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Practice Advisory on Anesthetic Care for Magnetic Resonance Imaging

*A Report by the American Society of Anesthesiologists Task Force on Anesthetic Care for Magnetic Resonance Imaging**

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The use of practice advisories cannot guarantee any specific outcome. Practice advisories summarize the state of the literature, and report opinions obtained from expert consultants and ASA members. Practice advisories are not supported by scientific literature to the same degree as standards or guidelines because of the lack of sufficient numbers of adequately controlled studies. Practice advisories are subject to periodic revision as warranted by the evolution of medical knowledge, technology, and practice.

The magnetic resonance imaging (MRI) suite is a hazardous location because of the presence of a strong static magnetic field, high-frequency electromagnetic (radiofrequency) waves, and a time-varied (pulsed) magnetic field. Secondary dangers of these energy sources include high-level acoustic noise, systemic and localized heating, and accidental projectiles. There may be significant challenges to anesthetic administration and monitoring capabilities due to static and dynamic magnetic fields as well as radiofrequency energy emissions. Direct patient observation may be compromised by noise, darkened environment, obstructed line of sight, and other characteristics unique to this environment (*e.g.*, distractions). Unlike a conventional operating room, the MRI environment frequently requires the anesthesiologist to assume broader responsibility for immediate patient care decisions.

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Methodology

A. Definition of Anesthetic Care for MRI and High-risk Imaging

This Advisory defines *anesthetic care for MRI* as moderate sedation, deep sedation, monitored anesthesia care, general anesthesia, or ventilatory and critical care support. *High-risk imaging* refers to imaging in patients with medical or health-related risks; imaging with equipment-related risks; and procedure-related risks, such as MRI-guided surgery, minimally invasive procedures (*e.g.*, focused ultrasound, radiofrequency ablation), or cardiac and airway imaging studies.

B. Purpose

The purposes of this Advisory are to (1) promote patient and staff safety in the MRI environment, (2) prevent the occurrence of MRI-associated accidents, (3) promote optimal patient management and reduce adverse patient outcomes associated with MRI, (4) identify potential equipment-related hazards in the MRI environment, (5) identify limitations of physiologic monitoring capabilities in the MRI environment, and (6) identify potential health hazards (*e.g.*, high decibel levels) of the MRI environment.

C. Focus

This Advisory focuses on MRI settings where anesthetic care is provided, specifically facilities that are designated as level II or III (appendix 1). *Level II* refers to facilities that image patients requiring monitoring or life support. *Level III* refers to facilities that are designed for operative procedures. This Advisory

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Address reprint requests to the American Society of Anesthesiologists: 520 North Northwest Highway, Park Ridge, Illinois 60068-2573. This Practice Advisory, as well as all published ASA Practice Parameters, may be obtained at no cost through the Journal Web site, www.anesthesiology.org.

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Table 1. Zone Definitions[1]

Zone I	This region includes all areas that are freely accessible to the general public. This area is typically outside the MR environment itself and is the area through which patients, healthcare personnel, and other employees of the MR site access the MR environment.
Zone II	This area is the interface between the publicly accessible uncontrolled zone I and the strictly controlled zone III (see below). Typically, the patients are greeted in zone II and are not free to move throughout zone II at will, but rather are under the supervision of MR personnel. It is in zone II that patient histories, answers to medical insurance questions, and answers to magnetic resonance imaging screening questions are typically obtained.
Zone III	This area is the region in which free access by unscreened non-MR personnel or ferromagnetic objects or equipment can result in serious injury or death as a result of interactions between the individuals or equipment and the MR scanner's particular environment. These interactions include, but are not limited to, those with the MR scanner's static and time-varying magnetic fields. All access to zone III is to be strictly restricted, with access to regions within it (including zone IV; see below) controlled by, and entirely under the supervision of, MR personnel.
Zone IV	This area is the MR scanner magnet room. Zone IV, by definition, will always be located within zone III because it is the MR magnet and its associated magnetic field, which generates the existence of zone III.

MR = magnetic resonance.

does not apply to level I facilities, where no anesthetic care is provided.

Four zones within the MRI suite have been identified, with ascending designations indicating increased hazard areas.[1,2] These areas within the MRI suite are categorized as zones I–IV (table 1).

D. Application

This Advisory is intended for use by anesthesiologists or other individuals working under the supervision of an anesthesiologist, and applies to anesthetic care performed, supervised, or medically directed by anesthesiologists, or to moderate sedation care supervised by other physicians. Because the safe conduct of MRI procedures requires close collaboration and prompt coordination between anesthesiologists, radiologists, MRI technologists, and nurses, some responsibilities are shared among the disciplines. When shared responsibilities are described in this Advisory, the intent is to give the anesthesiologist a starting point for participating in the allocation and understanding of shared responsibilities. The Advisory may also serve as a resource for other physicians and healthcare professionals (*e.g.*, technologists, nurses, safety officers, hospital administrators, biomedical engineers, and industry representatives).

This Advisory does not address specific anesthetic drug choices and does not apply to patients who receive minimal sedation (anxiolysis) to complete the scan or procedure safely and comfortably.

E. Task Force Members and Consultants

The ASA appointed a Task Force of 13 members. These individuals included 10 anesthesiologists in private and academic practice from various geographic areas of the United States, 1 radiologist, and 2 consulting methodologists from the ASA Committee on Standards and Practice Parameters.

The Task Force developed the Advisory by means of a seven-step process. First, they reached consensus on the criteria for evidence. Second, a systematic review and evaluation was performed on original published research studies from peer-reviewed journals relevant to MRI safety. Third, a panel of expert consultants was asked to (1) participate in opinion surveys on the effectiveness of various MRI safety strategies and (2) review and comment on a draft of the Advisory developed by the Task Force. Fourth, opinions about the Advisory were solicited from a random sample of active members of the ASA. Fifth, the Task Force held an open forum at two major national meetings† to solicit input on its draft recommendations. Sixth, the consultants were surveyed to assess their opinions on the feasibility of implementing this Advisory. Seventh, all available information was used to build consensus within the Task Force to create the final document, as summarized in appendix 2.

F. Availability and Strength of Evidence

Preparation of this Advisory followed a rigorous methodologic process (appendix 3). Evidence was obtained from two principal sources: scientific evidence and opinion-based evidence.

Scientific Evidence. Study findings from published scientific literature were aggregated and are reported in summary form by evidence category, as described below. All literature (*e.g.*, randomized controlled trials, observational studies, case reports) relevant to each topic was considered when evaluating the findings. For reporting purposes in this document, the highest level of evidence (*i.e.*, level 1, 2, or 3 identified below) within each category (*i.e.*, A, B, or C) is indicated in the summary.

Category A: Supportive Literature. Randomized controlled trials report statistically significant ($P < 0.01$)

† 82nd Clinical and Scientific Congress of the International Anesthesia Research Society, San Francisco, California, March 30, 2008, and Annual Meeting of the Society for Pediatric Anesthesia, San Diego, California, April 5, 2008.

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differences among clinical interventions for a specified clinical outcome.

Level 1: The literature contains multiple randomized controlled trials, and the aggregated findings are supported by meta-analysis.‡

Level 2: The literature contains multiple randomized controlled trials, but there is an insufficient number of studies to conduct a viable meta-analysis for the purpose of this Advisory.

Level 3: The literature contains a single randomized controlled trial.

Category B: Suggestive Literature. Information from observational studies permits inference of beneficial or harmful relations among clinical interventions and clinical outcomes.

Level 1: The literature contains observational comparisons (*e.g.*, cohort, case–control research designs) of two or more clinical interventions or conditions and indicates statistically significant differences between clinical interventions for a specified clinical outcome.

Level 2: The literature contains noncomparative observational studies with associative (*e.g.*, relative risk, correlation) or descriptive statistics.

Level 3: The literature contains case reports.

Category C: Equivocal Literature. The literature cannot determine whether there are beneficial or harmful relations among clinical interventions and clinical outcomes.

Level 1: Meta-analysis did not find significant differences among groups or conditions.

Level 2: There is an insufficient number of studies to conduct meta-analysis and (1) randomized controlled trials have not found significant differences among groups or conditions or (2) randomized controlled trials report inconsistent findings.

Level 3: Observational studies report inconsistent findings or do *not* permit inference of beneficial or harmful relations.

Category D: Insufficient Evidence from Literature. The *lack* of scientific evidence in the literature is described by the following terms.

Silent: No identified studies address the specified relations among interventions and outcomes.

Inadequate: The available literature cannot be used to assess relations among clinical interventions and clinical outcomes. The literature either does not meet the criteria for content as defined in the "Focus" of the Advisory or does not permit a clear interpretation of findings because of methodologic concerns (*e.g.*, confounding in study design or implementation).

‡ All meta-analyses are conducted by the ASA methodology group. Meta-analyses from other sources are reviewed but not included as evidence in this document.

§ When an equal number of categorically distinct responses is obtained, the median value is determined by calculating the arithmetic mean of the two middle values. Ties are calculated by a predetermined formula.

Opinion-based Evidence. All opinion-based evidence relevant to each topic (*e.g.*, survey data, open-forum testimony, Internet-based comments, letters, editorials) is considered in the development of this Advisory. However, only the findings obtained from formal surveys are reported.

Opinion surveys were developed by the Task Force to address each clinical intervention identified in the document. Identical surveys were distributed to two groups of respondents: expert consultants and ASA members.

Category A: Expert Opinion. Survey responses from Task Force–appointed expert consultants are reported in summary form in the text. A complete listing of consultant survey responses is reported in table 2 in appendix 3.

Category B: Membership Opinion. Survey responses from a random sample of members of the ASA are reported in summary form in the text. A complete listing of ASA member survey responses is reported in table 3 in appendix 3.

Survey responses are recorded using a 5-point scale and summarized based on median values.§

Strongly agree: median score of 5 (at least 50% of the responses are 5)

Agree: median score of 4 (at least 50% of the responses are 4 or 4 and 5)

Equivocal: median score of 3 (at least 50% of the responses are 3, or no other response category or combination of similar categories contain at least 50% of the responses)

Disagree: median score of 2 (at least 50% of the responses are 2 or 1 and 2)

Strongly disagree: median score of 1 (at least 50% of the responses are 1)

Category C: Informal Opinion. Open-forum testimony, Internet-based comments, letters, and editorials are all informally evaluated and discussed during the development of the Advisory. When warranted, the Task Force may add educational information or cautionary notes based on this information.

Advisories

I. Education

MRI safety education includes, but is not limited to, topics addressing: (1) MRI magnet hazards in zones III and IV, (2) challenges and limitations of monitoring, and (3) long-term health hazards.

There is insufficient published evidence to evaluate the effect of education regarding magnet hazards, monitoring limitations, or long-term health hazards associated with MRI. [Category D evidence] One observational study examined the potential long-term health hazards of pregnant MRI workers and pregnant non-MRI workers, and found no significant difference in the relative risk of

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early delivery, low birth weight, or spontaneous abortions.[3] [Category C evidence]

The consultants and ASA members strongly agree that all anesthesiologists should have general safety education on the unique physical environment of the MRI scanner. The ASA members agree and the consultants strongly agree that all anesthesiologists should have specific education regarding the features of individual scanners within their institution. The ASA members agree and the consultants strongly agree that anesthesiologists should work in collaboration with radiologists, technologists, and physicists within their institutions to develop safety training programs.

Advisory Statements. All anesthesiologists should have general safety education on the unique physical environment of the MRI scanner and specific education regarding the specific features of individual scanners within their institution. Education should emphasize safety for entering zones III and IV, with special emphasis on hazards in this environment and effects on monitoring capabilities. Education should address potential health hazards (*e.g.*, high decibel levels and high-intensity magnetic fields) and necessary precautions to deal with the specific field strength and the safety of the MRI scanners within their institutions. Education should include information regarding ferromagnetic items (*e.g.*, stethoscopes, pens, wallets, watches, hair clips, name tags, pagers, cell phones, credit cards, batteries) and implantable devices (*e.g.*, spinal cord stimulators, implanted objects) that should not be brought into zone III or IV of the MRI suite or should be brought in with caution. Anesthesiologists should work in collaboration with radiologists, technologists, and physicists within their institutions to ensure that the above topics are included in their safety training programs. Finally, education should include how to safely respond to code blue situations in zones III and IV, and this information should be integrated into protocols for the designated code blue team.

II. Screening of Anesthetic Care Providers and Ancillary Support Personnel

The MRI medical director or designated technologist is responsible for access to zones III and IV. Screening of all individuals entering zone III is necessary to prevent accidental incursions of ferromagnetic materials or inadvertent exposure of personnel with foreign bodies or implanted ferromagnetic items.

The literature is silent regarding whether the screening of anesthesia care providers and ancillary support personnel improves safety in the MRI suite. [Category D evidence] The ASA members agree and the consultants strongly agree that the anesthesiologist should work in collaboration with the MRI medical director or designee to ensure that all anesthesia team personnel entering zone III or IV have been properly screened.

Advisory Statements. The anesthesiologist should work in collaboration with the MRI medical director or designee (*e.g.*, safety officer) to ensure that all anesthesia team personnel entering zone III or IV have been screened for the presence of ferromagnetic materials, foreign bodies, or implanted devices.

III. Patient Screening

Patient screening consists of determining patient and equipment-related risks for adverse outcomes associated with MRI procedures.

Patient-related Risks: Risks related to the patient may include age-related risks, health-related risks, and risks from foreign bodies located in or on the patient or implanted ferromagnetic items. *Age-related risks* apply to neonates or premature infants, and elderly patients. *Health-related risks* include, but are not limited to, (1) the need for intensive or critical care; (2) impaired respiratory function (*e.g.*, tonsillar hypertrophy, sleep apnea); (3) changes in level of sedation, muscle relaxation, or ventilation; (4) hemodynamic instability and vasoactive infusion requirements; and (5) comorbidities that may contribute to adverse MRI effects (*e.g.*, burns or temperature increases in patients with obesity or peripheral vascular disease). *Risks from foreign bodies* include nonmedical ferromagnetic items imbedded in the patient (*e.g.*, eyeliner tattoos, metallic intraocular fragments) or attached to the patient (*e.g.*, pierced jewelry, magnetic dental keepers). *Risk from implanted ferromagnetic items* may include such items as aneurysm clips, prosthetic heart valves, or coronary arterial stents.

One comparative study reports that neonates undergoing MRI demonstrate increased fluctuations in heart rate, blood pressure, and oxygen saturation levels compared with neonates not undergoing MRI.[4] [Category B1 evidence] Two observational studies report that premature neonates can experience heart rate fluctuations, decreases in oxygen saturation, and increases in temperature during MRI.[5,6] [Category B2 evidence] One case report indicates that a child with a history of previous cardiac arrest experienced a cardiac arrest during MRI.[7] [Category B3 evidence] Four observational studies[8–11] and two case reports[12,13] indicate that patients with impaired renal function are at risk of nephrogenic systemic fibrosis after gadolinium administered for MRI. [Category B2 evidence]

Case reports indicate that exposure of iron filings to the magnetic field may result in hemorrhage,[7,14] and exposure of eyeliner tattoos may result in image artifacts, burns, swelling, or puffiness.[7,15–17] [Category B3 evidence] Numerous observational studies and case reports indicate interactions with the magnetic field (*e.g.*, movements, displacements, image artifacts) and increases in temperature during MRI for ferromagnetic items such as aneurysm clips, surgical clips, prosthetic heart valves, intravenous infusion pumps, coronary arterial stents, and implanted dental magnet keepers.[18–43] [Category B2 evidence]

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Both the consultants and the ASA members strongly agree that, for every case, the anesthesiologist should communicate with the patient and radiologist or referring physician to determine whether the patient has a high-risk medical condition. In addition, they both strongly agree that if the patient presents with a high-risk medical condition, the anesthesiologist should collaborate with all participants, including the referring physician, radiologist, and technologist, to determine how the patient will be managed during the MRI procedure. Both the consultants and the ASA members agree that, for patients with acute or severe renal insufficiency, the anesthesiologist should not administer gadolinium because of the increased risk of nephrogenic systemic fibrosis.

Equipment-related Risks: Patient equipment-related risks include, but are not limited to, (1) physiologic monitors; (2) invasive monitors (*e.g.*, intravascular catheters); (3) intubation equipment; (4) oxygenation and ventilation equipment; and (5) pacemakers, implanted cardiodefibrillators, and other implanted devices (*e.g.*, deep brain stimulators, vagal or phrenic nerve stimulators, middle-ear or cochlear implants).

One case report notes that cardiac monitor leads interfered with an MRI scan.[7] [Category B3 evidence] One observational study and one case report indicate that fire or burns occurred beneath or near cardiac monitor electrodes.[44,45] [Category B2 evidence] Five case reports note that burns occurred from the looping of a temperature probe or pulse oximetry cables.[46–50] [Category B3 evidence] One observational study reports ferromagnetic components in ventilators[51] [category B2 evidence], and three case reports describe projectile nitrous oxide or oxygen tanks[52–54] [category B3 evidence]. Additional observational studies and case reports indicate interactions of pacemakers or implanted cardioverter–defibrillators with MRI scanning, including, but not limited to, pacing artifacts, reed switch closure, generator movement or displacement, alterations of pacing rate, and temperature increases.[7,55–84] [Category B2 evidence] Two observational studies report palpitations, rapid heart rate, and discomfort at the pacemaker pocket after MRI.[75,85] [Category B2 evidence] Finally, two cases of cardiac arrest are reported in patients with pacemakers during or after an MRI scan; in one case, the patient died.[7,57] [Category B3 evidence]

Two observational studies report image artifacts when MRI is performed in patients with neurostimulators, infusion pumps, or implantable spinal fusion stimulators.[86,87] Six observational studies report increased temperatures in patients with deep brain stimulators, neurostimulators, or spinal cord stimulators,[88–93] and three report displacement of leads, pulse generators, or other components of deep brain stimulators or middle ear prostheses during MRI scans.[94–96] [Category B2 evidence]

Both the consultants and the ASA members agree that, for every case, the anesthesiologist should communicate with the radiologist or referring physician to determine whether the patient requires equipment that may pose a risk during the scan. In addition, they agree that anesthesiologists should determine the safety and effectiveness of the equipment needed by the patient during the procedure for each MRI location. Further, the consultants and ASA members strongly agree that anesthesiologists should work with their institutions to properly identify and label anesthesia-related equipment according to convention for each MRI scanner. The ASA members agree and the consultants strongly agree that care should be taken to ensure that anesthesia equipment does not interfere with image acquisition or quality. Both the consultants and the ASA members agree that, in general, MRI should not be performed on patients with implanted electronic devices. Finally, both the consultants and the ASA members strongly agree that, when MRI is considered essential by the referring physician and consulting radiologist, a plan for managing patients with implanted electronic devices during the scan should be developed in collaboration with the referring physician, medical director or on-site radiologist, and other appropriate consultants.

Advisory Statements for Patient and Equipment-related Risks. For every case, the anesthesiologist should communicate with the patient, referring physician, and radiologist to determine whether the patient (1) presents with a high-risk medical condition (*e.g.*, neonatal status or prematurity, intensive or critical care status, impaired respiratory function, hemodynamic instability and vasoactive infusion requirements, comorbidities such as obesity and peripheral vascular disease); (2) requires equipment (*e.g.*, physiologic or invasive monitors; intubation, oxygenation, or ventilation equipment); (3) has implanted devices (*e.g.*, pacemakers, cardioverter–defibrillators, nerve stimulators); (4) has been screened for the presence of implanted ferromagnetic items (*e.g.*, surgical clips, prosthetic heart valves); and (5) has been screened for the presence of *imbedded* foreign bodies (*e.g.*, orbital iron filings, eyeliner tattoos). Finally, the anesthesiologist should communicate with the technologist to ensure that the patient has been screened for the presence of foreign bodies *on the patient* (*e.g.*, pierced jewelry, rings) before entering zone III.

If a patient presents with a high-risk medical condition, the anesthesiologist should collaborate with all participants, including the referring physician, radiologist, and technologist, to determine how the patient will be managed during the MRI procedure. Anticipated changes in level of sedation, muscle relaxation, or ventilation may also place a patient in a high-risk situation.

For patients with acute or severe renal insufficiency, the anesthesiologist should not administer gadolinium

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because of the increased risk of nephrogenic systemic fibrosis.‖

Anesthesiologists should work with their institutions to properly identify and label anesthesia-related equipment according to convention (safe, unsafe, or conditional) for each MRI scanner.# For each MRI location, anesthesiologists should determine the safety and effectiveness of the equipment needed by the patient during the procedure. In addition, care should be taken to ensure that equipment does not interfere with image acquisition or quality.

The Task Force believes that cardiac pacemakers and implantable cardioverter–defibrillators are generally contraindicated for MRI. These devices pose an extreme hazard in this environment and may be life-threatening within the 5 gauss line. When MRI is considered essential by the referring physician and consulting radiologist, a plan for managing these patients during the scan should be developed in collaboration with the ordering physician, medical director or on-site radiologist, and other appropriate consultants (*e.g.*, the patient's pacemaker specialist or cardiologist, the diagnostic radiologist, the device manufacturer).**

Other implanted electronic devices also pose a hazard in the MRI environment. These devices and associated wiring may transfer energy during the MRI scan, causing tissue damage, malfunction of the device, image artifacts, and device displacement. MRI may be performed on a limited basis for patients with certain implanted electronic devices (*e.g.*, deep brain stimulators, vagal nerve stimulators, phrenic nerve stimulators, wire-containing thermodilution catheters, cochlear implants). In consultation with the referring physician, the radiologist responsible for the procedure, and the neurosurgeon, the anesthesiologist should ensure that the presence of the device has been noted and determined to be MRI safe/conditional before imaging of these patients.

IV. Preparation

Preparation consists of determining and implementing an individualized anesthetic plan before the MRI procedure begins. In addition to the anesthetic plan, preparation includes a plan for optimal positioning of equipment and personnel in the MRI suite during the procedure.

The literature is insufficient to determine whether active preparation or pre-MRI planning reduces the frequency of adverse events. [Category D evidence] One case report indicates that misinformation about the type of aneurysm clip resulted in intracerebral hemorrhage and death,[31] and a second case report indicates that a lack of communication among physicians caring for a pacemaker patient resulted in the death of the patient.[97] [Category B3 evidence]

Both the consultants and the ASA members strongly agree that, for every case, the anesthesiologist should prepare, with support personnel, a plan for providing optimal anesthetic care within the special environment of the MRI suite. They both strongly agree that the anesthesiologist should communicate with the radiology personnel to determine the requirements of the scan. The ASA members agree and the consultants strongly agree that the anesthesiologist should collaborate with the magnetic resonance (MR) technologist and/or facility biomedical engineer to determine and demarcate the optimal and safe location of movable equipment in relation to the gauss lines within the MRI suite. They both strongly agree that, because line of sight within the bore will vary depending on the facility, the anesthesiologist should choose a location or position for optimal patient observation and vigilance during delivery of care, whether in zone III or IV. Finally, they both strongly agree that the anesthesiologist should prepare a plan for rapidly summoning additional personnel in the event of an emergency.

Advisory Statements. For every case, the anesthesiologist should prepare, with support personnel, a plan for providing optimal anesthetic care within the special environment of the MRI suite. In addition to addressing the medical needs of the patient, features of the plan should include (1) requirements of the scan and personnel needs, (2) positioning of equipment, (3) special requirements or unique issues of patient or imaging study, (4) positioning of the anesthesiologist and the patient, and (5) planning for emergencies.

1. The anesthesiologist should communicate with the radiology personnel to determine the requirements for the scan (*e.g.*, duration of the scan, position of the patient or area of the body in the scanner, positioning of receiver coils, need for periods of paused respiration). The anesthesiologist should communicate with other anesthesia team members regarding individual roles for anesthetic care.
2. The anesthesiologist should collaborate with the MR technologist and/or facility biomedical engineer to determine and demarcate the optimal and safe location of movable equipment in relation to the gauss lines within the MRI suite.
3. Because line of sight within the bore will vary depending on the facility, the anesthesiologist should

‖ See US Food and Drug Administration alert. Available at: http://www.fda.gov/CDER/Drug/InfoSheets/HCP/gcca_200705.htm. Accessed October 17, 2008.

Equipment is categorized as safe, unsafe, or conditional for use in the MRI environment. MRI *safe* equipment is identified by the American Society for Testing and Materials as having no ferromagnetic parts or radiofrequency interference. MRI *unsafe* equipment is identified as having ferromagnetic parts or being affected by radiofrequency interference. MRI *conditional* equipment may be safe in certain locations of the suite depending on gauss line locations, but cannot be identified as having no ferromagnetic parts (see American Society for Testing and Materials Practice Standards F2503, F2119, and F2052, www.astm.org). In the past, equipment was described as MRI compatible, but because the safety of this equipment depended on the particular MRI environment, the word *conditional* now applies.

** American Society of Anesthesiologists: Practice advisory for the perioperative management of patients with cardiac rhythm management devices: Pacemakers and implantable cardioverter–defibrillators. ANESTHESIOLOGY 2005; 103: 186–98.

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choose a location or position for optimal patient observation and vigilance during delivery of care, whether in zone III or IV. In particular, anesthesiologists should have (1) a clear line of sight of the patient and physiologic monitors, whether by direct observation or by video camera; (2) anesthetic delivery equipment located for optimal control of anesthetic depth and rapid intervention; and (3) access to hospital information systems integral to patient care. In preparing for positioning, the anesthesiologist should take into account potential electromagnetic and auditory hazards.

4. Anesthesiologists should prepare a plan for rapidly summoning additional personnel in the event of an emergency. Because the MRI suite is frequently located in an isolated area of the facility, the anesthesiologist should ensure that (1) emergency equipment and drugs are immediately accessible; (2) emergency communication (*e.g.*, phone or code button) is immediately available; and (3) an evacuation plan is in place, including an appropriate location outside the scan room (zone IV) for resuscitation. This location should be complete with physiologic monitors, oxygen, suction, and other appropriate resuscitation equipment. Monitoring requirements, airway management, and emergency preparedness are additional features that should be included in the preparation and planning for an MRI scan, and are addressed in section V below.

V. Patient Management during MRI

Features of safe patient management during MRI procedures include (1) monitoring, (2) anesthetic care, (3) airway management, and (4) management of emergencies.

Monitoring. Safe monitoring conditions include (1) the use of MRI-safe/conditional monitors, (2) remote monitoring, and (3) compliance with ASA standards.[98]

Three observational studies indicate that the use of MRI-compatible monitoring equipment resulted in no radiofrequency interference, interruptions in scanning, or artifacts.[99–101] [Category B2 evidence] Five observational studies demonstrate that remote monitoring for heart rate, blood pressure, auscultation, respiration, and chest wall movement can be performed safely and effectively.[100,102–105] [Category B2 evidence] One observational study reported that compliance with the ASA Standards for Basic Anesthetic Monitoring can be obtained, provided that the monitoring equipment is properly tested before MRI.[106] [Category B2 evidence]

The consultants and ASA members both strongly agree that MRI patients should be monitored in a manner consistent with the ASA Standards for Basic Anesthetic Monitoring. In addition, they both strongly agree that (1) anesthesiologists should be familiar with the expected limitations of available monitoring equipment, (2) the anesthesiologist should make sure that all monitors used in zone IV are safe/conditional for the scan, and (3) a monitor should be available to view vital signs from zone III when the anesthesia care provider is not in zone IV.

Advisory Statements. MRI patients should be monitored in a manner consistent with the ASA Standards for Basic Anesthetic Monitoring. Anesthesiologists should be familiar with the expected limitations of available monitoring equipment. The Task Force notes that information from electrocardiograms may be limited because of superimposed voltages from blood flow in the high magnetic field (*e.g.*, ST-segment interpretation may be unreliable, even with highly filtered monitors). The anesthesiologist should make sure that all monitors used in zone IV are safe/conditional for the scan. A monitor should be available to view vital signs from zone III when the anesthesia care provider is not in zone IV. Additional care should be taken in positioning electrocardiographic and other monitor leads to eliminate burns, even with nonferromagnetic leads.

Anesthetic Care. Observational studies report a high rate of success in imaging of sedated patients or patients to whom light anesthesia is administered.[107–112] However, motion artifacts may still occur.[113–115] [Category B2 evidence] Observational studies and case reports also indicate that sedation or light anesthesia may be associated with respiratory depression, oxygen desaturation, bronchospasm, drowsiness, agitation, and vomiting.[99,108–113,116–128] [Category B2 evidence] The Task Force believes that automated apnea monitoring (by detection of exhaled carbon dioxide or other means) may decrease risks during both moderate and deep sedation.

Both the consultants and the ASA members strongly agree that, in general, because MRI is a nonpainful procedure, lighter levels of anesthesia may be appropriate, recognizing that institutional circumstances, patient characteristics, and anesthesiologist preference may warrant more aggressive airway management and deeper anesthetic levels. They both strongly agree that anesthesiologists should ensure that patients who receive moderate or deep sedation are monitored in a manner consistent with their institution's protocol for monitoring similarly sedated patients elsewhere in the facility. In addition, they both strongly agree that equipment and drugs for anesthetic care in the MRI suite should mirror what is available in the operating room. Both the consultants and the ASA members are equivocal that, when an MRI-safe/conditional anesthesia machine is not available, inhalation anesthetics may be administered from an anesthesia machine inside zone III *via* an elongated circuit through a wave guide. Finally, both the consultants and the ASA members agree that, if total intravenous anesthesia is used, it should be administered by using (1) MRI-safe/conditional pumps in zone IV, (2) traditional (*i.e.*, MRI-unsafe) pumps in zone III with intravenous tubing passed through a wave guide, or (3) periodic bolus injections in zone III or IV.

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Advisory Statements. Although lighter levels of anesthesia may be appropriate during an MRI scan, the anesthesiologist should be aware that these lighter levels may result in airway complications (*e.g.*, laryngospasm, coughing, other airway compromise) that may necessitate interruption of the scan for urgent treatment and alteration of anesthetic depth. Institutional circumstances, patient characteristics, and anesthesiologist preference may warrant more aggressive airway management and deeper anesthetic levels.

Anesthesiologists should ensure that patients who receive moderate or deep sedation are monitored in a manner consistent with their institution's protocol for monitoring similarly sedated patients elsewhere in the facility. Monitoring of exhaled carbon dioxide should be considered for all patients receiving deep sedation and for patients whose ventilation cannot be directly observed during moderate sedation.†† The Task Force cautions that, because ventilation and oxygenation are separate though related physiologic processes, monitoring oxygenation by pulse oximetry is not a substitute for monitoring ventilatory function.

Equipment and drugs for anesthetic care in the MRI suite should mirror what is available in other anesthetizing locations, including (1) an integrated anesthesia machine, medical gases, and waste anesthesia gas disposal or gas scavenging, when inhalational anesthesia is administered; (2) suction; (3) adequate electrical outlets and lighting; and (4) storage areas for equipment and drugs. The Task Force recognizes that physical plant variability exists among institutions.‡‡ Equipment used in the MRI suite should be appropriate for the age and size of the patient.

Magnetic resonance imaging–safe/conditional anesthesia machines are always preferred for use in an MRI facility.§§ However, when an MRI-safe/conditional anesthesia machine is not available, inhalational anesthetics can be administered from an anesthesia machine inside zone III *via* an elongated circuit through a wave guide.|||| Although this method of anesthetic delivery was commonplace before the commercial manufacture of MRI-safe/conditional anesthesia machines, this practice is inherently cumbersome and may be prone to more possibilities for mishaps than the use of an anesthesia machine specifically designed for the MRI environment.

Alternatively, if total intravenous anesthesia is used, it should be administered by using (1) MRI-safe/conditional pumps in zone IV, (2) traditional (*i.e.*, MRI unsafe) pumps in zone III with intravenous tubing passed through a wave guide, or (3) periodic bolus injections in zone III or IV. Although an anesthesia machine may not be required for the administration of total intravenous anesthesia, there must be equipment immediately available for the administration of positive-pressure ventilation with oxygen.

Airway Management. Unique features of airway management during an MRI scan include (1) the limited accessibility of the patient's airway and (2) the difficulty of conducting visual and auditory assessments of the patient. The literature is silent regarding the management of airway problems (*e.g.*, obstruction, secretions, laryngospasm, apnea and hypoventilation) during an MR scan. [Category D evidence] In addition, the literature is silent regarding whether the use of an endotracheal tube or laryngeal mask airway improves outcomes for patients at risk of airway compromise during MRI. [Category D evidence]

Both the consultants and the ASA members strongly agree that the anesthesiologist should have an advance plan in place to deal with instrumentation of the airway and common airway problems when patients are in an MRI environment. Both the consultants and the ASA members strongly agree that, if the patient is at risk for airway compromise, more aggressive airway management should be instituted because the patient's airway may be less accessible when the patient is in the scanner. Both the consultants and the ASA members strongly agree that (1) complex airway management (*e.g.*, fiberoptic intubation) should be performed in a controlled environment outside of zone IV, (2) alternative airway devices should be immediately available in the MRI suite, and (3) suction equipment should be immediately accessible to the patient's airway at all times.

Advisory Statements. The anesthesiologist should have an advance plan in place to deal with instrumentation of the airway and common airway problems (*e.g.*, obstruction, secretions, laryngospasm, apnea and hypoventilation) when patients are in an MRI environment. If the patient is at risk for airway compromise, more aggressive airway management (*e.g.*, use of a endotracheal tube or laryngeal mask airway) should be instituted because the patient's airway may be less accessible when the patient is in the scanner. Complex airway management (*e.g.*, fiberoptic intubation) should be performed in a controlled environment outside of zone IV.

Alternative MRI-safe/conditional airway devices should be immediately available in the MRI suite. Suction equipment should be immediately accessible to the patient's airway at all times.

Management of Emergencies. Emergencies in the MR suite include (1) medical emergencies (*e.g.*, cardiopulmonary arrest) and (2) environmental emergencies (*e.g.*,

†† American Society of Anesthesiologists: Practice guidelines for sedation and analgesia by non-anesthesiologists: An updated report. ANESTHESIOLOGY 2002; 96: 1004–17.

‡‡ When remodeling or building a new facility, input from the anesthesiologist is critical.

§§ An MRI facility that is newly built or that undergoes a major renovation should have an MRI-safe/conditional anesthesia machine.

|||| A wave guide is a copper-lined conduit with a specific length and diameter that maintains radiofrequency isolation of the magnet room installed during construction of the MRI suite. Wires or conducting material act as an antenna and should not be passed through a wave guide.

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quench, fire, projectiles). The remote location of the scanner within the facility may delay response of support personnel or availability of equipment during an emergency.

The literature is insufficient regarding the management of medical emergencies (*e.g.*, cardiopulmonary arrest) or quench in the MR suite. [Category D evidence] One case report indicates that a fire occurring on the patient was managed by extinguishing the flames, discontinuing the scan, and immediately removing the patient from the bore.[45] Two case reports of projectile nitrous oxide or oxygen tanks indicate that the emergency was managed by removing patients from zone IV and instituting a controlled quench.[53,54] [Category B3 evidence]

Both the consultants and the ASA members strongly agree that when a patient has a medical emergency in the MRI scanner, the following should occur: (1) initiate cardiopulmonary resuscitation, when needed, while immediately removing the patient from zone IV; (2) call for help; and (3) transport the patient to a previously designated safe location in proximity to the MRI suite. In addition, they both strongly agree that the designated safe location should contain the following resuscitation equipment: (1) a defibrillator; (2) vital signs monitors; and (3) a code cart that includes resuscitation drugs, airway equipment, oxygen, and suction. The consultants and ASA members both strongly agree that when a fire occurs in the MRI suite, team members should perform their preassigned fire management tasks as quickly as possible, in accordance with the ASA Practice Advisory for the Prevention and Management of Operating Room Fires.[129] The ASA members agree and the consultants strongly agree that, when a quench occurs, team members should perform their institution's protocol in reaction to this occurrence. In addition, the ASA members agree and the consultants strongly agree that, when a quench occurs, if possible, (1) the patient should be removed from zone IV immediately and (2) oxygen should be administered to the patient immediately. Finally, both the consultants and the ASA members agree that, because powerful static magnetic fields may persist after a quench or fire, emergency response personnel should be restricted from entering zone IV.

Advisory Statements. Medical emergencies may be difficult to manage while the patient is in the MRI scanner. When a patient has a medical emergency (*e.g.*, cardiopulmonary arrest) in the MRI scanner, the following should occur: (1) immediately remove the patient from zone IV while initiating cardiopulmonary resuscitation, if indicated; (2) call for help; and (3) transport the patient to a previously designated safe area for resuscitation that is not in zone IV. This location should be as close to zone IV as possible so as not to delay resuscitation efforts, and should contain the following resuscitation equipment: a defibrillator; vital signs monitors; and a code cart that includes resuscitation drugs, airway equipment, oxygen, and suction.

When a fire occurs in the MRI suite, team members should perform their preassigned fire management task as quickly as possible, in accordance with the ASA Practice Advisory for the Prevention and Management of Operating Room Fires. If a team member cannot rapidly perform his or her task in the predetermined order, other team members should perform their tasks *without waiting*. When a team member has completed a preassigned task, he or she should help other members perform tasks that are not yet complete.

In the case of projectile emergencies, team members should perform their institution's protocol in reaction to this occurrence. If possible, immediately remove the patient from zone IV and discontinue the scan. If the patient is injured, proceed with medical emergency management as indicated above. A controlled quench may be necessary to remove the patient from the bore.

A quench occurs when a superconducting magnet turns resistive and catastrophically releases all of the stored energy as heat, boiling off the stored cryogens as gas. The most common cause of quench is an intentional shutdown of the magnet for a life-threatening emergency. Quench may also be the consequence of an unintentional shutdown. If not properly vented, a quench can result in the complete dissipation of oxygen in zone IV, risking hypoxia to the patient and MRI personnel. In addition, entrance to zone IV may not be possible because of high pressure caused by escaping gases, making it impossible to open the door into zone IV. When a quench occurs, team members should perform their institution's protocol in reaction to this occurrence. If possible, (1) immediately remove the patient from zone IV and (2) immediately administer oxygen to the patient.

Powerful static magnetic fields may persist after a quench, and therefore the usual precautions apply when entering zone IV. Emergency response personnel should be restricted from entering zone IV during any environmental emergency because of the persistent magnetic field.

VI. Postprocedure Care

The literature is insufficient to determine whether postprocedure care consistent with that provided for other areas of the institution reduces the frequency of adverse events. [Category D evidence]

The ASA members agree and the consultants strongly agree that the anesthesiologist should collaborate with the radiologist and other staff in the postanesthetic care of the patient. Finally, both the consultants and the ASA members strongly agree that (1) patients receiving sedation or anesthesia within the MRI suite should have access to postanesthetic care consistent with that provided in other areas of the institution; (2) in all situations, intensive care and recovery areas should include access to vital signs monitors, oxygen, suction, and trained personnel; and (3) patients should be given written discharge instructions.

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Advisory Statements. The anesthesiologist should collaborate with the radiologist and other staff in the postanesthetic care of the patient. Patients receiving sedation or anesthesia within the MRI suite should have access to postanesthetic care consistent with that provided in other areas of the institution,[130] including transport to other recovery rooms, dedicated intensive care, or recovery areas within the MRI suite. In all situations, intensive care and recovery areas should include access to vital sign monitors, oxygen, suction, resuscitation equipment, and trained personnel.## Patients should be given oral and written discharge instructions.

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When remodeling or building a new facility, an attempt should be made to locate recovery and resuscitation in proximity to the MRI suite.

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Appendix 1: Facility Levels for MRI Suites

This Advisory categorizes MRI facilities into three general levels according to the anticipated level of patient care required. These levels describe the physical plant, technical infrastructure, and resources needed to deliver patient care according to standards already established by the ASA and other professional organizations for sedation, anesthesia, and monitored care.

Level I: Facilities That Image Patients Who Do Not Require Medical Support or Physiologic Monitoring

These facilities do not typically have available oxygen supplies, suction, physiologic monitors, resuscitation equipment, or non-MRI medical support personnel on site, although some level 1 facilities may provide such services or equipment. Level 1 facilities do not contain suitable equipment or infrastructure for the care of critical patients, infants, emergency patients, patients needing anesthesia or sedation, or other patients with high-risk medical conditions.

Level II: Facilities That Image Patients Requiring Any Level of Anesthesia or Critical Care, Including Noninvasive or Invasive Monitoring and Life Support

Facilities with this designation provide imaging for patients receiving sedation or anesthesia; intensive care patients requiring continuous monitoring, drug infusions, or mechanical ventilation; and patients needing emergent scans. Non-MRI personnel (*e.g.*, anesthesiologists, emergency physicians, intensivists, house staff, nurses, nurse practitioners) are typically present to provide patient care. Patient monitoring systems designated as safe/conditional for zone IV are required in these facilities. Level II facilities provide medical gases (oxygen, nitrous oxide, air), patient suction, and evacuation of anesthetic gases. Back up oxygen resources in nonferromagnetic (*e.g.*, aluminum) canisters are also available. Finally, oxygen and suction are readily available in zone II or III for patients who need to be evacuated from zone IV for emergent resuscitation.

Level III: Facilities That Provide Imaging for Operative Procedures

Facilities with this designation contain all resources (*i.e.*, physical plant and technical infrastructure) commensurate with level II facilities and, in addition, provide an operative team of non-MRI personnel with the appropriate surgical tools and equipment (*e.g.*, availability of additional gases such as nitrogen to power surgical equipment). All legal codes and standards for operating rooms (such as air turnover and ventilation) apply.

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Appendix 2: Primary Findings of the Advisory Task Force

I. Education

- All anesthesiologists should have general safety education on the unique physical environment of the MRI scanner, and specific education regarding the specific features of individual scanners within their institution.
  - Education should emphasize safety for entering zones III and IV, with special emphasis on hazards in this environment and effects on monitoring capabilities.
  - Education should address potential health hazards (*e.g.*, high decibel levels and high-intensity magnetic fields).
  - Education should address necessary precautions to deal with the specific field strength and the safety of the MRI scanners within their institutions.
  - Education should include information regarding ferromagnetic items (*e.g.*, stethoscopes, pens, wallets, watches, hair clips, name tags, pagers, cell phones, credit cards, batteries) and implantable devices (*e.g.*, spinal cord stimulators, implanted objects) that should *not* be brought into zone III or IV of the MRI suite or should be brought in with caution.
- Anesthesiologists should work in collaboration with radiologists, technologists, and physicists within their institutions to ensure that the above topics are included in their safety training programs.
- Education should include how to safely respond to code blue situations in zones III and IV, and this information should be integrated into protocols for the designated code blue team.

II. Screening of Anesthesia Care Providers and Ancillary Support Personnel

- The anesthesiologist should work in collaboration with the MRI medical director or designee (*e.g.*, safety officer) to ensure that all anesthesia team personnel entering zone III or IV have been screened for the presence of ferromagnetic materials, foreign bodies, and implanted devices.

III. Patient Screening

- For every case, the anesthesiologist should communicate with the patient, referring physician, and radiologist to determine whether the patient:
  - Presents with a high-risk medical condition (*e.g.*, neonatal status or prematurity, intensive or critical care status, impaired respiratory function; hemodynamic instability and vasoactive infusion requirements; comorbidities such as obesity and peripheral vascular disease)
  - Requires equipment (*e.g.*, physiologic or invasive monitors; intubation, oxygenation, or ventilation equipment)
  - Has been screened for implanted devices (*e.g.*, pacemakers, cardioverter–defibrillators, nerve stimulators)
  - Has been screened for implanted ferromagnetic items (*e.g.*, surgical clips, prosthetic heart valves)
  - Has been screened for the presence of *imbedded* foreign bodies (*e.g.*, orbital iron filings, eyeliner tattoos)
- The anesthesiologist should communicate with the technologist to ensure that the patient has been screened for the presence of foreign bodies on the patient (*e.g.*, pierced jewelry, rings) before entering zone III.
- If a patient presents with a high-risk medical condition, the anesthesiologist should collaborate with all participants, including the referring physician, radiologist, and technologist, to determine how the patient will be managed during the MRI procedure.
  - Anticipated changes in level of sedation, muscle relaxation, or ventilation may also place a patient in a high-risk situation.
- For patients with acute or severe renal insufficiency, the anesthesiologist should not administer gadolinium because of the increased risk of nephrogenic systemic fibrosis.
- Anesthesiologists should work with their institutions to properly identify and label anesthesia-related equipment according to convention (safe, unsafe, or conditional) for each MRI scanner.
- For each MRI location, anesthesiologists should determine the safety and effectiveness of the equipment needed by the patient during the procedure.
  - Care should be taken to ensure that the patient's equipment does not interfere with image acquisition or quality.
- Cardiac pacemakers and implantable cardioverter–defibrillators are generally contraindicated for MRI.
  - When MRI is considered essential by the referring physician and consulting radiologist, a plan for managing these patients during the scan should be developed in collaboration with the ordering physician, medical director or on-site radiologist, and other appropriate consultants (*e.g.*, patient's pacemaker specialist or cardiologist, diagnostic radiologist, device manufacturer).
- MRI may be performed on a limited basis for patients with certain implanted electronic devices (*e.g.*, deep brain stimulators, vagal nerve stimulators, phrenic nerve stimulators, wire-containing thermodilution catheters, cochlear implants).
  - In consultation with the referring physician, the radiologist responsible for the procedure, and the neurosurgeon, the anesthesiologist should ensure that the presence of the device has been noted and determined to be MRI safe/conditional before imaging of these patients.

IV. Preparation

- For every case, the anesthesiologist should prepare, with support personnel, a plan for providing optimal anesthetic care within the special environment of the MRI suite.
  - In addition to addressing the medical needs of the patient, features of the plan should include (1) requirements of the scan and personnel needs, (2) positioning of equipment, (3) special requirements or unique issues of patient or imaging study, (4) positioning of the anesthesiologist and the patient, and (5) planning for emergencies.
- The anesthesiologist should communicate with the radiology personnel to determine the requirements for the scan (*e.g.*, duration of the scan, position of the patient or area of the body in the scanner, positioning of receiver coils, need for periods of paused respiration).
- The anesthesiologist should communicate with other anesthesia team members regarding individual roles for anesthetic care.
- The anesthesiologist should collaborate with the MR technologist and/or facility biomedical engineer to determine and demarcate the optimal and safe location of movable equipment in relation to the gauss lines within the MRI suite.
- The anesthesiologist should choose a location or position for optimal patient observation and vigilance during delivery of care, whether in zone III or IV.
  - Anesthesiologists should have (1) a clear line of sight of the patient and physiologic monitors, whether by direct observation or by video camera; (2) anesthetic delivery equipment located for optimal control of anesthetic depth and rapid intervention; and (3) access to hospital information systems integral to patient care.
  - In preparing for positioning, the anesthesiologist should take into account potential electromagnetic and auditory hazards.
- Anesthesiologists should prepare a plan for rapidly summoning additional personnel in the event of an emergency.
  - The anesthesiologist should ensure that (1) emergency equipment and drugs are immediately accessible; (2) emergency communication (*e.g.*, phone or code button) is immediately available; and (3) an evacuation plan is in place, including an appropriate location outside the scan room (zone IV) for resuscitation.
    - This location should be complete with physiologic monitors, oxygen, suction, and other appropriate resuscitation equipment.

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V. Patient Management during MRI

- Monitoring
  - MRI patients should be monitored in a manner consistent with the ASA Standards for Basic Anesthetic Monitoring.
  - The anesthesiologist should be familiar with the expected limitations of available monitoring equipment.
    - Information from electrocardiograms may be limited due to superimposed voltages from blood flow in the high magnetic field (*e.g.*, ST-segment interpretation may be unreliable, even with highly filtered monitors).
  - The anesthesiologist should make sure that all monitors used in zone IV are safe/conditional for the scan.
  - A monitor should be available to view vital signs from zone III when the anesthesia care provider is not in zone IV.
  - Additional care should be taken in positioning electrocardiogram and other monitor leads to eliminate burns, even with nonferromagnetic leads.
- Anesthetic care
  - Although lighter levels of anesthesia may be appropriate during an MRI scan, the anesthesiologist should be aware that these lighter levels may result in airway complications (*e.g.*, laryngospasm, coughing, or other airway compromise), which may necessitate interruption of the scan for urgent treatment and alteration of anesthetic depth.
    - Institutional circumstances, patient characteristics, and anesthesiologist preference may warrant more aggressive airway management and deeper anesthetic levels.
  - Anesthesiologists should ensure that patients who receive moderate or deep sedation are monitored in a manner consistent with their institution's protocol for monitoring similarly sedated patients elsewhere in the facility.
  - Monitoring of exhaled carbon dioxide should be considered for all patients receiving deep sedation and for patients whose ventilation cannot be directly observed during moderate sedation.
  - Monitoring oxygenation by pulse oximetry is not a substitute for monitoring ventilatory function.
  - Equipment and drugs for anesthetic care in the MRI suite should mirror what is available in other anesthetizing locations, including (1) an integrated anesthesia machine, medical gases, and waste anesthesia gas disposal or gas scavenging, when inhalational anesthesia is administered; (2) suction; (3) adequate electrical outlets and lighting; and (4) storage areas for equipment and drugs.
  - Equipment used in the MRI suite should be appropriate for the age and size of the patient.
  - MRI-safe/conditional anesthesia machines are always preferred for use in an MRI facility.
    - When an MRI-safe/conditional anesthesia machine is not available, inhalational anesthetics can be administered from an anesthesia machine inside zone III *via* an elongated circuit through a wave guide.
    - If total intravenous anesthesia is used, it should be administered by using (1) MRI-safe/conditional pumps in zone IV, (2) traditional (*i.e.*, MRI unsafe) pumps in zone III with intravenous tubing passed through a wave guide, or (3) periodic bolus injections in zone III or IV.
- Although an anesthesia machine may not be required for the administration of total intravenous anesthesia, there must be equipment immediately available for the administration of positive pressure ventilation with oxygen.
- Airway management
  - The anesthesiologist should have an advance plan in place to deal with instrumentation of the airway and common airway problems (*e.g.*, obstruction, secretions, laryngospasm, apnea and hypoventilation) when patients are in an MRI environment.
  - If the patient is at risk for airway compromise, more aggressive airway management (*e.g.*, use of a endotracheal tube or laryngeal mask airway), should be instituted because the patient's airway may be less accessible when the patient is in the scanner.
  - Complex airway management (*e.g.*, fiberoptic intubation) should be performed in a controlled environment outside of zone IV.
  - Alternative airway devices should be immediately available in the MRI suite.
  - Suction equipment should be immediately accessible to the patient's airway at all times.

VI. Management of Emergencies

- When a patient has a medical emergency (*e.g.*, cardiopulmonary arrest) in the MRI scanner, the following should occur: (1) Immediately remove the patient from zone IV while initiating cardiopulmonary resuscitation, if indicated; (2) call for help; and (3) transport the patient to a previously designated safe area for resuscitation that is not in zone IV.
  - This location should be as close to zone IV as possible so as not to delay resuscitation efforts, and should contain the following resuscitation equipment: a defibrillator, vital signs monitors, and a code cart that includes resuscitation drugs, airway equipment, oxygen, and suction.
- When a fire occurs in the MRI suite, team members should perform their preassigned fire management task as quickly as possible, in accordance with the ASA Practice Advisory for the Prevention and Management of Operating Room Fires.
  - If a team member cannot rapidly perform his or her task in the predetermined order, other team members should perform their tasks *without waiting*.
  - When a team member has completed a preassigned task, he or she should help other members perform tasks that are not yet complete.
- In the case of projectile emergencies, team members should perform their institution's protocol in reaction to this occurrence.
  - If possible, immediately remove the patient from zone IV and discontinue the scan.
  - If the patient is injured, proceed with medical emergency management as indicated above.
  - A controlled quench may be necessary to remove the patient from the bore.
- When a quench occurs, team members should perform their institution's protocol in reaction to this occurrence. If possible, (1) immediately remove the patient from zone IV and (2) immediately administer oxygen to the patient.
  - Powerful static magnetic fields may persist after a quench, and therefore the usual precautions apply when entering zone IV.
- Emergency response personnel should be restricted from entering zone IV during any environmental emergency because of the persistent magnetic field.

VII. Postprocedure Care

- The anesthesiologist should collaborate with the radiologist and other staff in the postprocedure care of the patient.
- Patients receiving sedation or anesthesia within the MRI suite should have access to postanesthetic care consistent with that provided in other areas of the institution, including transport to other recovery rooms, dedicated intensive care, or recovery areas within the MRI suite.
- In all situations, intensive care and recovery areas should include access to vital sign monitors, oxygen, suction, resuscitation equipment, and trained personnel.
- Patients should be given oral and written discharge instructions.

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Appendix 3: Methods and Analyses

For this Advisory, a systematic review and evaluation of the literature was conducted, and formal survey opinion data were obtained from experts and ASA members. Informal opinion-based information from other sources (*e.g.*, open forums, Internet postings) was also used in the development of this document. Both the literature evaluation and the survey opinion data were based on *evidence linkages*, or statements regarding potential relations between patient care interventions and safety outcomes in the MRI suite.*** The evidence linkage *interventions* are listed below.

I. Education
   1. MRI education for magnet hazards
   2. MRI education for monitoring limitations
   3. MRI education for long-term health hazards

II. Screening of Anesthesia Care Providers and Ancillary Support Personnel
   4. Mandatory screening of all personnel entering zone III or IV

III. Patient Screening
   5. Patient-related risks for adverse outcomes related to MRI
   6. Equipment-related risks for adverse outcomes related to MRI

IV. Preparation
   7. Planning for the anesthetic care of the patient for the scan
   8. Planning for rapidly summoning additional personnel in the event of an emergency

V. Patient Management during MRI
   9. Monitoring during MRI
   10. Anesthetic care during MRI
   11. Airway management during MRI

VI. Management of Emergencies
   12. Medical emergencies
   13. Environmental emergencies

VII. Postprocedure Care
   14. Postprocedure care consistent with that provided for other areas of the institution

A. State of the Literature

For the literature review, potentially relevant studies were identified *via* electronic and manual searches of the literature. The literature search covered a 36-yr period from 1973 through 2008. More than 1,200 citations were initially identified, yielding a total of 343 articles that addressed topics related to the evidence linkages and met our criteria for inclusion. After review of the articles, 186 studies did not provide direct evidence and were subsequently eliminated. A total of 157 articles contained direct linkage-related evidence (see Supplemental Digital Content 1, which is a complete list of references used to develop this Advisory, http://links.lww.com/A623).††† No evidence linkage contained enough studies with well-defined experimental designs and statistical information to conduct a quantitative analysis (*i.e.*, meta-analysis).

Interobserver agreement among Task Force members and two methodologists was established by interrater reliability testing. Agreement levels using a κ statistic for two-rater agreement pairs were as follows: (1) type of study design, κ = 0.49–0.85; (2) type of analysis, κ = 0.54–0.93; (3) evidence linkage assignment, κ = 0.77–1.00; and (4) literature inclusion for database, κ = 0.78–1.00. Three-rater chance-corrected agreement values were (1) study design, Sav = 0.65, Var (Sav) = 0.009; (2) type of analysis, Sav = 0.69, Var (Sav) = 0.010; (3) linkage assignment, Sav = 0.85, Var (Sav) = 0.004; and (4) literature database inclusion, Sav = 0.85, Var (Sav) = 0.013. These values represent moderate to high levels of agreement.

B. Consensus-based Evidence

Consensus was obtained from multiple sources, including (1) survey opinion from consultants who were selected based on their knowledge or expertise in MRI, (2) survey opinions solicited from active members of the ASA, (3) testimony from attendees of a publicly held open forum at two national anesthesia meetings, (4) Internet commentary, and (5) Task Force opinion and interpretation. The survey rate of return was 63% (n = 50 of 79) for the consultants, and 989 surveys were received from active ASA members. Results of the surveys are reported in tables 2 and 3 and are reported in summary form in the text of the Advisory.

The consultants were asked to indicate which, if any, of the evidence linkages would change their clinical practices if the Advisory was instituted. The rate of return was 29% (n = 23 of 79). The percent of responding consultants expecting a change in their practice associated with each linkage topic was as follows: (1) education, 30%; (2) screening of anesthesia care providers and ancillary support personnel, 13%; (3) patient screening, 26%; (4) preparation,13%; (5) patient management during MRI—monitoring, 4%; (6) patient management during MRI—anesthetic care, 0%; (7) patient management during MRI—airway, 0%; (8) patient management during MRI— emergencies, 13%; and (9) postprocedure care, 9%. Seventy-four percent indicated that their clinical practice would not need new equipment, supplies, or training to implement the Practice Advisory. Eighty-five percent indicated that the Advisory would not require ongoing changes in their practice that would affect costs. Ninety-five percent of the respondents indicated that the Advisory would have *no effect* on the amount of time spent on a typical case, and 5% indicated that there would be a 10-min increase in the amount spent on a typical case with the implementation of this Advisory.

*** Outcomes for the listed interventions refer to the occurrence of safety-based outcomes.

††† A complete list of references used to develop this Advisory is also available by writing to the American Society of Anesthesiologists.

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Table 2. Consultant Survey Responses

	n	Percent Responding to Each Item				
		Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree
Education						
1. All anesthesiologists should have general safety education on the unique physical environment of the MRI scanner	50	90.0*	10.1	0.0	0.0	0.0
2. All anesthesiologists should have specific education regarding the features of individual scanners within their institutions	50	58.0*	38.0*	2.0	2.0	0.0
3. All anesthesiologists should work in collaboration with radiologists, technologists, and physicists within their institutions to develop safety training programs	50	80.0*	16.0	2.0	2.0	0.0
Screening of anesthesia care providers and ancillary support personnel						
4. The anesthesiologist should work in collaboration with the MRI medical director or designee to ensure that all anesthesia team personnel entering zone III or IV have been properly screened	50	60.0*	34.0	4.0	2.0	0.0
Patient screening						
5a. For every case, the anesthesiologist should communicate with the patient and radiologist or referring physician to determine whether the patient has a high-risk medical condition	58.0*	20.0	10.0	10.0	2.0	58.0*
5b. If the patient presents with a high-risk medical condition, the anesthesiologist should collaborate with all participants, including the referring physician, radiologist, and technologist, to determine how the patient will be managed during the MRI procedure	50	58.0*	26.0	4.0	10.0	2.0
5c. For patients with acute or severe renal insufficiency, the anesthesiologist should not administer gadolinium because of the increased risk of nephrogenic systemic fibrosis	49	34.7	34.7*	26.5	4.1	0.0
6a. For every case, the anesthesiologist should communicate with the radiologist or referring physician to determine whether the patient requires equipment that may pose a risk during the scan	49	28.6	36.7*	18.4	14.3	2.0
6b. The anesthesiologist should determine the safety and effectiveness of the equipment needed by the patient during the procedure for each MRI location	50	46.0	34.0*	10.0	10.0	0.0
6c. Anesthesiologists should work with their institutions to properly identify and label anesthesia-related equipment according to convention (safe, unsafe, or conditional) for each MRI scanner	50	74.0*	26.0	0.0	0.0	0.0
6d. Care should be taken to ensure that anesthesia equipment does not interfere with image acquisition or quality	50	68.0*	30.0	2.0	0.0	0.0
7a. In general, MRI should not be performed on patients with implanted electronic devices	50	22.0	48.0*	14.0	14.0	2.0
7b. When MRI is considered essential by the referring physician and consulting radiologist, a plan for managing a patient with implanted electronic devices during the scan should be developed in collaboration with the referring physician, medical director, or on-site radiologist and other appropriate consultants	50	72.0*	26.0	0.0	2.0	0.0
Preparation						
8. For every case, the anesthesiologist should prepare, with support personnel, a plan for providing optimal anesthetic care within the special environment of the MRI suite	50	72.0*	26.0	0.0	2.0	0.0
9. The anesthesiologist should communicate with the radiology personnel to determine the requirements for the scan (*e.g.*, duration of the scan, position of the patient or area of the body in the scanner, positioning of receiver coils, need for periods of paused respiration)	50	68.0*	30.0	0.0	2.0	0.0
10. The anesthesiologist should collaborate with the MRI technologist and/or facility biomedical engineer to determine and demarcate the optimal and safe location of movable equipment in relation to the gauss lines within the MRI suite	50	62.0*	34.0	2.0	0.0	2.0
11. Because line of sight within the bore will vary depending on the facility, the anesthesiologist should choose a location or position for optimal patient observation and vigilance during delivery of care, whether in zone III or IV	50	64.0*	28.0	8.0	0.0	0.0
12. The anesthesiologist should prepare a plan for rapidly summoning additional personnel in the event of an emergency	50	82.0*	18.0	0.0	0.0	0.0

(*continued*)

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Table 2. Continued

	n	Percent Responding to Each Item				
		Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree
Patient management during MRI						
Monitoring						
13. MRI patients should be monitored in a manner consistent with the ASA "Standards for Basic Anesthetic Monitoring"	50	72.0*	26.0	2.0	0.0	0.0
14. Anesthesiologists should be familiar with the expected limitations of available monitoring equipment	50	84.0*	16.0	0.0	0.0	0.0
15. The anesthesiologist should make sure that all monitors used in zone IV are safe/conditional for the scan	50	82.0*	12.0	0.0	4.0	2.0
16. A monitor should be available to view vital signs from zone IV when the anesthesia care provider is not in zone IV	50	78.0*	16.0	6.0	0.0	0.0
Anesthetic care						
17. In general, because MRI is a nonpainful procedure, lighter levels of anesthesia may be appropriate, recognizing that institutional circumstances, patient preference, and anesthesiologist preference may warrant more aggressive airway management and deeper anesthetic levels	50	58.0*	34.0	2.0	6.0	0.0
18. Anesthesiologists should ensure that patients who receive moderate or deep sedation are monitored in a manner consistent with their institution's protocol for monitoring similarly sedated patients elsewhere in the facility	50	82.0*	18.0	0.0	0.0	0.0
19. Equipment and drugs for anesthetic care in the MRI suite should mirror what is available in the OR	50	76.0*	18.0	4.0	2.0	0.0
20a. When an MRI-safe/conditional anesthesia machine is not available, inhalation anesthetics may be administered from an anesthesia machine inside zone III *via* an elongated circuit through a wave guide	50	6.0	30.0	24.0*	34.0	6.0
20b. If total intravenous anesthesia is used, it should be administered by using (1) MRI-safe/conditional pumps in zone IV, (2) traditional (*i.e*., MRI-unsafe) pumps in zone III with the intravenous tubing passed through a wave guide, or (3) periodic bolus injections in zone III or IV	50	30.0	58.0*	10.0	2.0	0.0
Airway management						
21. The anesthesiologist should have an advance plan in place to deal with instrumentation of the airway and common airway problems when patients are in an MRI environment	50	88.0*	12.0	0.0	0.0	0.0
22. If the patient is at risk for airway compromise, more aggressive airway management (*e.g.*, use of a tracheal tube or LMA) should be instituted because the patient's airway may be less accessible when the patient is in the scanner	50	58.0*	34.0	6.0	2.0	0.0
23. Complex airway management (*e.g.*, fiberoptic intubation) should be performed in a controlled environment outside of zone IV	50	76.6*	18.0	6.0	0.0	0.0
24. Alternative airway devices should be immediately available in the MRI suite	50	78.0*	16.0	4.0	2.0	0.0
25. Suction equipment should be immediately accessible to the patient's airway at all times	49	91.8*	6.1	0.0	2.1	0.0
Management of emergencies						
26a. When a patient has a medical emergency (*e.g.*, cardiopulmonary arrest) in the MRI scanner, the following should occur: (1) Initiate CPR, when needed, while immediately removing the patient from zone IV; (2) call for help; and (3) transport the patient to a previously designated safe location in proximity to the MRI suite	49	81.6*	18.4	0.0	0.0	0.0
26b. The designated safe location should contain the following resuscitation equipment: a defibrillator, vital signs monitors, and a code cart that includes resuscitation drugs, airway equipment, oxygen, and suction	49	85.7*	14.3	0.0	0.0	0.0
27. When a fire occurs in the MRI suite, team members should perform their preassigned fire management task as quickly as possible, in accordance with the ASA "Practice Advisory for the Prevention and Management of Operating Room Fires"	49	71.4*	14.3	14.3	0.0	0.0
28a. When a quench occurs, team members should perform their institution's protocol in reaction to this occurrence	49	65.3*	28.6	6.1	0.0	0.0

(*continued*)

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Table 2. Continued

	n	Percent Responding to Each Item				
		Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree
28b. When a quench occurs, if possible, (1) immediately remove the patient from zone IV and (2) immediately administer oxygen to the patient	49	55.1*	22.5	20.4	2.0	0.0
29. Because powerful static magnetic fields may persist after a quench or fire, emergency response personnel should be restricted from entering zone IV	49	44.9	26.5*	20.4	8.2	0.0
Postprocedure care						
30. The anesthesiologist should collaborate with the radiologist and other staff in the postanesthetic care of the patient	50	62.0*	28.0	0.0	10.0	0.0
31. Patients receiving sedation or anesthesia within the MRI suite should have access to postanesthetic care consistent with that provided in other areas of the institution	50	82.0*	16.0	0.0	2.0	0.0
32. In all situations, intensive care and recovery areas should include access to vital sign monitors, oxygen, suction, and trained personnel	50	84.0*	14.0	2.0	0.0	0.0
33. Patients should be given written discharge instructions	50	66.6*	32.0	2.0	0.0	0.0

* Median.

ASA = American Society of Anesthesiologists; CPR = cardiopulmonary resuscitation; LMA = laryngeal mask airway; MRI = magnetic resonance imaging; n = number of consultants who responded to each item; OR = operating room.

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Table 3. American Society of Anesthesiologists Membership Survey Responses

	n	Percent Responding to Each Item				
		Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree
Education						
1. All anesthesiologists should have general safety education on the unique physical environment of the MRI scanner	989	73.6*	25.0	1.0	0.2	0.2
2. All anesthesiologists should have specific education regarding the features of individual scanners within their institutions	986	33.7	42.4*	18.4	5.1	0.5
3. All anesthesiologists should work in collaboration with radiologists, technologists, and physicists within their institutions to develop safety training programs	989	47.0	41.3*	8.1	3.4	0.2
Screening of anesthesia care providers and ancillary support personnel						
4. The anesthesiologist should work in collaboration with the MRI medical director or designee to ensure that all anesthesia team personnel entering zone III or IV have been properly screened	988	43.5	45.5*	8.0	2.8	0.2
Patient screening						
5a. For every case, the anesthesiologist should communicate with the patient and radiologist or referring physician to determine whether the patient has a high-risk medical condition	988	54.7*	30.6	6.7	6.9	1.2
5b. If the patient presents with a high-risk medical condition, the anesthesiologist should collaborate with all participants, including the referring physician, radiologist, and technologist, to determine how the patient will be managed during the MRI procedure	983	53.8*	34.2	4.6	6.4	1.0
5c. For patients with acute or severe renal insufficiency, the anesthesiologist should not administer gadolinium because of the increased risk of nephrogenic systemic fibrosis	981	23.7	29.5*	42.9	3.7	0.3
6a. For every case, the anesthesiologist should communicate with the radiologist or referring physician to determine whether the patient requires equipment that may pose a risk during the scan	976	36.2	38.1*	10.5	12.9	2.4
6b. The anesthesiologist should determine the safety and effectiveness of the equipment needed by the patient during the procedure for each MRI location	977	46.9	38.4*	6.7	6.4	1.7
6c. Anesthesiologists should work with their institutions to properly identify and label anesthesia-related equipment according to convention (safe, unsafe, or conditional) for each MRI scanner	981	56.6*	38.8	3.0	1.5	0.1
6d. Care should be taken to ensure that anesthesia equipment does not interfere with image acquisition or quality	980	46.2	49.4	3.1	1.0	0.3
7a. In general, MRI should not be performed on patients with implanted electronic devices	982	27.8	42.9*	22.2	6.7	0.4
7b. When MRI is considered essential by the referring physician and consulting radiologist, a plan for managing a patient with implanted electronic devices during the scan should be developed in collaboration with the referring physician, medical director, or on-site radiologist and other appropriate consultants	979	53.7*	41.6	2.8	1.3	0.6
Preparation						
8. For every case, the anesthesiologist should prepare, with support personnel, a plan for providing optimal anesthetic care within the special environment of the MRI suite	977	63.2*	33.6	1.7	1.1	0.4
9. The anesthesiologist should communicate with the radiology personnel to determine the requirements for the scan (*e.g.*, duration of the scan, position of the patient or area of the body in the scanner, positioning of receiver coils, need for periods of paused respiration)	980	64.5*	33.1	1.2	1.2	0.0
10. The anesthesiologist should collaborate with the MRI technologist and/or facility biomedical engineer to determine and demarcate the optimal and safe location of movable equipment in relation to the gauss lines within the MRI suite	974	48.8	43.2*	6.7	1.2	0.1
11. Because line of sight within the bore will vary depending on the facility, the anesthesiologist should choose a location or position for optimal patient observation and vigilance during delivery of care, whether in zone III or IV	982	53.8*	39.3	5.1	1.3	0.5
12. The anesthesiologist should prepare a plan for rapidly summoning additional personnel in the event of an emergency	978	70.6*	28.0	1.0	0.4	0.0

(*continued*)

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Table 3. Continued

	n	Percent Responding to Each Item				
		Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree
Patient management during MRI						
Monitoring						
13. MRI patients should be monitored in a manner consistent with the ASA "Standards for Basic Anesthetic Monitoring"	977	73.7*	22.5	1.4	1.8	0.5
14. Anesthesiologists should be familiar with the expected limitations of available monitoring equipment	978	71.9*	27.8	0.2	0.0	0.1
15. The anesthesiologist should make sure that all monitors used in zone IV are safe/conditional for the scan	977	68.3*	27.7	2.4	1.3	0.3
16. A monitor should be available to view vital signs from zone IV when the anesthesia care provider is not in zone IV	976	71.6*	24.7	3.5	0.1	0.1
Anesthetic care						
17. In general, because MRI is a nonpainful procedure, lighter levels of anesthesia may be appropriate, recognizing that institutional circumstances, patient preference, and anesthesiologist preference may warrant more aggressive airway management and deeper anesthetic levels	976	53.3*	43.3	1.6	1.2	0.5
18. Anesthesiologists should ensure that patients who receive moderate or deep sedation are monitored in a manner consistent with their institution's protocol for monitoring similarly sedated patients elsewhere in the facility	976	66.9*	30.2	1.3	1.1	0.4
19. Equipment and drugs for anesthetic care in the MRI suite should mirror what is available in the OR	980	61.4*	33.3	3.3	2.0	0.0
20a. When an MRI-safe/conditional anesthesia machine is not available, inhalation anesthetics may be administered from an anesthesia machine inside zone III *via* an elongated circuit through a wave guide	975	10.3	22.8	31.0*	29.1	6.9
20b. If total intravenous anesthesia is used, it should be administered by using (1) MRI-safe/conditional pumps in zone IV, (2) traditional (*i.e.*, MRI-unsafe) pumps in zone III with the intravenous tubing passed through a wave guide, or (3) periodic bolus injections in zone III or IV	978	24.0	53.2*	12.0	8.7	2.2
Airway management						
21. The anesthesiologist should have an advance plan in place to deal with instrumentation of the airway and common airway problems when patients are in an MRI environment	979	79.6*	20.1	0.3	0.0	0.0
22. If the patient is at risk for airway compromise, more aggressive airway management (*e.g.*, use of a tracheal tube or LMA) should be instituted because the patient's airway may be less accessible when the patient is in the scanner	981	72.8*	23.0	2.6	1.6	0.0
23. Complex airway management (*e.g.*, fiberoptic intubation) should be performed in a controlled environment outside of zone IV	981	71.9*	24.5	2.7	1.0	0.0
24. Alternative airway devices should be immediately available in the MRI suite	981	70.2*	26.1	2.5	1.2	0.0
25. Suction equipment should be immediately accessible to the patient's airway at all times	978	86.4*	12.8	0.7	0.1	0.0
Management of emergencies						
26a. When a patient has a medical emergency (*e.g.*, cardiopulmonary arrest) in the MRI scanner, the following should occur: (1) Initiate CPR, when needed, while immediately removing the patient from zone IV; (2) call for help; and (3) transport the patient to a previously designated safe location in proximity to the MRI suite	976	72.2*	25.7	1.8	0.2	0.0
26b. The designated safe location should contain the following resuscitation equipment: a defibrillator, vital signs monitors, and a code cart that includes resuscitation drugs, airway equipment, oxygen, and suction	978	79.4*	19.9	0.5	0.1	0.1
27. When a fire occurs in the MRI suite, team members should perform their preassigned fire management task as quickly as possible, in accordance with the ASA "Practice Advisory for the Prevention and Management of Operating Room Fires"	970	65.4*	30.4	4.5	0.0	0.1
28a. When a quench occurs, team members should perform their institution's protocol in reaction to this occurrence	967	49.1	29.7*	21.2	0.0	0.0
28b. When a quench occurs, if possible, (1) immediately remove the patient from zone IV and (2) immediately administer oxygen to the patient	963	49.0	27.6*	22.5	0.7	0.1

(*continued*)

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Table 3. Continued

	n	Percent Responding to Each Item				
		Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree
29. Because powerful static magnetic fields may persist after a quench or fire, emergency response personnel should be restricted from entering zone IV	973	22.3	28.7*	41.0	7.2	0.8
Postprocedure care						
30. The anesthesiologist should collaborate with the radiologist and other staff in the postanesthetic care of the patient	979	41.5	41.5*	4.9	10.5	1.6
31. Patients receiving sedation or anesthesia within the MRI suite should have access to postanesthetic care consistent with that provided in other areas of the institution	981	72.0*	27.1	0.5	0.4	0.0
32. In all situations, intensive care and recovery areas should include access to vital sign monitors, oxygen, suction, and trained personnel	977	77.7*	22.3	0.0	0.0	0.0
33. Patients should be given written discharge instructions	981	53.1*	39.4	5.9	1.5	0.1

* Median.

ASA = American Society of Anesthesiologists; CPR = cardiopulmonary resuscitation; LMA = laryngeal mask airway; MRI = magnetic resonance imaging; n = number of American Society of Anesthesiology members who responded to each item; OR = operating room.

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