety considerations for both patient and health practitioner with respect to the use of clinical MRI.

Keywords: Diagnosis, Detection, Magnetic resonance, Treatment

INTRODUCTION

Magnetic resonance imaging (MRI) is primarily a medical imaging technique most commonly used in Radiology to visualize the structure and function of the body. Since its introduction as a clinical tool in the early 1980's the progress of magnetic resonance imaging (MRI) has been phenomenal.[1,2] As it provides much greater contrast between the different soft tissues of the body making it especially useful in neurological, musculoskeletal, cardiovascular, and oncological imaging.

It uses a powerful magnetic field to align the nuclear magnetization of (usually) hydrogen atoms in water in the body. Radio-frequency fields are used to systematically alter the alignment of this magnetization, causing the hydrogen nuclei to produce a rotating magnetic field detectable by the scanner.[3] This signal can be manipulated by additional magnetic fields to build up enough information to reconstruct an image of the body. The degree of blackness, whiteness or tone of gray depends on the composition of the anatomical structures being imaged but in MRI the same object can appear black (dark or hypotense) on one MR image and white (bright or hypertense) on another. MRI is a pre-eminent soft tissue diagnostic modality. The chief strengths of MRI are its ability to provide cross-sectional images of anatomical regions in any plane and its excellent soft tissue contrast and also there are relatively lack of side-effects and high patient acceptability.[3] Although there are no known Biohazard associated with MRI but since during the performance of MRI, the patient is exposed to three different forms of electromagnetic radiation: a static magnetic field, gradient magnetic fields and radiofrequency(RF) electromagnetic fields, each of these may cause significant bio-effects if applied at sufficiently high exposure levels.[4,5] Also MRI is contraindicated in patients having electrically, magnetically or mechanically activated, implants such as cardiac pacemakers and

infusion pumps. Numerous investigations have been conducted to identify potentially adverse bio-effects of MRI. So here in this article we provide an overview of safety considerations for both the patient and health practitioner with respect to the use of clinical MRI.

SAFETY CONSIDERATIONS

Implants and foreign bodies

Pacemakers are generally considered an absolute contraindication towards MRI scanning. Several cases of arrhythmia or death have been reported in patients with pacemakers who have undergone MRI scanning without appropriate precautions.[6] Though pacemakers receive significant attention, it should also be noted that many other forms of medical or biostimulation implants may be contraindicated for MRI scans. These may include vagus nerve stimulators, implantable cardioverter-defibrillators, loop recorders, insulin pumps, cochlear implants, deep brain stimulators, and many others. Conventional pacemakers are no longer an absolute rather a relative contraindication towards MRI scanning. Highly specialized protocols have been developed to permit scanning of select pacing devices such as MR conditional device. The term MR conditional refers to an item that has been demonstrated to pose no known hazards in specified MR environment with specified conditions of use.[7,8] MRI scanning in patients with cardiac implantable electronic devices (CIEDs) was formerly felt to be contraindicated but an increasing number of patients have an implanted MR conditional device allowing them to safely undergo MR scanning.[9]

The advancement of MR conditional technology has led to greater options for patient management. One such development in the works is a nano-coating for implants intended to screen them from the radio frequency waves, helping to make MRI exams available to patients currently prohibited from receiving them. Ferromagnetic foreign bodies (e.g. shell fragments), or metallic implants (e.g. surgical prosthesis, aneurysm clips) are also potential risks.[10,11] Interaction of the magnetic and radio frequency fields with such objects can lead to: trauma due to movement of the object in the magnetic field, thermal injury from radio frequency induction heating of the object, or failure of an implanted device. Because of it non-ferromagnetic nature and poor electrical conductivity, titanium and its alloys are useful for long term implants and surgical instruments intended for use in image -guided surgery. In particular, not only is titanium safe from movement from the magnetic field, but artifacts around the implant are less frequent and less severe than with more ferromagnetic materials e.g. stainless steel.

Projectile or missile effect

As a result of the very high strengths of the magnetic field needed to produce scans (frequently up to 60,000 times the earth's own magnetic field effects), there are several incidental safety issues. Missile-effect accidents, where ferromagnetic objects are attracted to the center of the magnet, have resulted in injury and death.[12] In order to help reduce the risks of projectile accidents, ferrous objects and devices are typically prohibited in proximity to the MRI scanner, with non-ferromagnetic versions of many tools and devices typically retained by the scanning facility. Patients undergoing MRI examinations are required to remove all metallic objects, often by changing into a gown or scrubs. The magnetic field and the associated risk of missile effect accidents remains a permanent hazard as superconductive MRI magnets retain their magnetic field, even in the event of a power outage.

Radio frequency energy

A powerful radio transmitter is needed for excitation of proton spins. This can heat the body to the point of risk of hyperthermia in patients, particularly in obese patients or those with thermoregulation disorders. Several countries have issued restrictions on the maximum specific absorption rate that a scanner may produce.[13]

Peripheral nerve stimulation (PNS)

The rapid switching on and off of the magnetic field gradients is capable of causing nerve stimulation. The biological effects are related to the changes in the magnetic field that induces the current.[14] Volunteers report a twitching sensation when exposed to rapidly switched fields, particularly in their extremities. The reason the peripheral nerves are stimulated is that the changing field increases with distance from the center of the gradient coils (which more or less coincides with the center of the magnet). Theoretically, electrical impulse conduction in nerve tissue may be affected by exposure to static magnetic fields, some studies have reported remarkable effects on both the function and the structure of those portions of CNS associated with exposure to static magnetic fields whereas others have failed to show any significant changes.[15-18]

Acoustic noise

Rapidly switched magnetic gradients interact with the main magnetic field to cause minute expansions and contractions of the coil itself, resulting in loud noises and vibrations.[19] This is most marked with high field machines and rapid imaging techniques in which sound intensity can reach 130dB (equivalent to a jet engine at take-off). So appropriate use of ear protection is essential for anyone inside the MRI scanner room during the examination.[20,21] MRI has caused patient annoyance, interference with oral communication, and reversible hearing loss in patients who did not wear ear protection. A study of patients undergoing MRI without earplugs reported temporary hearing loss in 43% of the subjects. Furthermore, the possibility exists that significant

gradient coil-induced noise may produce permanent hearing impairment in certain patients who are particularly susceptible to the damaging effects of relatively loud noises. The safest and least expensive means of preventing problems associated with acoustic noise during clinical MRI is to encourage the routine use of disposable earplugs. The use of hearing protection has been demonstrated to successfully avoid the potential temporary hearing loss that can be associated with clinical MR examinations.[21]

Cryogens

Many MRI scanners rely on cryogenic liquids to enable superconducting capabilities of the electromagnetic coils within. Though the cryogenic liquids most frequently used are non-toxic, their physical properties present specific hazards. An emergency shut-down of a superconducting electromagnet, an operation known as 'quenching,' involves the rapid boiling of liquid helium from the device. If the rapidly expanding helium cannot be dissipated through an external vent, sometimes referred to as 'quench pipe', it may be released into the scanner room where it may cause displacement of the oxygen and present a risk of asphyxiation.[6] Liquid helium, the most commonly used cryogen in MRI, undergoes near explosive expansion as it changes from liquid to a gaseous state. Rooms built in support of superconducting MRI equipment should be equipped with pressure relief mechanisms and an exhaust fan, in addition to the required quench pipe. Since a quench results in rapid loss of all cryogens in the magnet, re-commissioning the magnet is extremely expensive and time-consuming. Every MR environment should have a written policy describing what to do in the event of a quench. Spontaneous quenches are uncommon, but may also be triggered by equipment malfunction, improper cryogen fill technique, contaminates inside the cryostat, or extreme magnetic or vibrational disturbances.[6]

Contrast agents

The most frequently used intravenous contrast agents are based on chelates of gadolinium. In general, these agents have proved safer than the iodinated contrast agents used in X-ray radiography or CT. Anaphylactoid reactions are rare occurring in approx 0.03-0.1%.[22] Of particular interest is the lower incidence of nephrotoxicity, compared with iodinated agents, when given at usual doses¬. This has made contrast enhanced MRI scanning an option for patients with renal impairment, who would otherwise not be able to undergo contrast-enhanced CT.[23] Although gadolinium agents have proved useful for patients with renal impairement, in patients with severe renal failure requiring dialysis there is a risk of a rare but serious illness, nephrogenic systemic fibrosis, that may be linked to the use of certain gadolinium-containing agents: the most frequently linked is gadodiamide, but other agents have been linked too.[24] The first case was observed in 1997 and the disease was formerly described in 2000.[25,26] Although a causal link has not been definitively established, current guidelines in the United States are that dialysis patients should only receive gadolinium agents where essential and that dialysis should be performed as soon as possible after the scan is complete, in order to remove the agent from the body promptly.[27] In Europe, where more gadolinium-containing agents are available, a classification of agents according to potential risks has been released.[28,29] Several Gadolinium based contrast agents have been introduced and more are in development .However they should be administered with the same care and attention as any other pharmaceutical product.[30]

Pregnancy

MRI avoids the use of ionizing radiation, to which the fetus is particularly sensitive. However, no harmful effects of MRI on the fetus have been demonstrated.[31] The biological effects and safety issues in pregnant patients are mainly related to the use of static magnetic field, gradient magnetic field, radio frequency magnetic field and any combination of these time varying or static electromagnetic field and magnetic resonance contrast agents. On the other hand, the pregnant health workers is exposed only to the static magnetic field unless the worker accompanies the patient into the magnetic field.[32] Although magnetic resonance imaging of the fetal brain is a safe and powerful adjunct to sonography in prenatal diagnosis.[33] According to ICNIRP, when gadolinium used in large doses as MR contrast agent resulted in post-implantation foetal loss, retarded development, increased locomotive activity and skeletal and visceral abnormalities in experimental animals. Therefore, these contrast agents are advised to be used cautiously during pregnancy.[34,35] Despite these concerns, MRI is rapidly growing in importance as a way of diagnosing and monitoring congenital defects of the fetus because it can provide more diagnostic information than ultrasound and it lacks the ionizing radiation of CT.MRI without contrast agents is the imaging mode of choice for pre-surgical, in-utero diagnosis and evaluation of fetal tumors, primarily teratomas, facilitating open fetal surgery, other fetal interventions and planning for procedures(such as the EXIT procedure) to safely deliver and treat babies whose defects would otherwise be fatal.

Claustrophobia and Discomfort

Due to the construction of some MRI scanners, they can be potentially unpleasant to lie in. Older models of closed bore MRI systems feature a fairly long tube or tunnel. The part of the body being imaged needs to lie at the centre of the magnet which is at the absolute centre of the tunnel. Because scan times an these older machines may be long (occasionally up to 40 minutes for the entire procedure), people with even mild claustrophobia are sometimes unable to tolerate an MRI scan without management.36 This may be further precipitated by the restricted space inside the MR bore , anxiety about the

scan and the possible outcome, noise and the duration of the examination.[37-39] The good news is that modern scanners have short bores- (70mm for example) and scan times are very much quicker. This means that claustrophobia is less of an issue, and many patients now find MRI an innocuous and easily tolerated procedure. Alternative scanner designs, such as open or upright systems, can also be helpful where these are available. Though open scanners have increased in popularity, they produce inferior scan quality because they operate at lower magnetic fields than closed scanners. For babies and young children chemical sedation or general anesthesia are the norm, as these subjects cannot be instructed to hold still during the scanner session.

DISCUSSION

Magnetic Resonance Imaging is one of the most versatile imaging modality. MRI has the ability to generate high resolution multiplanar (3D) images in addition to providing superior contrast resolution. Further MR can be used as a unique means to probe the biochemistry of living systems with diagnostic importance in vivo magnetic resonance spectroscopy (MRS). So far in dentistry, MRI has proved to be most valuable in the diagnosis of internal derangement of the temporomandibular joint (TMJ) due to its ability to define the cartilagenious disk. Other indications include inflammatory and neoplastic lesions of the nasopharynx, salivary glands, paranasal sinuses as well as orbits and intracranial structures. However, due to exposure to three different forms of electromagnetic radiation: a static magnetic field, gradient magnetic fields and radiofrequency electromagnetic fields, patient may suffer from significant bioeffects. In addition to bio-effects there are several other areas of health concern related to MRI in patient with implants, projectile accidents, pregnancy, use of cryogens etc. So the preservation of asafe magnetic resonance environment requires constant vigilance by MR health care professionals, particularly with regard to the management of patient's with metallic biomedical implants or devices.[35] Inspite of its present selective and restrictive uses due to its costs, MRI quality has already set it apart from other imaging modalities and it is only a matter of time before its use in dentistry is an everyday occurrence. The MR safety course about basic MR and patient related safety should be implemented so that medical students receive basic understanding of MR principles and safety considerations.[40]

Funding: No funding sources
Conflict of interest: None declared
Ethical approval: Not required

REFERENCES

1. Crooks L. Selective irradiation line scan technique for NMR imaging. IEEE Trans Nucl Sci. 1998;27:1239.
2. Edelstein WA, Hutchison JM, Johnson G, Redpath T. Spin warp NMR imaging and applications to human whole body imaging. Phys Med Biol. 1980;25:751-6.
3. Lerski RA. Physical principles of nuclear magnetic resonance imaging. Radiography. 1983;49:85-90.
4. Adzamli IK, Jolesz FA, Blau M. An assessment of blood-brain barrier integrity under MRI conditions: brain uptake of radiolabeled Gd-DTPA and In-DPTA-IgG. Nucl Med. 1989;30:839.
5. Barber BJ, Schaefer DJ, Gordon CJ, Zawieja DC, Hecker J. Thermal effects of MR imaging: worst-case studies on sheep. AJR Am J Roentgenol. 1990;155:1105-10.
6. Kanal E, Shellock FG, Talagala L. Safety considerations in MR imaging. Radiology. 1990;176:593-606.
7. Shellock FG, Woods TO, Crues JV 3rd. MR labelling information for implants and devices: explanation of terminology. Radiology. 2009;253:26-30.
8. Shinbane JS, Colletti PM, Shellock FG. Magnetic resonance imaging in patients with cardiac pacemakers: era of "MR Conditional" designs. J Cardiovasc Magn Reson. 2011;13:63.
9. Lowe MD, Plummer CJ, Manisty CH, Linker NJ. Safe use of MRI in people with Cardiac Implantable Electronic devices. Heart. 2015;101:1950-3.
10. Shellock FG. Biological effects and safety aspects of magnetic resonance imaging. Magn Reson Q. 1989;5:243-61.
11. Ahmed S, Shellock FG. Magnetic resonance imaging safety: implications for cardiovascular patients. J Cardiovasc Magn Reson. 2001;3:171-82.
12. Holscher HC, Bloem JL, Vanel D, Hermans J, Nooy MA, Taminiau AH et al. Osteosarcoma: chemotherapy-induced changes at MR imaging. Radiology. 1992;182:839-44.
13. Shellock FG, Schaefer DJ, Grundfest W, Crues JV. Thermal effects of high-field (1.5 tesla) magnetic resonance imaging of the spine. Clinical experience above a specific absorption rate of 0.4 W/kg. Acta Radiol Suppl. 1986;369:514-6.
14. Stuart Crozier, Trakic A, Wang H, Liu F. Numerical study of currents in workers induced by body-motion around high-ultrahigh field MRI magnets. J Magn Reson Imaging. 2007;26:1261-77.
15. Boecker H, Drzezga A. A perspective on the future role of brain pet imaging in exercise science. Neuroimage. 2016;131:73-80.
16. Budinger TF. Nuclear magnetic resonance (NMR) in vivo studies: known thresholds for health effects. J Comput Assist Tomogr. 1981;5:800-11.
17. Doherty JU, Whitman GJ, Robinson MD, Harken AH, Simson MB, Spear JF et al. Changes in cardiac excitability and vulnerability in NMR fields. Invest Radiol. 1985;20:129-35.
18. Gulch RW, Lutz O. Influence of strong static magnetic fields on heart muscle contraction. Phys Med Biol. 1986;31:763-9.

19. Price DL, De Wilde JP, Papadaki AM, Curran JS, Kitney RI. Investigation of acoustic noise on 15 MRI scanners from 0.2 T to 3 T. J Magn Reson Imaging. 2001;13:288-93.
20. Brummett RE, Talbot JM, Charuhas P. Potential hearing loss resulting from MR imaging. Radiology. 1988;169:539-40.
21. Shellock FG, Kanal E. Policies, guidelines, and recommendations for MR imaging safety and patient management. SMRI Safety Committee. J Magn Reson Imaging. 1991;1:97-101.
22. Mosier KM. Magnetic resonance imaging of the maxilla and mandible: signal characteristics and features in the differential diagnosis of common lesions. Top Magn Reson Imaging. 2015;24:23-37.
23. Meyers SP, Hirsch WL Jr, Curtin HD, Barnes L, Sekhar LN, Sen C. Chondrosarcomas of the skull base: MR imaging features. Radiology. 1992;184:103-8.
24. Maleux G, Demaerel P, Vanslambrouck K, Aerts P, Brijs S, Tanghe W. Chondrosarcoma of the skull base: CT, MR and pathological features. Rofo. 1996;165:599-601.
25. Shellock FG, Parker JR, Venetianer C, Pirovano G, Spinazzi A. Safety of gadobenate dimeglumine (MultiHance): Summary of findings from clinical studies and postmarketing surveillance. Invest Radiol. 2006;41:500-9.
26. Kuo PH, Kanal E, Abu-Alfa AK, Cowper SE. Gadolinium-based MR contrast agents and nephrogenic systemic fibrosis. Radiology. 2007;242:647-9.
27. Salivary gland pathology. In Neville BW: Oral and Maxillofacial pathology, 1995 WB Saunders.
28. Gingel JC, Levy BA, DePaola LG. Median palatine cyst. J Oral Maxillofac Surg. 1985;43:47-51.
29. Wysocki GP, Goldblatt LI. The so-called "globulomaxillary cyst" is extinct. Oral Surg Oral Med Oral Pathol. 1993;76:185-6.
30. Kanal E, Broome DR, Martin DR, Thomsen HS. Response to the FDA's May 23, 2007, nephrogenic systemic fibrosis update. Radiology. 2008;246:11-4.
31. Wolff S, Crooks LE, Brown P, Howard R, Painter RB. Tests for DNA and chromosomal damage induced by nuclear magnetic resonance imaging. Radiology. 1980;136:707-10.
32. De Wilde JP, Rivers AW, Price DL. A review of the current use of magnetic resonance imaging in pregnancy and safety implications for the fetus. Prog Biophys Mol Biol. 2005;87:335-53.
33. Tee LM, Kan EY, Cheung JC , Leung WC. Magnetic resonance imaging of the fetal brain. Hong Kong Med J. 2016;22:270-8.
34. International Commission on Non-Ionizing Radiation Protection. Medical magnetic resonance (MR) procedures: protection of patients. Health Phys. 2004;87:197-216.
35. Alorainy IA, Albadr FB, Abujamea AH. Attitude towards MRI safety during pregnancy. Ann Saudi Med. 2006;26:306-9.
36. Granet RB, Gelber LJ. Claustrophobia during MR imaging. N J Med. 1990;87:479-82.
37. Kanal E, Borgstede JP, Barkovich AJ, Bell C, Bradley WG, Felmlee JP et al. American College of Radiology White Paper on MR Safety. AJR Am J Roentgenol. 2002;178:1335-47.
38. Kanal E, Borgstede JP, Barkovich AJ, Bell C, Bradley WG, Etheridge S et al. American College of Radiology White Paper on MR Safety: 2004 update and revisions. AJR Am J Roentgenol. 2004;182:1111-4.
39. Van Moore A Jr. Commentary on "ACR guidance document for safe MR practices: 2007". AJR Am J Roentgenol. 2007;188:1446.
40. Shellock FG. Magnetic resonance safety update 2002: implants and devices. J Magn Reson Imaging. 2002;16:485-96.

Cite this article as: Kaur A, Dhillon N, Singh S, Gambhir RS. MRI: an update and review on bio-effects and safety considerations. Int J Res Med Sci 2017;5:759-63.