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Reduction of motion artifacts in MRI: anesthetic strategies

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Abstract

Introduction. Motion artifacts remain a major limitation of magnetic resonance imaging (MRI), often compromising image quality and diagnostic accuracy. In patients unable to remain motionless, sedation and anesthesia are frequently required, introducing additional challenges related to safety and airway management.

Aim. To analyze current evidence on anesthetic strategies for reducing motion artifacts in MRI, with a focus on pharmacological agents, sedation depth, and airway management.

Methods. A narrative literature review was conducted using PubMed, Embase, the Cochrane Library, and Web of Science databases from 2015 to March 2026. Studies evaluating anesthetic techniques for MRI, motion artifact reduction, image quality, and safety outcomes were included.

Results. Propofol-based sedation provides the highest success rates for MRI completion, with rapid onset and recovery, but is associated with dose-dependent respiratory depression and airway obstruction. Dexmedetomidine preserves respiratory drive and offers a needle-free administration route but has slower onset and variable efficacy when used alone. Combination therapy may optimize both efficacy and safety. Airway management plays a critical role, as pharyngeal micromotion associated with airway obstruction can significantly degrade image quality. Supraglottic airway devices may improve imaging outcomes while maintaining spontaneous ventilation. Safety in the MRI environment requires specialized monitoring, equipment, and adherence to established guidelines.

Conclusions. Effective reduction of motion artifacts in MRI requires an integrated approach combining appropriate anesthetic technique, airway management, and patient-specific considerations. Propofol and dexmedetomidine remain the primary pharmacological options, while optimization of airway management represents an important and often underrecognized factor in improving image quality.

Keywords: magnetic resonance imaging, artifacts, anesthesia, propofol, dexmedetomidine.

1. Introduction

Magnetic resonance imaging (MRI) has become a fundamental diagnostic tool in modern medicine, providing superior soft tissue contrast and multiplanar imaging without the use of ionizing radiation. However, MRI's prolonged acquisition times and sensitivity to motion make it especially vulnerable to image degradation from patient movement. These artifacts arise from multiple sources, including voluntary patient movement, involuntary physiological motion (respiration, cardiac pulsation, peristalsis), and subtle micromotion associated with airway obstruction during sedation (1,2). These artifacts appear as ghosting, blurring, and signal loss that can compromise diagnostic accuracy, necessitate repeat examinations, and increase healthcare costs (3).

Despite advances in technical solutions such as respiratory gating, parallel imaging, and motion correction algorithms, patient motion remains an ongoing challenge. This is particularly evident in pediatric populations, patients with developmental disabilities, those experiencing pain or anxiety, and in imaging sequences requiring prolonged acquisition times (4). In these contexts, anesthetic intervention, ranging from minimal sedation to general anesthesia, provides a practical solution by ensuring patient immobility during image acquisition.

The MRI environment also presents unique challenges for anesthetic care. The strong static magnetic field, radiofrequency emissions, acoustic noise exceeding 100 decibels, limited patient access, and constraints on monitoring equipment create hazards distinct from traditional operating rooms (5). In the MRI setting, anesthetic technique must balance several competing demands. These include immobility, respiratory stability, rapid recovery,

and safety in a remote environment. Together, these factors draw attention to the importance of optimizing anesthetic strategies to minimize motion artifacts and ensure diagnostic-quality imaging.

To address these issues, this review analyzes the current evidence on anesthetic strategies to reduce motion artifacts in MRI. It evaluates the efficacy and safety of sedation strategies, with particular attention to pharmacological agents and airway management, and highlights optimal protocols for different patient populations.

2. Materials and Methods

2.1. Literature Search Strategy

A comprehensive literature search was conducted using PubMed, Embase, the Cochrane Library, and Web of Science databases from 2015 to March 2026. Search terms included combinations of the following keywords: "magnetic resonance imaging," "MRI," "motion artifacts," "sedation," "anesthesia," "propofol," "dexmedetomidine," "sevoflurane," "pediatric," "airway management," and related terms. Reference lists of included articles were manually reviewed to identify additional relevant studies.

2.2. Inclusion and Exclusion Criteria

Studies were included if they met the following criteria: (1) evaluated anesthetic or sedative techniques for MRI procedures, (2) assessed motion artifacts or image quality as outcomes, (3) reported safety outcomes related to sedation/anesthesia in the MRI environment, or (4) provided guidance on anesthetic management in MRI settings. Both original research (randomized controlled trials, observational studies) and clinical practice guidelines were included. Case reports with fewer than five patients and non-English

language articles without available translations were excluded.

2.3. Data Extraction and Synthesis

Data were extracted on the following variables: study design, patient populations, anesthetic techniques, motion artifact assessment methods, image quality outcomes, safety events, and recovery parameters. Due to substantial heterogeneity in study design and outcome measures, a narrative synthesis was conducted instead of a formal meta-analysis.

3. Results

3.1. Mechanisms of Motion Artifacts in MRI

Motion artifacts in MRI arise from the physics of image acquisition. MRI images are constructed by sampling k-space data over time, usually requiring seconds to minutes for complete acquisition (1). Any motion during this period causes phase and frequency encoding errors that appear as characteristic artifacts (2). Periodic motion (cardiac or respiratory) produces discrete ghost artifacts that are displaced along the phase-encoding direction, whereas random motion causes diffuse blurring and signal loss (2,4). Understanding these mechanisms is essential, as they underpin both technical and anesthetic strategies aimed at minimizing motion-related image degradation.

The severity of motion artifacts depends on multiple factors: the timing of motion relative to k-space sampling (central k-space motion is most detrimental), the amplitude and frequency of motion, the imaging sequence employed, and the anatomic region being imaged (1,2). High-resolution sequences with prolonged acquisition times are particularly susceptible (4). Notably, even subtle head micromotion of 1-2 mm, often associated with pharyngeal muscle relaxation and airway obstruction during sedation, can

significantly degrade image quality in neuroimaging applications (6).

3.2. Levels of Sedation and Anesthesia

The American Society of Anesthesiologists defines a continuum of sedation depths: minimal sedation (anxiolysis), moderate sedation (conscious sedation), deep sedation, and general anesthesia (5). Each level has distinct implications for motion control and safety in the MRI environment.

Observational studies report that moderate sedation achieves acceptable success rates, but imaging failure due to motion still occurs in 10–30% of cases (5). Deep sedation and general anesthesia achieve higher rates of successful imaging with lower motion artifact rates, typically exceeding 95% success. However, deeper levels of sedation carry risks of airway complications, including laryngospasm, coughing, and airway obstruction, that may necessitate scan interruption. The choice of sedation depth must be individualized based on patient characteristics, imaging requirements, and institutional capabilities (5). This reflects a fundamental trade-off between achieving reliable immobility and maintaining airway and respiratory safety.

3.3. Pharmacological Agents

3.3.1. Propofol

Propofol remains the most reliable agent for MRI sedation due to its rapid onset, short context-sensitive half-time, and high efficacy in achieving immobility (7,8). Meta-analyses in pediatric populations demonstrate that it provides shorter onset of sedation (approximately 6 minutes faster than dexmedetomidine) and faster recovery times (7). Image quality with propofol-based sedation is

consistently rated as good to excellent, with successful scan completion rates exceeding 99% in large registry studies (9).

However, propofol causes dose-dependent respiratory depression and upper airway obstruction, particularly at deeper sedation levels (9). Airway interventions (jaw thrust, oral/nasal airway placement, positive-pressure ventilation) are required in 15-45% of cases, depending on patient population and dosing (10). Propofol also produces hemodynamic effects, including hypotension, though these are generally mild and well-tolerated in healthy patients (7,11). This reflects a fundamental trade-off between reliability of immobility and respiratory safety.

3.3.2. Dexmedetomidine

Dexmedetomidine, an α_2 -adrenergic agonist, offers unique advantages for MRI sedation through its preservation of respiratory drive and minimal respiratory depression (8). Studies show successful sedation rates of 62-95% with dexmedetomidine, with higher success when combined with other agents (12-14). Intranasal dexmedetomidine has emerged as an effective needle-free option for pediatric patients, with efficacy dependent on dose and patient selection (12,14,15). The main limitations of dexmedetomidine include longer onset time (typically 7-15 minutes for adequate sedation), dose-dependent bradycardia and hypotension (occurring in 5-20% of patients), and prolonged recovery compared to propofol (16,17). Some studies report that dexmedetomidine monotherapy may result in inferior image quality, likely due to insufficient sedation depth or arousal during acoustic stimulation (16).

3.3.3. Combination Therapy

Recent evidence supports combining low-dose dexmedetomidine with propofol to optimize

both efficacy and safety. Research shows that dexmedetomidine preloading followed by propofol infusion reduces total propofol requirements, decreases airway interventions, and improves hemodynamic stability without prolonging recovery time (8). This approach may be especially useful in balancing the respiratory safety of dexmedetomidine with the reliable immobility provided by propofol.

3.3.4. Sevoflurane

Inhaled sevoflurane provides effective sedation for MRI with success rates approaching 98% (12). Its non-irritating properties and rapid titratability make it suitable for pediatric patients. However, sevoflurane requires specialized MRI-compatible anesthesia machines or extended breathing circuits, as well as scavenging systems for waste-gas management (5). Recovery times are intermediate between propofol and dexmedetomidine. Despite its efficacy, use of sevoflurane is often limited by logistical and equipment-related constraints in the MRI environment.

3.3.5. Other Agents

Traditional agents, including midazolam, chloral hydrate, and pentobarbital, are still used, particularly for needle-free sedation in young children (12). However, these agents generally have lower success rates (36-94%), prolonged and unpredictable recovery times, and higher rates of paradoxical agitation compared to propofol, dexmedetomidine, or sevoflurane (12,13). These limitations make them less suitable for modern MRI practice, particularly when high-quality imaging and rapid recovery are required.

3.4. Airway Management and Motion Artifacts

An important but often overlooked source of motion artifacts is pharyngeal micromotion resulting from airway obstruction during sedation. When sedation causes pharyngeal muscle relaxation, patients may develop snoring, partial airway obstruction, and associated head micromotion, which degrades image quality, particularly in neuroimaging (6).

A retrospective study comparing airway management strategies found that supraglottic airway devices significantly improved MRI image quality compared to no airway device (mean combined quality score 27.3 vs 22.0, $P < 0.0001$) (6). The supraglottic airway eliminated snoring-related vibrations and micromotion while maintaining spontaneous ventilation. Endotracheal intubation provides the highest image quality scores but requires general anesthesia and more invasive airway management (6). This highlights that motion artifacts are not solely related to sedation depth but also to airway management.

These findings suggest that for patients requiring deep sedation or general anesthesia, especially during high-resolution neuroimaging, supraglottic airway placement should be considered to optimize image quality by reducing micromotion artifacts (6,18).

3.5. Safety Considerations in the MRI Environment

The American Society of Anesthesiologists Practice Advisory emphasizes multiple safety considerations unique to the MRI environment. The strong magnetic field poses risks to ferromagnetic objects and can interfere with implanted devices, including pacemakers and nerve stimulators. In addition, all equipment

must be appropriately labeled as MRI-safe, MRI-conditional, or MRI-unsafe (5).

Monitoring in the MRI environment may be limited by magnetic field interference and radiofrequency artifacts (5). The Task Force recommends that monitoring for MRI sedation/anesthesia should mirror standards for other locations, including continuous pulse oximetry, blood pressure monitoring, electrocardiography, and end-tidal CO₂ monitoring for all patients receiving deep sedation or those whose ventilation cannot be directly observed during moderate sedation. The advisory also emphasizes that pulse oximetry is not a substitute for ventilatory monitoring, as oxygenation and ventilation are separate physiological processes (5).

Patient access is restricted when the patient is positioned within the scanner bore, potentially delaying emergency interventions (5). Anesthesiologists should implement clear emergency protocols, ensure MRI-safe resuscitation equipment is immediately available, and maintain visual observation of patients through direct line-of-sight or video monitoring (5,19).

3.6. Pediatric Populations

Children account for the majority of patients requiring sedation/anesthesia for MRI. Systematic reviews show variable success rates for needle-free sedation techniques: oral chloral hydrate (94%), intranasal dexmedetomidine (62-95%), oral midazolam (36%), and inhaled sevoflurane (98%) (12). Intravenous propofol with or without dexmedetomidine achieves the highest success rates (> 95%) with acceptable safety profiles (7,11).

Adverse events during pediatric MRI sedation are generally minor, including transient oxygen desaturation, airway obstruction requiring

intervention, and emergence delirium (5,8). Serious adverse events (aspiration, cardiac arrest, unplanned hospital admission) are rare, occurring in less than 0.1% of cases when appropriate monitoring and personnel are present (8).

3.7. Neurodevelopmental Considerations

Concerns about anesthetic neurotoxicity in young children have emerged from animal studies demonstrating neuroapoptosis and functional deficits after exposure to GABA agonists and NMDA antagonists (20,21). The FDA issued a warning in 2016 regarding the potential effects of repeated or prolonged anesthesia on brain development in children under 3 years (18).

Reassuringly, large prospective human studies, including the GAS trial and the PANDA study, have not demonstrated neurodevelopmental deficits from single, brief anesthetic exposures in infancy (18,20,22). Evidence suggests that multiple anesthetic exposures (≥ 3 procedures) or prolonged cumulative anesthesia duration may be associated with small deficits in cognitive testing and increased behavioral problems, although residual confounding from underlying medical conditions cannot be excluded (9,21,23). These findings support a balanced approach, that minimizes unnecessary exposure while avoiding delays in clinically indicated imaging.

For children requiring repeated MRI examinations, the risks and benefits of sedation/anesthesia must be carefully weighed (18). Strategies to minimize exposure include optimizing patient preparation to attempt non-sedated imaging when feasible, using faster imaging sequences, and consolidating multiple imaging studies into single sessions when possible (18).

3.8. Special Populations

Certain patient populations require tailored anesthetic approaches during MRI. Those with mucopolysaccharidosis and other conditions associated with difficult airways may benefit from dexmedetomidine rather than propofol to reduce the need for airway intervention (10). In contrast, critically ill patients requiring MRI present additional challenges related to transport, monitoring, and hemodynamic instability (5). Claustrophobic adults may require only anxiolysis or light sedation, so in this context, propofol appears more effective than dexmedetomidine (16). These examples highlight the importance of individualizing anesthetic strategies based on patient-specific risks and procedural requirements.

4. Discussion

Anesthetic strategy is a key determinant of MRI success in patients unable to remain motionless. The optimal approach must be individualized based on patient characteristics, imaging requirements, and institutional resources.

For pediatric patients, propofol-based sedation (with or without dexmedetomidine) provides the most reliable combination of high success rates, excellent image quality, and acceptable safety when administered by appropriately trained personnel with proper monitoring (7,9,11). Dexmedetomidine offers advantages for patients at higher risk of airway complications and provides a needle-free option via intranasal administration, though with longer onset and recovery times (10,12,14).

The recognition that airway obstruction during sedation can, in turn, cause motion artifacts through pharyngeal micromotion is a critical and often underrecognized contributor to image degradation (6). For high-resolution neuro-

imaging under deep sedation or general anesthesia, supraglottic airway devices may improve image quality while maintaining spontaneous ventilation and avoiding the invasiveness of endotracheal intubation (6,18). This shifts the focus from sedation depth alone to the combined role of sedation and airway management in motion control. Safety in the MRI environment requires a structured approach that includes appropriate patient screening, use of MRI-conditional equipment, comprehensive monitoring, including capnography, maintenance of visual observation, and preparation for emergencies in a location with restricted access (5,19). Adherence to professional society guidelines is essential. The concern about anesthetic neurotoxicity in young children, while based on compelling animal data, has not been substantiated for single, brief exposures in human studies (18,20–22). Nevertheless, it is advisable to limit unnecessary anesthetic exposures in young children, particularly repeated procedures (9,18,23). This can be achieved through patient preparation programs, faster imaging sequences, and consideration of non-sedated imaging when feasible.

Future research directions include the development of ultra-fast imaging sequences that could reduce or eliminate the need for sedation, refinement of combination pharmacological approaches to optimize efficacy and safety, integration of advanced motion correction algorithms with anesthetic strategies, and continued analysis of long-term neurodevelopmental outcomes in children requiring repeated anesthesia.

5. Conclusions

Despite technical advances, motion artifacts remain a major limitation of MRI. However,

current evidence indicates that they can be substantially reduced through appropriate anesthetic planning, optimized airway management, and strict adherence to MRI-specific safety standards. Propofol and dexmedetomidine are currently the most effective pharmacological options, either alone or in combination, and the choice between them should be guided by the clinical context, airway risk, and imaging requirements.

Importantly, airway-related micromotion represents an underrecognized contributor to image degradation, highlighting the importance to incorporate airway management into motion-reduction strategies. The use of supraglottic airway devices may improve image quality in selected cases while preserving spontaneous ventilation. Ensuring safety in the MRI environment requires strict adherence to established protocols, including appropriate monitoring and MRI-compatible equipment.

In pediatric patients, available evidence is reassuring regarding single brief anesthetic exposures, although minimizing repeated anesthesia remains advisable. Further improvements are likely to arise from the integration of optimized anesthetic techniques with advances in imaging technology and motion correction methods.

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