Practice Advisory on Anesthetic Care for Magnetic Resonance Imaging: An Updated Report
American Society of Anesthesiologists

Bibliography by Section

I. Education and training

MRI education for long term health hazards.

Observational studies, case reports, or comparisons without pertinent control groups

1. Kanal E, Gillen J, Evans JA, Savitz DA, Shellock FG: Survey of reproductive health among female MR workers. Radiology 1993; 187:395-399

II. Patient screening

Neonates or premature infants.

Nonrandomized comparative studies

1. Philbin MK, Taber KH, Hayman LA: Preliminary report: changes in vital signs of term newborns during MR. AJNR Am J Neuroradiol 1996; 17:1033-1036

Observational studies, case reports, or non-pertinent comparison groups

1. Battin M, Maalouf EF, Counsell S, Herligy A, Hall A, Azzopardi D, Edwards AD: Physiologic stability of preterm infants during magnetic resonance imaging. Early Hum Dev 1998; 52:101-110
2. Foran AM, Fitzpatrick JA, Allsop J, Schmitz S, Franklin J, Pamboucas C, O'Regan D, Hanjal JV, Edwards D: Three-tesla cardiac magnetic resonance imaging for preterm infants. Pediatrics 2007; 120:78-83
3. Taber KH, Hayman LA, Northrup SR, Maturi L: Vital sign changes during infant magnetic resonance examinations. J Magn Reson Imaging 1998; 8:1252-1256

Intensive or critical care patients.

Observational studies, case reports, or non-pertinent comparison groups

1. Tobin JR, Spurrier EA, Wetzel RC: Anaesthesia for critically ill children during magnetic resonance imaging. Br J Anaesth 1992; 69:482-486Butler PJ, Mujnro HM, Kenny MB: Preoxygenation in children using expired oxygraphy. Br J anaesth 1996; 77:333-334
2. Whitby EH, Paley MN, Smith MF, Sprigg A, Woodhouse N, Griffiths PD: Low field strength magnetic resonance imaging of the neonatal brain. Arch Dis Child Fetal Ed 2003; 88:F203-F208

Patients with impaired respiratory function (e.g., tonsillar hypertrophy, sleep apnea).

Observational studies, case reports, or non-pertinent comparison groups

1. Mattioli C, Gemma M, Baldoli C, Sessa M, Albertin A, Beretta L: Sedation for children with metachromatic leukodystrophy undergoing MRI. Paediatr Anaesth 2007; 17:64-69

Patients with hemodynamic instability and vasoactive infusion requirements.

Observational studies, case reports, or non-pertinent comparison groups

1. Gangarosa RE, Minnis JE, Nobbe J, Praschan D, Genberg RW: Operational safety issues in MRI. Magn Reson Imag 1987;5:287-292

Patients with impaired renal function (e.g., diabetes, elderly patients, hypertension, hepatic disease) who are administered gadolinium.

Observational studies, case reports, or non-pertinent comparison groups

1. Arsenault TM, King BF, Marsh JW Jr., Goodman JA, Weaver AL, Wood CP, Ehman RL: Systemic gadolinium toxicity in patients with renal insufficiency and renal failure: retrospective analysis of an initial experience. Mayo Clin Proc 1996; 71:1150-1154
2. Broome DR, Girguis MS, Baron PW, Cottrell AC, Kjellin I, Kirk GA: Gadodiamide-associated nephrogenic systemic fibrosis: why radiologists should be concerned. AJR Am J Roentgenol 2007; 188:586-592
3. Dharnidharka VR, Wesson SK, Fennel RS: Gadolinium and nephrogenic fibrosing dermopathy in pediatric patients. Pediatr Nephrol 2006; 22:1395
4. Grobner T: Gadolinium - a specific trigger for the development of nephrogenic fibrosing dermopathy and nephrogenic systemic fibrosis? Nephrol Dial Transplant 2006; 21:1104-1108
5. Khurana A, Runge VM, Narayanan M, Greene JF Jr., Nickel AE: Nephrogenic systemic fibrosis: a review of 6 cases temporally related to gadodiamide injection. Invest Radiol 2007; 42:139-145
6. Marckmann P, Skov L, Rossen K, Dupont A, Damholt MB, Heaf JG, Thomsen HS: Nephrogenic systemic fibrosis: suspected etiological role of gadodiomide used for contrast-enhanced magnetic resonance imaging. J Am Soc Nephrol 2006; 17:2359-2362
7. Murphy KJ, Brunberg JA, Cohan RH: Adverse reactions to gadolinium contrast media: a review of 36 cases. AJR Am J Roentgenol 1996; 167:847-849
8. Okada S, Katagiri K, Kumazaki T, Yokoyama H: Safety of gadolinium contrast agent in hemodialysis patients. Acta Radiol 2001; 42:339-341
9. Thakral C, Alhariri J, Abraham JL: Long-term retention of gadolinium in tissues from nephrogenic systemic fibrosis patient after multiple gadolinium-enhanced MRI scans: case report and implications. Contrast Media Mol Imaging 2007; 2:199-205

III. Equipment-related risks for adverse outcomes related to MRI

Foreign bodies.

Observational studies, case reports, or comparisons without pertinent control groups

1. Gangarosa RE, Minnis JE, Nobbe J, Praschan D, Genberg RW: Operational safety issues in MRI. Magn Reson Imag 1987;5:287-292
2. Jackson JG, Acker JD: Permanent eyeliner and MR imaging. AJR Am J Roentgenol 1987; 49:1080
3. Kelly WM, Paglen PG, Pearson JA, San Diego AG, Soloman MR: Ferromagnetism of intraocular foreign body causes unilateral blindness after MR study. AJNR Am J Neuroradiol 1986; 7:243-245

4. Lund G, Nelson JD, Wirtschafter JD, Williams PA: Tatooing of eyelids; magnetic resonance imaging artifacts. Ophthalmol Surg 1986; 17:550553
5. Wagle WA, Smith M: Tattoo-induced skin burn during MR imaging. AJR Am J Roentgenol 2000; 174:1795

Ferromagnetic items.

Observational studies, case reports, or non-pertinent comparison groups

1. Applebaum E, Valvassori G: Further studies on the effects of magnetic resonance fields on middle ear implants. Ann Otol Rhinol Laryngol 1990; 99:801-804
2. Barrafato D, Henkelman RM: Magnetic resonance imaging and surgical clips. Can J Surg 1984; 27:509-512
3. Becker RL, Forfray JF, Teitelbaum GP, Bradley WG Jr, Jacobs JB, Wacaser L, Rieman RL: MR imaging in patient with intracranial aneurysm clips. AJNR Am J Neuroradiol 1988; 9:885-889
4. Brown MA, Carden JA, Coleman RE, McKinney R, Spicer LD: Magnetic field effects on surgical ligation clips. Magn Reson Imaging 1987; 5:443-453
5. Buchli R, Boesiger P, Meier D: Heating effects on metallic implants by MRI examination. Magn Reson Med 1988; 7:255-261
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11. Hartnell GG, Spence L, Hughe LA, Cohen MC, Saouf R, Buff B: Safety of MR imaging in patients who have retained metallic materials after cardiac surgery. Am J Roentgenol 1997; 168:1157-1159
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Physiologic monitors.

Observational studies, case reports, or non-pertinent comparison groups

1. Anonymous: ECRI: The safe use of equipment in the magnetic resonance environment. Health Devices 2001; 30:421-444
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Invasive monitors (e.g., intravascular catheters).

Observational studies, case reports, or non-pertinent comparison groups

1. Peden CJ, Collins AG, Butson PC, Whitwam JG, Young IR: Induction of microcurrents in critically ill patients in magnetic resonance systems. Crit Care Med 1993; 21:1923-1928

Oxygenation and ventilation equipment.

Observational studies, case reports, or non-pertinent comparison groups

1. Anonymous: ECRI hazard report: patient death illustrates the importance of adhering to safety precautions in magnetic resonance environments. Health Devices 2001; 30:311-314
2. Chaljub G, Kramer LA, Johnson RF III, Singh H, Crow WN: Projectile cylinder accidents resulting from the presence of ferromagnetic nitrous oxide or oxygen tanks in the MR suite. AJR Am J Roentgenol 2001;177:27-30
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Pacemakers and implanted cardioverter defibrillators (ICDs).

Observational studies, case reports, or non-pertinent comparison groups

1. Achenbach S, Moshage W, Diem B, Bieberle T, Schibgilla V, Bachmann K: Effects of magnetic resonance imaging on cardiac pacemakers and electrodes. Am Heart J 1997; 134:467-473
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9. Fiek M, Remp T, Reithmann C, Steinbeck G: Complete loss of ICD programmability after magnetic resonance imaging. Pacing Clin Electrophysiol 2000; 27:1002-1004
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17. Gimbel JR, Trohman RL, Lindsay WC, Clair WK, Wilkoff BL: Strategies for the safe performance of magnetic resonance imaging in selected ICD patients. Pacing Clin Electrophysiol 2002; 25:618
18. Hayes DL, Holmes DR Jr., Gray JE: Effect of 1.5 Tesla nuclear magnetic resonance imaging scanner on implanted permanent pacemakers. J Am Coll Cardiol 1987; 10:782-786
19. Heatlie G, Pennell DJ: Cardiovascular magnetic resonance at 0.5T in five patients with permanent pacemakers. J Cardiovasc Magn Reson 2007; 9:15-19
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Other implanted electronic devices (e.g., deep brain stimulators, vagal nerve stimulators, phrenic nerve stimulators).

Observational studies, case reports, or non-pertinent comparison groups

1. Baker KB, Nyenhuis JA, Hrdlicka G, Rezai AR, Tkach JA, Shellock FG: Neurostimulation systems: assessment of magnetic field interactions associated with 1.5- and 3-Tesla MR systems. J Magn Reson Imaging 2005; 21:72-77
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IV. Preparation for MRI

Patient preparation.

Observational studies, case reports, or non-pertinent comparison groups

1. Ferris NJ, Kavnoudias H, Thiel C, Stuckey S: The 2005 Australian MRI safety survey. AJR Am J Roentgenol 2007; 188:1388-1394
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V. Patient Management during MRI

Monitoring during MRI.

MRI-safe/conditional monitors:

Observational studies, case reports, or non-pertinent comparison groups

1. Holshouser BA, Hinshaw DB, Shellock FG: Sedation, anesthesia, and physiologic monitoring during MR imaging: evaluation of procedures and equipment. J Magn Reson Imaging 1993; 3:553-558
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Remote MRI monitoring:

Observational studies, case reports, or non-pertinent comparison groups

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Monitoring to comply with ASA standards:

Observational studies, case reports, or non-pertinent comparison groups

1. Jorgensen NH, Messick JM, Gray J, Nugent M, Berquist TH: ASA monitoring standards and magnetic resonance imaging. Anesth Analg 1994;79:1141-1147

VI. Anesthetic care during MRI

Moderate Sedation.

Observational studies, case reports, or non-pertinent comparison groups

1. Beebe DS, Tran P, Bragg M, Stillman A, Truwitt C, Belani KG: Trained nurses can provide safe and effective sedation for MRI in pediatric patients. Can J Anaesth 2000; 47:205-210
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Light anesthesia/Deep Sedation.

Randomized controlled trials

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Observational studies, case reports, or non-pertinent comparison groups

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Anesthesia equipment, availability and location (e.g., integrated anesthesia machine, medical gases, gas scavenging, suction, adequate electrical outlets and lighting, storage areas for equipment and drugs).

Observational studies, case reports, or non-pertinent comparison groups

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VII. Environmental emergencies

Fire.

Observational studies, case reports, or non-pertinent comparison groups

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Projectiles.

Observational studies, case reports, or non-pertinent comparison groups

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